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James A. Singleton Date

Evaluation of pandemic and seasonal influenza vaccination surveys

By

James A. Singleton

Doctor of Philosophy

Epidemiology

Carolyn Drews-Botsch, Ph.D., M.P.H.
Advisor

James W. Buehler, M.D., M.P.H.
Committee Member

William Dana Flanders, M.D., D.SC., M.P.H.
Committee Member

David G. Kleinbaum, Ph.D.
Committee Member

David Shay, M.D., M.P.H.
Committee Member

Accepted:

Lisa A. Tedesco, Ph.D.
Dean of the James T. Laney School of Graduate Studies

Date

Evaluation of pandemic and seasonal influenza vaccination surveys

By

James A. Singleton
B.S., University of California, Davis, 1983
M.S., University of California, Davis, 1985

Advisor: Carolyn Drews-Botsch, Ph.D., M.P.H.

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Abstract
Evaluation of pandemic and seasonal influenza vaccination surveys
By James A. Singleton

In response to the influenza A(H1N1)pdm09 (pH1N1) pandemic starting April 2009, a monovalent pH1N1 vaccine was developed and distributed in the United States along with the trivalent seasonal influenza vaccine. To monitor the 2009-10 vaccination campaign, the Centers for Disease Control and Prevention developed systems to monitor use, safety and effectiveness of pH1N1 vaccine. A key component was the National 2009 H1N1 Flu Survey (NHFS), conducted from October 2009 through June 2010 to provide weekly estimates of pH1N1 and seasonal influenza vaccination coverage. Evaluation of the validity of findings from the NHFS is needed to improve design, implementation, analysis and interpretation of future pandemic and inter-pandemic influenza vaccination surveys.

Three questions about sources of systematic error in measures of frequency based on surveys of influenza vaccination were addressed:

1. Can a quicker and cheaper telephone survey be conducted without introducing too much additional selection bias?

2. How much selection bias is incurred by conducting a telephone survey compared to the National Health Interview Survey (NHIS), a less timely data source with a more complete sampling frame and higher response rates?

3. How accurate is parental report of young children's influenza vaccination status, compared to provider reported status in the National Immunization Survey (NIS)?

From analysis of NHFS based on interviews conducted within the first two weeks compared with the full sample recruited over five weeks, there was little difference in influenza vaccination estimates. However, estimates from the full NHFS were five to seven percentage points higher than estimates from the NHIS. Further, comparison of parental to provider reported influenza vaccination status for children aged 10-37 months indicated that vaccination prevalence based on parental report was five to twelve percentage points higher.

This evaluation quantified levels of potential selection and misclassification bias incurred by telephone surveys of influenza vaccination. Telephone surveys to collect influenza vaccination data by parental and self report remain a timely and efficient approach for surveillance of vaccination programs at the national and state levels. The attributes of ongoing surveillance systems must be monitored to ensure they are meeting the needs of intended use and are correctly interpreted.

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The 2009-10 “swine flu” pandemic was an intense period for those of us involved in the public health response. While this delayed completion of my dissertation by about a year, it also afforded an opportunity to conduct a timely evaluation of the surveys conducted to monitor the pandemic influenza vaccination campaign. The Nation is better prepared for the next possibly more deadly pandemic, but I hope that day never comes.

Finally, I am most grateful for the unwavering support from my wife, without whom I would not have completed this dissertation. From the moment she heard of my dream of going back to school for a Ph.D. in epidemiology in 1992, she was with me every step of the way the past 20 years to make that dream a reality.

Roni, now it is your turn…

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Chapter 1 INTRODUCTION

SURVEILLANCE OF INFLUENZA VACCINATION

Vaccines and vaccination programs are two of the greatest achievements of public health. During the 20th century, readily available vaccines and universal vaccination recommendations for children led to high vaccination coverage levels and dramatic declines in morbidity for many vaccine-preventable diseases. Accurate vaccination assessment data is critical to maintaining high vaccination coverage, allowing national and state programs to monitor vaccination coverage, identifying pockets of under immunization, prioritizing limited resources, and providing accountability for the investment in immunization programs.

Surveillance of influenza vaccination coverage among the civilian, non-institutionalized population of the United States has historically relied on the National Health Interview Survey (NHIS) for national data (1) and the Behavioral Risk Factor Surveillance System (BRFSS) for state-specific data (2). These surveys rely on self and parental reported vaccination status. More recently, provider reported data on influenza vaccination has been collected by the National Immunization Survey (NIS) for children aged 19-35 months and by the NIS-Teen for adolescents aged 13-17 years (3). BRFSS, NIS and NIS-Teen were initially landline-based telephone surveys, while NHIS is an in-person area sample. All of these surveys are subject to non-response bias. None of these surveys have been timely enough to provide estimates from one influenza season before start of the next influenza season's vaccination period.

In July 2009, the Advisory Committee on Immunization Practices (ACIP) issued recommendations for use of the influenza A(H1N1)pdm09 (pH1N1) pandemic monovalent vaccine, in response to the pandemic of this virus that emerged in April, 2009 (4). Trivalent seasonal vaccination continued to be recommended, so many persons were recommended for both pH1N1 and seasonal influenza vaccinations during 2009-2010 (5). In addition to ongoing

surveillance of influenza infections, the Centers for Disease Control and Prevention (CDC) developed systems to monitor use, safety and effectiveness of pH1N1 vaccine. A comprehensive, multi-component system was developed to track use of pH1N1 and seasonal vaccination, providing weekly estimates of vaccination coverage, intent for vaccination, and public opinions about vaccination (6-9).

Influenza vaccinations were added to the core BRFSS survey for adults to assess pH1N1 vaccination, and child modules added in the majority of states to assess pH1N1 and seasonal influenza vaccination. The National 2009 H1N1 Influenza Survey (NHFS) was developed and implemented. The NHFS was a dual frame (landline and cell phone) survey of 6,000 households per month conducted October 2009 – June 2010 to provide weekly estimates of monovalent pH1N1 and trivalent seasonal influenza vaccination coverage, intent for vaccination and opinions related to vaccination (10). The NHFS was supplemented by influenza vaccination data collected from parents of children aged 6 months-17 years who participated in screening for the NIS. To provide timely estimates per state by age and target group, estimates of vaccination coverage for BRFSS and NHFS were computed using Kaplan-Meier survival analysis, and estimates from BRFSS and NHFS combined into final estimates based on effective sample size (11). To provide timely estimates for healthcare personnel, an internet panel survey was developed (12). Influenza vaccination questions were added to the Pregnancy Risk Assessment Monitoring System (PRAMS) in over 30 states, and pH1N1 vaccinations questions added to the NHIS in January 2010; data from these surveys were not available during the pH1N1 vaccination campaign, but are useful in post-season assessment (13.14). Other opinion polls related to influenza were conducted before and during the 2009 H1N1 vaccination campaign by a variety of organizations (15).

To supplement survey data, administrative data on influenza vaccine distribution and administration were utilized. The federal government paid for the production cost of pH1N1 vaccine and distributed the vaccine through state health departments. In contrast, seasonal

influenza vaccine is purchased primarily by private providers, with public purchase comprising about 10%. Information on the number of pH1N1 doses distributed to each state was tracked. To monitor early uptake of pH1N1 vaccination, state health departments were funded to track and report doses of monovalent vaccine administered by age (16). While this potentially provided an unprecedented opportunity to compare survey estimates of influenza vaccination coverage to a true gold standard, completeness of reporting of doses administered in public and private settings has not been assessed, and likely varies across states. Projected numbers of influenza vaccinations administered in provider offices with billing to third party payers from SDI, Inc. (now IMS) were also monitored weekly. Specific CPT codes were established to allow for billing for the cost of administering pH1N1 vaccine.

The information collected by these systems was used in development of public messages about the vaccination campaign, to help assess safety and effectiveness of the vaccine, and provide feedback to states on their vaccination programs. Vaccination coverage estimates were used as denominators for rates of reported influenza-vaccine-associated adverse events (17,18), assessment of influenza vaccine effectiveness (19), evaluation of pH1N1 infection rates in conjunction with serologic data (20), and in models estimating influenza-associated morbidity and mortality averted by pH1N1 vaccination (21,22). Further evaluation of this enhanced surveillance system is needed to identify areas of improvement for future pandemics and for enhanced surveillance during inter-pandemic seasons. Such evaluation must consider the critical information for action needed during pandemic and inter-pandemic seasons, and balance surveillance attributes such as timeliness, validity, precision, and geographic scope of estimates.

SOURCES OF SYSTEMATIC ERROR IN SURVEYS OF INFLUENZA VACCINATION

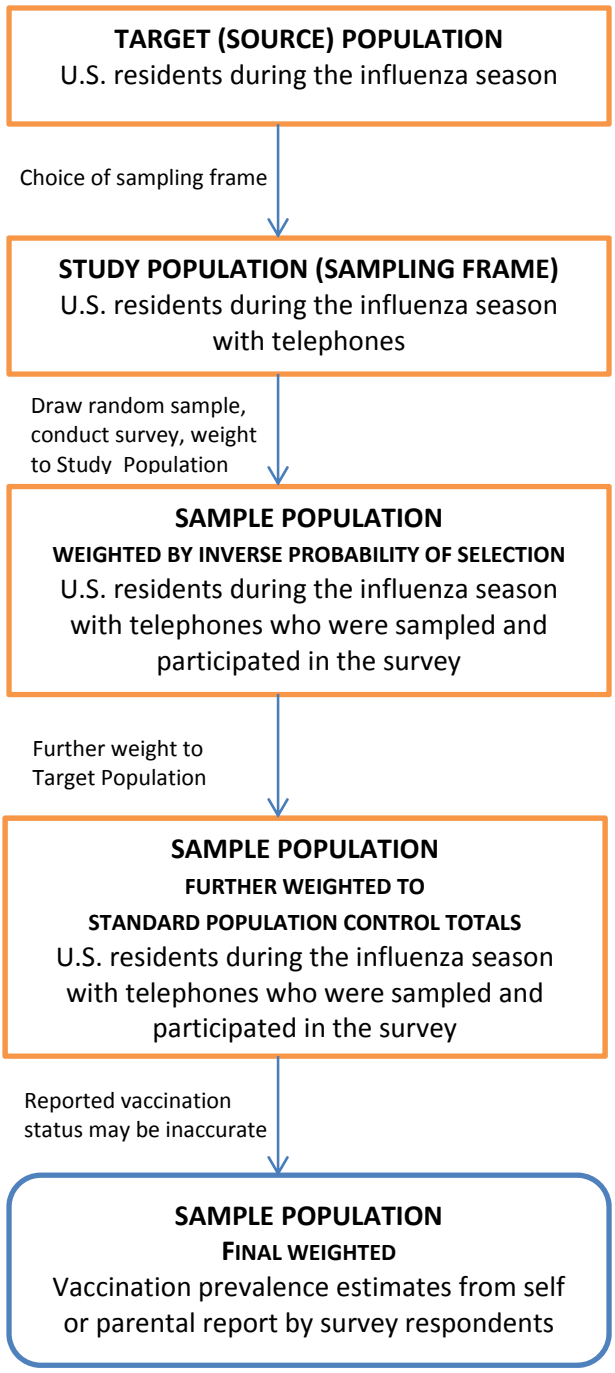
Systematic error in survey estimates of the prevalence of an outcome of interest (e.g., the proportion of persons vaccinated) can result from noncoverage of the target population by the sampling frame, nonresponse at multiple stages of the survey, and measurement error. Both

survey methodologists and epidemiologists have taken a "quality" approach to evaluating surveys ("total survey error") (23) and epidemiologic studies (24,25), which focus on qualitatively and quantitatively evaluating each type of possible error separately and in combination. Probabilistic analysis of bias from noncoverage and nonresponse has been used for both surveys (26-28) and epidemiologic studies (29). A similar approach could be used for telephone surveys of influenza vaccination, with addition of misclassification of self or parental reported vaccination status to the model. This type of model has become increasingly important as information needs have shifted from monitoring trends with a presumably consistently biased system to accurate estimation for evaluating vaccine safety and estimating influenza-associated morbidity and mortality averted by annual vaccination campaigns. The need for more timely data has led to use of multiple data sources, which could be incorporated into an expanded model that provides near real-time estimates based on incomplete administrative data and rapid biased surveys, calibrated to less biased surveys available post-season.

Figure 1-1 illustrates a possible construction of such a model. This shows the potential selection bias that can incur moving from the target (or source) population (e.g. residents of the United States during the influenza season) to the study population (e.g., residents of the United Stated during the influenza season with landline telephones) to the sample population (e.g., residents of the United States during the influenza season with landline phones that responded to the survey). At each step (X) from target population to weighted sample population, probabilities of selection to the next step for vaccinated ($\alpha_{X\,V}$) and unvaccinated (α_{XN}) persons may differ from each other and from selection probabilities from prior steps. A further step attempts to mitigate selection bias by weighting the survey respondents to account for probability of selection and nonresponse, so that their weighted sums correspond to selected sociodemographic distributions from the target population (e.g. to Census estimates by age group, sex and racial/ethnic group). The final step considered is information bias (e.g., self or parental reported influenza vaccination status may differ from actual vaccination status). At this step, the cumulative bias resulting from

selection bias from the previous steps is compounded by a possible difference between the actual vaccination prevalence in the sample population and the vaccination prevalence in the weighted sample population based on self and parental reported influenza vaccination status.

Figure 1-1. Selection and information bias in estimated prevalence of influenza vaccination from sample survey data.



Proportion vaccinated in Target Population =
$\mathbf{N_V / (N_V + N_{\tilde{V}})}$

Number of persons in Target Population vaccinated is N_V and unvaccinated is $N_{\tilde{V}}$

Proportion vaccinated in Study Population =
$\mathbf{\alpha_{1V} N_V / (\alpha_{1V} N_V + \alpha_{1\tilde{V}} N_{\tilde{V}})}$

α_1's are proportion of vaccinated (V) and unvaccinated ($\tilde{V}$) in Target Population that are in the Study Population

Proportion vaccinated in Sample Population (weighted to Study Population) =
$\mathbf{\alpha_{2V}\, \alpha_{1V} N_V / (\alpha_{1V} N_V + \alpha_{1\tilde{V}} N_{\tilde{V}})}$

α_2's are probabilities of survey participation among those in the Study Population that were randomly sampled

Proportion vaccinated in Sample Population (final weighted) =
$\mathbf{\omega_V\, \alpha_{2V}\, \alpha_{1V} N_V / (N_V + N_{\tilde{V}})}$

ω's are adjustments so that the weighted sums of sample participants match specified Target Population subtotals. Ideally, $\omega_V = 1 / \alpha_{2V}\, \alpha_{1V}$, but population totals by vaccination status are not known

Observed proportion vaccinated in final weighted Sample Population based on self or parental reported vaccination status =
$\mathbf{(\gamma_V \omega_V \alpha_{2V} \alpha_{1V} N_V + \gamma_{\tilde{V}} \omega_{\tilde{V}} \alpha_{2\tilde{V}} \alpha_{1\tilde{V}} N_{\tilde{V}}) / (N_V + N_{\tilde{V}})}$

False positive vaccinations, $\gamma_{\tilde{V}} \omega_{\tilde{V}} \alpha_{2\tilde{V}} \alpha_{1\tilde{V}} N_{\tilde{V}}$, are included and false negatives, $(1-\gamma_V)\omega_V \alpha_{2V} \alpha_{1V} N_V$, excluded from the numerator

Selection Bias

Rothman, Greenland and Lash define selection bias as, "distortions that result from procedures used to select subjects and from factors that influence study participation." (30). In the context of probabilistic sample surveys with telephone number sampling frames used to estimate prevalence of an outcome, an initial potential source of selection bias results from differences in the target population and the sampling frame of telephone numbers chosen. This type of selection bias is referred to as "noncoverage" bias by survey methodologists, and includes exclusion of persons without phones, and can result in decisions for efficiency in how landline sampling frames are constructed (31) or exclusion of persons with only wireless telephone service. Further selection bias can result from nonparticipation of persons with the telephone numbers selected from the survey, either because they are never available when called or they are reached but decline to participate. This type of selection bias if referred to as "nonresponse" bias.

Surveys based on landline telephone sampling frames are subject to bias in estimates intended to represent the target population of all households. This noncoverage bias is a function of the prevalence of non-landline households and the difference in study outcome between landline and non-landline households, in the target population. Based on NHIS interview data from July-December 2009, 24.5% of persons in the United States lived in households with only wireless telephone service, and 2% with no telephone service (32). Wireless-only prevalence was 25.9% for children, and for adults was highest among those aged 18-24 years and decreased to 5.2% for persons aged ≥65 years. Other factors associated with higher wireless-only prevalence included living only with other unrelated adults, renting residence, living below or near the poverty level, and Hispanic ethnicity.

NHIS data have been used to evaluate the bias in the target population of surveys based on landline telephone samples (33). Estimated noncoverage bias was generally low (e.g., 2.5 percentage points too high for receipt of influenza vaccination), but varied by health outcome and by sociodemographic factors. Many landline telephone surveys have supplemented their frames

with cell phone samples, and compared characteristics and survey outcomes between landline and cell phone respondents (33-36). Preliminary results from the NHFS indicate that cell phone respondents differed from landline respondents as expected, and estimates of influenza vaccination coverage based only on the landline respondents were 0.9 percentage points higher than dual frame estimates for H1N1 and 2.0 percentage points higher for seasonal vaccination (37). These studies evaluated differences based on landline only compared to combined landline and cell samples, adjusting for factors available for survey weighting. Thus, these studies assume that nonresponse bias is the same for landline and cell phone samples; otherwise the comparisons provide biased estimates of noncoverage bias. However, response rates to cell phone samples are typically lower than landline; final CASRO response rates for the NHFS were 34.7% for the landline sample and 27.0% for the cell phone sample (which screened for households with only wireless service or relied mainly on their cell phone). Cell phones are considered personal devices and persons deciding to respond to a survey when called on their cell phone may differ in important ways from cell phone users who do not respond. While survey weighting is designed to mitigate bias from noncoverage and nonresponse, these estimation strategies may not substantially reduce these biases (38). Additional research is needed to evaluate potential for differential nonresponse bias in landline and cell phone survey samples. Another source of noncoverage in random digit dialed landline telephone surveys arises from exclusion of some landline households from the sample frame to make the sample more cost-efficient (31).

Response rates to surveys have generally been declining over the past 20 years (39). While the potential for selection (nonresponse) bias increases as response rates decrease, a review of empirical studies have demonstrated that there is not necessarily a link between nonresponse rates and nonresponse bias (40). Nonresponse bias will occur to the extent that there is covariance between a survey outcome variable and the propensity to respond to a survey, and various causal models have been postulated linking survey outcome, response propensity, and other survey variables that might be used in weighting adjustments aimed at reducing

nonresponse bias in estimates (40). Salience of the survey topic may influence response (41). For example, the NHFS was introduced to potential respondents as a survey about influenza conducted on behalf of the CDC, while BRFSS and NHFS were introduced as more general health surveys; if saliency is related to propensity for influenza vaccination, nonresponse bias could result (42).

Study designs to evaluate nonresponse bias include: comparing survey responders to non-responders using available data on the sample frame, e.g. when the sample frame is from an administrative data base; comparing to similar estimates from another, more accurate source; comparing early to later survey respondents; and contrasting alternative postsurvey adjustments for nonresponse (40). Studies of early vs. later responders used to evaluate nonresponse bias assume a continuum of resistance with nonresponders represented by hardest to reach respondents (43). Such studies are also useful for evaluating potential change in validity of survey estimates that would result by reducing the effort expended to obtain interviews. This information is relevant for improving cost-efficiency and in special circumstances when timely information is needed for decision making and some systematic error in estimates can be tolerated or accounted for based on past experience.

Preliminary analysis of the NHFS indicated that influenza vaccination coverage was slightly higher for respondents in the first two weeks of follow-up compared to those responding the final 4th and 5th weeks (44). Larger differences in influenza vaccination were found in a similar analysis of 2004 BRFSS data for adults (45). Starting with the 2010-2011 influenza season, CDC has conducted two-week rapid influenza vaccination surveys nationally and in twenty local areas to provide information for promoting continued influenza vaccination during National Influenza Vaccination Week, typically the first week of December (46, 47).

Estimates of influenza vaccination coverage among adults based on BRFSS have typically been several percentage points lower than similar estimates based on NHIS. Potential reasons for these differences include noncoverage of the BRFSS sample frame of wireless-only

and non-telephone households; higher nonresponse bias in BRFSS; and difference in mode of survey administration (face-to-face interview for NHIS vs. telephone for BRFSS). Response rates for the 2009 NHIS were 65.4% for adults and 73.4% for children (48), higher than state median BRFSS response rate (54%) in 2009 (9). Estimates of the number of persons receiving seasonal influenza vaccination based on combined BRFSS and NHFS data were higher than the actual number of doses distributed (119 million estimated vs. 114-115 million doses distributed), an overestimation likely resulting from a combination of noncoverage (for BRFSS), nonresponse, and misclassification of vaccination status by parental or self report (9).

Information Bias

Based on the level of inaccuracy found in studies of parental report of childhood vaccination, the NIS established provider-reported vaccination histories as the standard for estimating childhood vaccination coverage (49-54). Validity of self-reported influenza vaccination has been most studied among older adults, with estimates of sensitivity across five studies in a variety of populations ranging from 92% to 100% and estimates of specificity ranging from 38% to 96% (55-59). The net bias in estimation of vaccination coverage, measured by the difference in coverage estimated by self report and provider records, ranged from 1 to 29 percentage points overestimation of self-report.

One study reported on validity of influenza vaccination of adults aged <65 years in a managed care organization, with reported sensitivity of self-report of 86% (60). A study during the 2006-2007 and 2007-2008 influenza seasons among residents in the Marshfield, WI area found self and parental reported influenza vaccination status had sensitivity of 95% and specificity of 95%, with evidence for lower sensitivity and higher specificity of parental report for children aged 6-59 months compared to self report by adults aged ≥50 years (61). Net bias among persons aged ≥6 months in this study was <1%.

Four other studies have been reported assessing validity of parental report of child influenza vaccination. Evaluations of 2002-2003 influenza season in patients of inner city neighborhood clinics found parental-reported sensitivity, specificity and net bias to be 86%, 66%, and 13%, respectively, among children aged 6-23 months, and 85%, 69%, and 19%, respectively, among children aged 2-13 years with chronic medical conditions (62, 63). A national study of parental reported influenza vaccination for the 2003-2004 influenza season among children aged 19-35 months based on NIS found sensitivity, specificity and net bias of 86%, 81%, and 11%, respectively (64). A study of 2004-2005 influenza season vaccinations among children aged 6-59 months in a pediatric clinic found sensitivity, specificity and net bias of 88%, 90%, and <1%, respectively (65).

Published studies of validity of reported influenza vaccination status generally indicate a moderate level of misclassification and that vaccination coverage based on parental or self report tends to be higher than coverage based on documented vaccinations. Interpretation of these studies depends on many factors, including population studied, characteristics of the survey used to determine reported vaccination status (survey noncoverage and nonresponse bias, wording of questions to determine vaccination status, mode of survey), completeness of the ascertainment of actual vaccination status, and length of time from vaccination to recall. None of these studies have assessed the potential bias in validity parameter estimation of incomplete ascertainment of actual vaccination status. Validity parameters (sensitivity and specificity) in this context are less likely to be stable than biologic markers across different populations and over time in the same population. For example, as knowledge about influenza vaccination among parents increases over time, they may be more likely to accurately report their child's vaccination status. Persons in managed care organizations that actively promote influenza vaccination each year are likely more aware of their influenza vaccination status.

Net bias is the most relevant validity parameter when the primary objective is to estimate vaccination coverage. Net bias can be expressed as a function of sensitivity and specificity of

self-report, and the true vaccination rate, and thus will vary for fixed levels of sensitivity and specificity as the true vaccination rate changes. Even if net bias is close to zero for estimation of vaccination coverage, analysis of factors associated with vaccination may be biased unless sensitivity and specificity are 100% in all subgroups. If appropriate estimates of sensitivity and specificity of reported vaccination status are available, estimates of vaccination coverage based on self or parental reported vaccination status can be adjusted for misclassification. Such adjustments are particularly important for accurate assessments of vaccination safety and morbidity and mortality averted by vaccination.

Factors of specific relevance for validity of reported influenza vaccination status include validity of reporting of month and year of vaccination, misclassification of 2009 H1N1 and seasonal influenza vaccinations during the 2009-2010 influenza season, and validity of reporting both recommended doses of 2009 H1N1 vaccination among children aged ≤10 years. Decreasing accuracy of recall of past events as length of the recall period increases is a common problem in surveys (66). This may particularly affect reported month of influenza vaccination, which is useful for estimating the shape of the cumulative vaccination curve. Month of vaccination is also needed for Kaplan Meier survival estimation of cumulative proportion of the population vaccinated (10). Use of survival analysis techniques allows updated estimation of influenza vaccination as each new week or month of interview data become available, uses cumulative data collected to maximize precision and minimize random fluctuations in estimates over time that cause concern for users of the data, uses interview data closest to period of vaccination to maximize accuracy of recall, and maximizes precision of estimates for states and other subgroups. Increasing level of misclassification or missing data on month of vaccination by date of interview is problematic for survival analysis, requiring truncation of interview data, imputation of vaccination month, or more complicated estimation procedures.

Further data are needed on validity of parental report of influenza vaccination among children, and among adults aged <65 years. The NIS provides an opportunity for annual

assessment of validity of parental report of influenza vaccination of children aged 6-35 months and 13-17 years. CDC is conducting a study of self-reported vaccination among adults aged ≥18 years in collaboration with Health Partners managed care organization in MN.

DISSERTATION AIMS

The goal of the proposed studies is to evaluate sources of systematic error in estimates of frequency based on surveys of influenza A (H1N1) 2009 monovalent and trivalent seasonal influenza vaccination during 2009-2010, and use the results to improve design, implementation, analysis and interpretation of future pandemic and inter-pandemic influenza vaccination surveys. Three questions about sources of systematic error in measures of frequency based on surveys of influenza vaccination were addressed:

1. Can a quicker and cheaper telephone survey be conducted without introducing too much additional selection bias?
2. How much selection bias is incurred by conducting a telephone survey compared to the National Health Interview Survey (NHIS), a less timely data source with a more complete sampling frame and higher response rates?
3. How accurate is parental report of young children's influenza vaccination status, compared to provider reported status in the National Immunization Survey (NIS)?

These questions are addressed in three separate chapters of this dissertation (Chapters 3, 4 and 5). Chapter 2 provides an overview of the methods used in the three dissertation research studies, and Chapter 6 presents conclusions about the strengths and limitations of these research studies and their contribution to public health and survey methodology.

Chapter 2 METHODS

This chapter provides an overview of objectives and selected methods for the three studies described in detail in the next three chapters. Methods relevant to two or more studies are highlighted in this chapter.

The first study (Chapter 3) seeks to determine the level of incremental selection bias that would have incurred if the NHFS had been conducted with a shorter (one or two week) interview period, compared to the full five week interview period. A secondary objective is to assess overall nonresponse bias in NHFS by level-of-effort analysis based on weeks from sample release to survey participation (Chapter 3). The analysis focuses on comparison of characteristics and influenza-related outcomes between early responders (those participating in the survey within two weeks after their telephone number is released for dialing) and later responders.

The second study (Chapter 4) seeks to assess selection bias in estimates of influenza vaccination prevalence from the NHFS by comparison to the National Health Interview Survey (NHIS), an in-person survey with a sample frame based on enumeration of households. Using January-June 2010 data from NHFS and NHIS, the weighted characteristics of NHFS and NHIS respondents are compared, as are estimates of influenza vaccination stratified by respondent characteristics. This study also evaluates the contribution of the NHFS cell phone sample, by comparing characteristics of respondents from landline and cell phone sampling frames, and comparing influenza vaccination prevalence estimates from the full NHFS sample to the weighted sample that would have been used if the cell phone sample had not been used.

The final study (Chapter 5) seeks to assess the validity of parental report of pH1N1 and seasonal influenza vaccination in children aged 10-37 months during 2009-2010 in the United States. Using NIS data for children aged 19-35 months when sampled during October 2009-June 2010, this study estimates sensitivity, specificity and net bias of caregiver report of children's receipt of pH1N1 and seasonal influenza vaccinations (one or more doses, or two or more doses),

as compared to provider report. Variations in sensitivity and specificity by time from vaccination period to interview date and sociodemographic characteristics of respondents are investigated. Accuracy of caregiver report of their children's type of influenza vaccination (inactivated and injected vs. live-attenuated and intranasally administered) is evaluated. A misclassification model is developed to assess potential bias in estimates of validity parameters resulting from incompleteness of ascertainment and reporting of influenza vaccinations by providers. Finally, scenarios are constructed using study findings to illustrate potential biases in apparent trends in influenza vaccination prevalence based on surveys relying on parental reported vaccinations status.

DATA SOURCES

National 2009 H1N1 Flu Survey (NHFS)

NHFS was conducted October 2009 – June 2010. The CDC contracted with NORC at the University of Chicago to design and implement the NHFS. The NHFS consisted of a national random-digit–dialed telephone survey based on a rolling weekly sample of landline and cellular telephones contacted to identify residential households. For the landline sample, within each contacted NHFS sample household, one adult was randomly selected for interview, and the parent or guardian of one randomly selected child (if present) was selected for interview. For the cell sample, the target was owners of privately-used cell phones and an interview attempted if the person answering was ≥18 years. A written version of the NHFS computer-assisted telephone interview is available online at: http://www.cdc.gov/nchs/nis/h1n1_introduction.htm.

Monthly targets for the NHFS sample were established to achieve a total of approximately 6,000 total completed adult interviews (4,889 from landline and 1,111 from cellular-phone-only or cellular-phone-mainly households). The cellular phone sample was screened for households with wireless only service (cell-only), or households with both cellular and landline service who responded "somewhat unlikely" or "not at all likely" to the question,

"Thinking just about the land line home phone, not your cell phone, if that telephone rang and someone was home, under normal circumstances how likely is it that it would be answered?" (cell-mainly). Of 38,536 active personal cell phones numbers screened for non-minor status and telephone use status, 6,426 minors were screened out. Of the remaining 32,110 adults identified, 16,203 (50.4%) were reported as cell-only, 3,624 (11.3%) cell-mainly, and 12,283 (38.3%) other dual landline and cell phone households. Interviews were completed for 8,881 cell-only cases and 2,176 cell-mainly cases.

The landline NHFS sample was augmented with a sample of children aged less than 18 years identified during screening for the National Immunization Survey (NIS); the NIS child data were not analyzed for the studies presented in this dissertation. Batches of telephone numbers randomly sampled for the NHFS were released to the NORC at the University of Chicago calling center on a weekly basis, with week defined as Sunday through Saturday, and each released panel remaining active for five weeks. Each sampled telephone number continued to be called across the five weeks until the number was resolved as non-residential, there was a confirmed refusal, or a completed interview was obtained. A minimum of eight call attempts were made to each sampled telephone number, more if there was evidence the number was associated with a household. Varying times of the day and days of the week were called to maximize response rates.

Completed interviews obtained within a survey week (regardless of which panel they belonged to) were then used in generating the estimates for that survey week. The estimates for a given survey week were thus based upon completed interviews from five panels that included both early and late responders.

The final response rates (AAPOR type 3) were 33.4% for the landline sample (product of 77.6% resolution, 99.6% screening, 43.2% interview completion) and 26.1% for the cell-only/mainly sample (product of 54.6% resolution, 85.7% screening, and 55.8% interview completion (67). The resolution rate is the proportion of sampled telephone numbers that were

determined to be in a household, the screening rate is the proportion of identified households that completed the initial telephone screening to identify a person aged ≥18 years in the household (and for cell phone sample, to screen for cell phone only or mainly status), and the interview completion rate is the proportion of screened households that completed the interview. The AAPOR type 3 response rate is calculated as the number of completed interviews with reporting units divided by the number of eligible reporting units in the sample, using an estimate of the proportion of cases with unknown eligibility that are actually eligible (67). Of households with completed adult interviews in which a child was reported living in the household (27.9% for landline and 34.9% for cell phone cases), an interview for a randomly selected child was completed for 88.4% of landline and 78.9% of cell phone cases.

National Health Interview Survey (NHIS)

The NHIS has been conducted by the CDC since 1957 to monitor the health of the civilian, non-institutionalized U.S. population (68). It uses an area sample frame based on the 2000 Census and is augmented with updated address lists developed specifically for the NHIS. The survey is conducted in four independent quarterly samples using a state-stratified, multistage design, with oversampling of blacks and Hispanics. Primary sampling units are counties or groups of contiguous counties. Secondary sampling units are clusters of housing units. For sampled housing units, a core questionnaire is administered for each family living in the household. For each family, one adult aged ≥18 years and one child aged <18 years (if any in the family) are sampled randomly and administered a separate survey. Interviews about the randomly selected child, and for the randomly selected adult if that adult is not home at the time of the interview, are conducted with a knowledgeable adult aged ≥18 years in the family.

Surveys are administered by U.S. Census Bureau interviewers via personal household interview using computer-assisted personal interviewing. Written versions of the NHIS

computer-assisted personal interview are available online at: ftp://ftp.cdc.gov/pub/Health_Statistics/NCHS/Survey_Questionnaires/NHIS/2010/English .

Of sampled households in the 2010 NHIS, 79.5% (n=34,329) participated. Among participating households, 99.1% (n=35,177) of identified families participated. Among participating families with at least one child, child core interviews were completed for 89.8%, for an overall response rate for sampled children of 70.7%. Among participating families, an adult core interview was completed for 77.3%, for an overall response rate for sampled adults of 60.8%. To illustrate the declining response rates even for in-person surveys, the 2000 NHIS final response rates for children and adults were 79.4% and 72.1%, respectively. The NHIS added questions to determine pH1N1 vaccination status in sample children and adults starting in January 2010. Thus, for comparison to the NHFS in Chapter 4, NHIS data from January-June 2010 interviews were analyzed, including 14,021 sample adults and 5,383 sample children.

National Immunization Survey (NIS)

The NIS is a list-assisted random digit dialed (RDD) telephone survey of households with children aged 19-35 months followed by a mail survey of providers identified during the household interview to obtain vaccination histories (69). The target population for the NIS is children aged 19-35 months living in households in the United States at the time of the interview. The NIS data used in Chapter 5 of this dissertation were collected when the NIS sample frame was restricted to landline telephones; a full dual landline and cell telephone sampling frame was implemented in 2012. Samples of telephone numbers are drawn independently for each calendar quarter, stratified by state and selected urban areas. Interviews about age-eligible children in the household are conducted with the adult who is most knowledgeable about the child's vaccinations. A survey to collect the child's vaccination histories is mailed to the child's health care providers who are identified during the interview, if the parent or guardian gives consent for this follow-up.

For NIS data for the four calendar quarters from July 2009 through June 2010, 6.8 million landline telephone numbers were randomly selected, of which 5.6 million (83.2%) were resolved through pre-screening and dialing in the survey phone center as either a household, or a non-working, non-residential, cell telephone, or "take me off the list" numbers. Of 1,172,341 households identified, 92.4% (1,080,670) were successfully screened by telephone for presence of an age-eligible child. Of screened households, 2.68% (29,056) had at least one child aged 19-35 months. Of identified eligible households, interviews were completed for 83.5% (24,271) households, and for 24,986 children 19-35 months in these households. The final household response rate (AAPOR response rate 3) was 64.2%, the product of the resolution (83.2%), screening (92.4%) and interview completion (83.5%) rates (67).

Of the 24,986 children with completed interviews, consent from the parent or guardian to contact the child's medical providers was obtained for 19,750 (79.0%), for which a total of 26,817 providers were identified and mailed immunization history questionnaires. Of these providers, 94.1% (25,223) returned questionnaires. All children for whom all providers identified by parents or guardians responded were considered to have adequate provider data; if not all identified providers responded, a child was determined to have adequate provider data if they were up-to-date with vaccinations (DTaP, polio, MMR, Hib, Hepatitis B) based on the provider report(s) or the provider reports matched the parent's shot card data or numbers of household reported vaccinations, when reported, matched the provider record (see Table D.1 of reference 69). After combining the vaccination data obtained from multiple providers for the same child, and reviewing the provider-reported vaccination data, 17,499 (88.6%) children were deemed to have adequate provider data for purposes of estimating vaccination coverage. Overall, 70% of the children with completed household interviews had adequate provider data.

SURVEY WEIGHTING AND ANALYSIS

Each of the three data sources used for the studies in this dissertation are from surveys with complex sampling designs. Thus, data analyses were conducted using SAS version 9.2 for data management, and SAS-callable SUDAAN release 10.0.1 for statistical analyses to account for survey weighting and complex survey design (70). Using SUDAAN design statements specific for each survey, appropriate estimates of variance and statistical tests were obtained. All analyses were also weighted using survey weights for each respondent designed so that the weighted sums of all survey respondents matched certain population totals derived from U.S. Census data. Development of survey weights for the NHFS, NHIS and NIS are described below. Generally, weights are developed in two broad steps, the first to account for the sample design (e.g. initial weight is the inverse of the probability of a unit in the sampling frame being selected), and then to account for nonresponse using post-stratification to population control totals (23). This latter type of adjustment is designed to reduce potential nonresponse bias in survey estimates by weighting each survey respondent so that weighted numbers of respondents match the sociodemographic characteristics of the target population, using control variables that are available both in the sample and target populations, are associated with response propensity, and that are likely to be associated with outcomes of interest. This approach can reduce nonresponse bias but not eliminate it if there is covariance between response propensity and survey outcomes of interest within the sociodemographic strata used for weighting.

NHFS sample weights were developed with adjustments for probability of selection, multiple phone lines per household, age-specific national proportion of the population estimated to be in landline vs. cell-only/mainly households, post-stratification to 2008 and 2009 Census population estimates by age group, and a final "raking" post-stratification adjustment (71) of trimmed, post-stratified weights using national level control totals for three raking dimensions: age group by gender, race/ethnicity and state of residence. For the "raking" post-stratification

adjustment, iterative proportional fitting was used to adjust the survey weights so that weighted sums of respondents matched the marginal population control totals for age group by gender, race/ethnicity and state of residence.

Alternative survey weights for NHFS were constructed by NORC at the University of Chicago for specific analyses. In Chapter 3, new weights were constructed for the subset of the NHFS sample who responded to the survey within two weeks of sample release, and for the subset responding within one week. These new weights used the same base and post-stratification weighting procedures for the subsets of respondents as for the full set of respondents. Comparisons of estimates from the alternative-weighted one and two week respondents with estimates from the original-weighted full set of respondents allowed evaluation of a simulated scenario in which a shorter, more timely survey was used. In Chapter 4, the effect of including a cell telephone sample was simulated by comparing estimates from the original-weighted full dual (landline and cell telephone) frame sample with estimates from the alternative-weighted subset of landline respondents.

NHIS survey weights adjusted for probability of selection with adjustments for non-response and post-stratification to Census population controls by sex, age and race/ethnicity. An improvement to the weighting adjustments for non-response at the sample child and adult levels was made starting in 2010 (72), but further evaluation of non-response bias in NHIS, particularly for influenza vaccination, does not appear to be available.

NIS weights were constructed by NORC at the University of Chicago for the quarter 4 2009 through quarter 2 2010 sample, with adjustments for probability of selection, non-response and post-stratification adjustments made separately for the household and provider phases. Details of the NIS weighting procedures are described in reference 69.

ESTIMATING PREVALENCE OF INFLUENZA VACCINATION

In each of the three studies presented in this dissertation, prevalence of influenza vaccination is a primary outcome of interest. Influenza vaccination is seasonal, with vaccine distribution beginning as early as July and promoted through winter and early spring (5, 73, 74). The classic approach for estimating influenza vaccination levels based on data from the NHIS and BRFSS has been development of estimates of prevalence of self or parental reported influenza vaccination in the 12 months prior to the interview, using the calendar year of data (75). For example, persons interviewed early in 2012 may recall an influenza vaccination received late for the 2010-11 season, persons interviewed anytime during 2012 may recall an influenza vaccination received for the 2011-12 season, and persons interviewed late in 2012 may recall an influenza vaccination received for the 2012-13 season. Persons interviewed late in 2012 also may receive influenza vaccination for the 2012-13 season after their survey interview, so their influenza vaccination status for that season is censored by date of interview. Thus, estimates using the classic approach represent a rolling average of influenza vaccination over three seasonal vaccination cycles, with the predominance of reported vaccinations likely reflecting the season ending by June of the data collection year. This approach may be adequate for general assessment of trends and for identifying variations in vaccination prevalence by population subgroups.

In 2000 and 2001, substantial delays in distribution of influenza vaccination (73, 74) led to the need for season-specific estimates of influenza vaccination levels, and this was reinforced by the 2004-05 influenza vaccination shortage (76, 77). Various approaches were used to obtain estimates more likely to reflect the most recent prior season, including restriction of data to persons interviewed January-March (73, 74, 77) or January-June (78). This approach acknowledged the incomplete information about the season of interest from persons interviewed later in the calendar year, evidence of low incidence of vaccinations past December (76,79), and

presumption that accuracy of recall of past influenza vaccinations dropped over time. Further refinements restricted data to include persons interviewed March-August (post-vaccination period approach), reflecting possibility of increased levels of later season vaccinations and balancing concerns about inaccuracy of vaccination status recall with increasing precision of estimates (1, 80).

Associated with the 2004-05 influenza vaccine shortage, questions were added to the NHIS asking for the month and year of most recent influenza vaccination, for those reporting influenza vaccination in the past 12 months. Similar questions were added to the core BRFSS in 2008. This information was used to refine the post-vaccination period approach, by including in the numerator only those persons reporting vaccination during a specified vaccination period, e.g. September-February (2, 81, 82). This approach typically excluded persons reporting influenza vaccination in the past 12 months but who did not report the month and year of their most recent influenza vaccination, primarily giving a "don't know" response. This strategy implicitly assumes that the proportion of persons with unknown month and year of most recent vaccination that were vaccinated during the vaccination period ($P_{v|DK}$) equaled the same as among those reporting full vaccination status (either reported no to receipt of influenza vaccination in the past 12 months or reported yes and reported month and year of most recent vaccination) ($P_{v|K}$). However, the denominator for $P_{v|DK}$ includes persons who reported vaccination in the past 12 months, while the denominator for $P_{v|K}$ also includes persons who reported they were not vaccinated in the past 12 months, so it is highly likely that $P_{v|DK}$ is greater than $P_{v|K}$. Expressing the vaccination rate as a weighted sum of vaccination rates among those reporting vs. not reporting full vaccination status (among those reporting yes or no to the question about receipt of influenza vaccination in the past 12 months), the bias in the estimate that excludes respondents with missing month and year of vaccination is: $(1-P_K)*(P_{v|K} - P_{v|DK})$, where P_K is the proportion reporting full vaccination status. This bias will be zero if there are no cases with unknown month and year of most recent vaccination, and otherwise is always negative (too low) assuming $P_{v|DK} >$

$P_{v|K}$. For example, if 90% of those with a yes or no response to vaccination in the past 12 months reported either they were not vaccinated or they were vaccinated and reported a month and year of vaccination, 50% of persons with known status were vaccinated, and 90% of those reporting vaccination but not the month and year were vaccinated during the specified vaccination period, the bias in the estimate excluding those with missing month/year of vaccination would be -4 percentage points ({1-0.9}*{0.5 – 0.9} = -0.04).

During the 2009-10 pH1N1 influenza vaccination campaign, national and state-level estimates were needed during the campaign and shortly after (6, 8-11). A post-vaccination period approach, e.g. using each successive month of interview data to estimate the cumulative proportion vaccinated as of approximately mid-month, did not utilize the cumulative data collected to date and random fluctuations could lead to drops in the estimated cumulative percent vaccinated over time. Thus, the non-parametric product limit or Kaplan-Meier approach was utilized (6, 8-11, 30, 83). This is a natural approach for consistent estimation of the cumulative proportion of the population vaccinated as survey data are collected, and has become CDC's standard approach for estimating influenza vaccination levels at national and state levels based on the BRFSS, NIS (84) and NHIS. Compared to an approach estimating vaccination coverage using post-vaccination period data, the survival analysis approach allows use of data from interviews conducted during the vaccination period, increasing precision and likely reducing misclassification of vaccination status given shorter recall period for some months of interview. It also produces estimates of the monthly cumulative proportion vaccinated.

This approach assumes a relatively stable population during the course of the vaccination period and that each month of interview data provides a reasonably representative sample of the population. Similar assumptions apply to the post-vaccination period approach (e.g. if using interview data from March-June to estimate influenza vaccinations through February, it is assumed that persons interviewed March-June represent the cohort of persons residing in the U.S. during the vaccination period). The Kaplan-Meier approach should not be used to estimate

influenza vaccination levels for women currently pregnant from NHIS and BRFSS. Women pregnant during the influenza vaccination period are a dynamic cohort with women entering and leaving continuously. Dates of pregnancy during the vaccination period would be needed to apply survival analysis models. Women currently pregnant in December and January would be most likely pregnant during, and interviewed by NHIS or BRFSS after, the peak vaccination period. Women currently pregnant in other months are more likely to include women currently pregnant but were not pregnant during the vaccination period, and women not currently pregnant (and thus not identified as pregnant during the NHIS or BRFSS interview) but who were pregnant during the vaccination period.

The studies presented in Chapters 3 and 4 used the Kaplan-Meier procedure KAPMEIR in SUDAAN (70) for primary outcomes of influenza vaccination prevalence, and details of implementation are described in the Methods sections of those Chapters. Kaplan-Meier estimation using survey data with reported month of influenza vaccination typically uses the earliest reported influenza vaccination during the specified vaccination period (e.g., August – May) as the event. Time-to-event is measured by the month of reported vaccination. Persons reporting they had not received influenza vaccination by date of interview are assigned a time value of the month prior to their month of interview, since vaccination could have occurred between date of interview and end of the month. Persons reporting vaccination in a month prior to month of interview are assigned a time value of the month of vaccination. Persons reporting vaccination in the same month as interviewed are classified as not having the event and assigned a time value of the month prior to month of interview, because persons not vaccinated by date of interview are interval-censored. Vaccination coverage, the cumulative proportion vaccinated, is estimated as one minus the cumulative proportion without vaccination directly produced by the Kaplan-Meier procedure.

PROTECTION OF HUMAN SUBJECTS

The studies in this dissertation consisted of secondary analyses of existing data, and no human subjects were contacted for these secondary data analyses. The 2010 NHIS public use data file was used. Non-public NIS and NHFS data files were also used, with access to these secured, limited-access confidential data files approved as part of my duties as an employee of the CDC. The original data collections for the NHFS and NIS were conducted under the authority of the National Center for Health Statistics (NCHS), CDC, and reviewed and approved by the NCHS Research Ethics Review Board (protocol 2006-04 National Immunization Survey). The conduct of the studies using these data was reviewed and approved by the Emory IRB on July 25, 2011 (study IRB00050957).

Chapter 3 DESIGN OF HEALTH SURVEYS FOR PUBLIC HEALTH EMERGENCIES: EARLY RESPONDER BIAS IN THE NATIONAL 2009 H1N1 FLU SURVEY (NHFS)[1]

ABSTRACT

In response to the influenza A(H1N1)pdm09 (pH1N1) pandemic, the Centers for Disease Control and Prevention (CDC) developed the National 2009 H1N1 Flu Survey (NHFS) to provide weekly estimates of pH1N1 and trivalent seasonal influenza vaccination coverage and related opinions about influenza and influenzas vaccination. This paper compares early and later responders to the NHFS to assess potential change in validity of survey estimates if effort to obtain interviews had been reduced, and to assess nonresponse bias in the NHFS in a level of effort analysis comparing early and late respondents.

The NHFS was a landline and cell telephone survey conducted October 2009 through June 2010, with interviews completed for 56,656 adults and 14,652 children. Sampled telephone numbers were called for up to five weeks; early responders were those completing the interview within two weeks of sample release (77%). Socio-demographic differences were identified between early and later respondents, with nature of differences varying between landline and cell phone samples. While some differences in estimated influenza vaccination coverage were found between early and later respondents, these differences were reduced when comparing estimates based on the subset of early respondents weighted back to the control population to estimates based on all respondents. In all subgroups examined, the differences in these estimates based on

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[1] This chapter includes and expands on a paper submitted for publication in the proceedings of the 10th Conference on Health Survey Research Methods, held April 8-11, 2011 in Peachtree City, GA. Co-authors included: Tammy Santibanez, Centers for Disease Control and Prevention; Nicholas Davis, Kennon R. Copeland, N. Ganesh and Kirk Wolter, NORC at the University of Chicago; and Carey Drews-Botsch, Emory University, chair of the dissertation committee.

early weighted and all respondents was less than the 95% confidence interval half-width of the final estimate. In a level-of-effort nonresponse bias analysis, estimated nonresponse bias across 44 vaccination coverage estimates ranged from -3.5 to 6.6 percentage points (median 0.4, 25th percentile -1.4, 75th percentile 1.4). This study indicates that shortening the field period of a telephone-based influenza vaccination survey can provide more rapid results without substantively increasing systematic error. Results may apply to other polls or surveys with short interview periods to assess how estimates might change if there were more effort to maximize response rates.

INTRODUCTION

Design of surveillance systems for public health emergencies must consider the content, frequency and turn-around time of information needed, use of existing systems, need for development of new systems, and possible tradeoffs in data quality and precision given time and resource constraints (85). In response to the influenza A(H1N1)pdm09 (pH1N1) pandemic, the Centers for Disease Control and Prevention (CDC) developed systems to monitor pH1N1 disease and the use, safety and effectiveness of pH1N1 vaccine (86). The goals for monitoring pH1N1 vaccination included use of surveys to provide weekly estimates of the proportion of target groups vaccinated, place of vaccination, reasons for non-vaccination, and opinions about risk of influenza and safety and effectiveness of influenza vaccination (6). Given the uncertainty regarding the types of influenza viruses that would circulate in the upcoming 2009-2010 influenza season, both monovalent pH1N1 and trivalent seasonal influenza vaccines were recommended for various target groups (4, 5).

The National 2009 H1N1 Influenza Survey (NHFS), a dual landline and cell telephone survey, was conducted October 2009 – June 2010 to provide weekly estimates for pH1N1 and

seasonal influenza vaccinations (7). Data from NHFS and other systems were used in development of public messages about the vaccination campaign, to help assess safety and effectiveness of the vaccine, and provide feedback to states on their vaccination programs (8, 9, 13, 17, 19). Evaluation of this enhanced surveillance system is needed to identify areas of improvement for influenza vaccination surveys during future pandemic and inter-pandemic seasons.

It is important to understand non-response bias in surveys, particularly in rapid response surveys which may have lower response rates than routine surveys. Comparison of survey respondents by level of effort (e.g., time or number of call attempts) is one readily available approach for assessing nonresponse bias (40). These studies assume a continuum of resistance or difficulty in reaching potential respondents, with nonresponders represented by the most resistant or hardest to reach respondents (43, 45). Such studies are also useful for evaluating potential change in validity of survey estimates that would result by altering the effort expended to obtain interviews. This information is relevant for improving cost-efficiency, and for decision making in special circumstances when timely information is needed and some level of systematic error in estimates can be tolerated or accounted for based on past experience.

The purpose of this paper is to compare early and late responders to the NHFS to assess potential change in validity of survey estimates if effort to obtain interviews had been reduced, and to assess nonresponse bias in the NHFS in a level of effort analysis comparing early and late respondents. This paper expands on previous preliminary analysis of early responder bias in the NHFS (44).

METHODS

DATA SOURCE

Details about the NHFS are included in Chapter 2. NHFS data collected October 2009-June 2010 were used for this analysis (56,656 completed adult interviews and 14,652 completed interviews for children).

ANALYSIS

Respondents were classified by week since sample release (WSR), from one to five weeks, and grouped into early (WSR=1,2) and later (WSR=3,4,5) respondents. Respondent characteristics examined included age group, race/ethnicity, sex, region, level of education, pH1N1 and seasonal influenza vaccination target groups, health care worker status, household income, Metropolitan Statistical Area status, housing tenure, and employment status. Influenza vaccine-related outcomes examined include receipt of pH1N1 vaccination since October 2009, receipt of seasonal influenza vaccination since August 2009, opinions about safety and effectiveness of influenza vaccines, risk of influenza illness if not vaccinated, and level of concern about "swine flu".

All analyses were conducted with SUDAAN software to account for the complex survey design (70). Associations between WSR and respondent characteristics were assessed by Chi-square tests, overall and by source of sample (landline vs. cell-only/mainly). The prevalence of influenza vaccine-related outcomes for early vs. later responders were compared, overall and stratified by sample source. Because vaccination and other outcomes varied over time, logistic regression models were fit for each outcome and sample source, with main effects for WSR group (early, later) and interview week. The first four weeks of interview data from October 2009 were excluded from this analysis, because little pH1N1 vaccine was available then, and analysis by date of interview was not balanced during that period with a cross-section of early and later responders until week five. Adjusted differences in outcome proportions were estimated from

predictive marginals obtained from the logistic regression models. This analysis was repeated for 1st WSR compared to later respondents.

Nonresponse bias assessment

To assess the potential increase in nonresponse bias if the survey had been restricted to early respondents, differences in influenza vaccination coverage between early and later respondents were estimated. Comparisons were also made between all respondents and the subset of early respondents weighted back to the control population. Comparisons were made for pH1N1 and seasonal vaccination for adults and children, and for adults stratified by race/ethnicity, age, target group and healthcare personnel. To weight the early responder sample, the sample restricted to early responders was post stratified to the Census population controls. Vaccination coverage was estimated as the cumulative proportion of persons vaccinated by end of May 2010, estimated using the Kaplan-Meier SUDAAN procedure KAPMEIER based on reported month of vaccination as the time unit. This analysis was repeated for 1st WSR compared to later (i.e., WSR=3,4,5) respondents.

To assess overall nonresponse bias in final survey results, the difference in estimated vaccination coverage based on all respondents and later respondents was multiplied by the nonresponse rate. This is based on expressing the "true" vaccination rate as a weighted average of vaccination rates in responders and nonresponders, and then expressing the nonresponse bias as the difference in vaccination rate among responders compared to nonresponders. Here, later respondents are assumed to represent nonrespondents. Vaccination coverage estimates were examined for each of the five weeks since sample release to assess for possible dose-response (larger difference between estimates for 1st week vs. later week responders, as week since release increases), to determine if WSR=5 responders or WSR=3, 4, or 5 should be used to represent non-responders.

Effect of restriction to early respondents on vaccination prevalence ratios

To assess the effect of restricting the sample to early respondents on measures of association, logistic regression models of influenza vaccination were fit for all respondents, the subset of early respondents weighted back to the control population, and the subset of 1st week responders weighted back to the control population. The models based on the weighted subsets simulate what would have been found if the survey had been restricted to early or 1st week respondents. Separate models were fit for children and adults and for pH1N1 and seasonal influenza vaccination, using selected sociodemographic and risk covariates in main effects models. Simple models using sociodemographic and risk covariates found to be associated with influenza vaccination in past studies were used for purposes of identifying potential differences in typical descriptive logistic regression models associated with conducting a shorter survey. For adults, another model was assessed that included opinions about effectiveness and safety of influenza vaccination, and risk of influenza if not vaccinated. This model was used in an analysis prepared for publication (87), and is included here as an example of actual models constructed based on these data.

RESULTS

Of the 56,656 adult respondents, 53.7% responded by the first week since sample release, 23.3% in the 2nd week, 12.5% in the 3rd week, 6.7% in the 4th week, and 3.8% in the 5th week. Thus, 77% were classified as early and 23% as later respondents. The distribution by WSR did not differ between landline (80.5% of respondents) and cell-only/mainly samples (19.5% of respondents) (Figure 3-1). The median number of call attempts for completed interviews across landline and cell-only/mainly samples ranged from 2, 5-6, 8-10, 11-13, and 14-15 for weeks 1, 2, 3, 4, and 5 since release, respectively (Figure 3-2); level-of-effort analysis based on number of call attempts was not included in this study because the main purpose was to evaluate the length of time the telephone sample was actively dialed. For the landline sample, there were differences

between early and later responders for 13 of 16 characteristics, with the largest differences by age (25.5% of early responders ≥65 years vs. 17.8% of later respondents), race/ethnicity (non-Hispanic white only 75.8% vs. 68.9%), having a child in the household (34.8% vs. 40.9%), employment status (employed, 50.8% vs. 56.9%; retired, 23.8% vs. 16.3%), and member of seasonal target group (72.5% vs. 66.4%) (Table 3-1). Fewer characteristics differed by responder status for the cell-only/mainly sample, and effects were different for age and sex compared to the landline sample (in the cell-only/mainly sample, early responders were more likely to be 18-24 years and male). Overall, the cell-only/mainly respondents were more likely than landline respondents to be younger, non-white, interviewed in Spanish, male, have a child in the household, live in the principal city of a metropolitan statistical area, live below the poverty level, rent their dwelling, be employed, have no health insurance, not have a chronic medical condition, be in the pH1N1 target group, and not be in the seasonal target group.

Comparing influenza-related opinions and vaccination status, some statistically significant differences by responder status were found in bivariable analysis. For the landline sample, early responders had higher adjusted pH1N1 and seasonal vaccination coverage than later responders, by 1.6 and 2.2 percentage points, respectively (Table3-2a). Early responders had a 2.2 percentage point higher prevalence than later responders of reporting they had very or somewhat high chances of seasonal flu sickness if not vaccinated for the landline sample, while for the cell-only/mainly sample, prevalence was 4.3 percentage points lower for early responders. For the cell-only/mainly sample, early responders were also less likely to report they were very or somewhat worried about getting sick from seasonal flu vaccine.

For selected opinion outcomes, weekly prevalence for early and late respondents and for reweighted early responders and all responders were compared graphically (Figure 3-3). Examining the overall weekly prevalence of worry about getting sick from seasonal flu, large differences were observed during February-March between early and late respondents; when comparing early reweighted to all responders, these differences were reduced (Figure 3-3, lower

panels). For concern about pH1N1 flu, differences in prevalence between early and late respondents was more sporadic, and very similar when comparing early reweighted to all responders (Figure 3-3, upper panels).

Comparing 1st week to later respondents, similar differences were found in pH1N1 and seasonal vaccination prevalence adjusted for week of interview for the landline sample, while in the cell sample differences were larger for 1st week vs. later (3.8 and 3.7 percentage points) and early vs. late respondents (1.8 and -0.6 percentage points) for receipt of pH1N1 and seasonal influenza vaccinations, respectively (Table 3-2b). Comparisons that became statistically significant when restricting to 1st week respondents included lower adjusted prevalence of 1st week vs. later respondents in worry about getting sick from pH1N1 flu vaccine in the cell sample (-4.1 percentage points) and lower prevalence of 1st week vs. later respondents in worry about getting sick from seasonal flu vaccine in the landline sample (-1.8 percentage points). Other statistically significant differences based on the early vs. late respondents were similar when restricted to 1st week respondents.

NONRESPONSE BIAS ASSESSMENT

When comparing influenza vaccination coverage as of end of May 2010 between early and later responders by age, race/ethnicity and target groups, most differences were not significant; however, some statistically significant differences were found in bivariable analysis, ranging from 7.3 percentage point lower seasonal vaccination coverage for Hispanic adults to 15.0 percentage points higher pH1N1 coverage among non-Hispanic black only children (Tables 3-3a, 3-3b). When comparing early responders weighted back to population controls to all responders, differences were reduced substantially; in all subgroups examined, the point estimate for reweighted early responders fell within the 95% confidence interval for all respondents, and the difference between reweighted early respondents was less than the 95% confidence interval half-width of the final estimate. When restricted to 1st week respondents, differences in estimates

for reweighted 1st week respondents were less than four percentage points than estimates for all respondents for most comparisons; for pH1N1 vaccination, the difference for non-Hispanic black only children was 9.4 percentage points (Tables 3-3c, 3-3d).

To evaluate nonresponse bias by level-of-effort, differences in vaccination coverage estimates for all minus later respondents (from Tables 3-3a and 3-3b) were multiplied by the nonresponse rate (67.8%, calculated as the weighted average of landline and cell-only/mainly CASRO rates, using the weighted percent of the population in landline households of 64.6%). Estimated nonresponse bias across the 44 vaccination coverage estimates in Tables 3-3a and 3-3b ranged from -3.5 to 6.6 percentage points (median 0.4, 25th percentile -1.4, 75th percentile 1.4). No trends were detected in vaccination coverage estimates for adults or children (pH1N1 or seasonal) by 5-level weeks since release (data not shown). Figure 3-4 illustrates the linear relationship of nonresponse bias as a function of the difference in estimated outcome between resonders and nonresponders. The slope of the line increase as the response rate decreases. With a 30% response rate similar to observed with the NHFS, nonresponse bias would be 5-6 percentage points if the difference in estimated outcome between resonders and nonresponders was 8 percentage points.

EFFECT OF RESTRICTION TO EARLY RESPONDENTS ON VACCINATION PREVALENCE RATIOS

Results of logistic regression models for all, early weighted and 1st week weighted samples were compared, with separate models for children (Table 3-4a) and two models for adults (Tables 3-4b, 3-4c). Across al l models, prevalence ratios comparing influenza vaccination coverage between levels of each covariate were not substantively different whether based on all, early weighted or 1st week weighted respondent samples. For example, in Table 3-4c, non-Hispanic white adults had higher prevalence of pH1N1 vaccination than Hispanic adults in the overall sample (prevalence ratio 1.6), with similar prevalence ratios in the early weighted (1.8)

and 1st week weighted (1.9) samples. Similar prevalence ratios across the three analytic samples were also observed for the interactive effects of opinions about vaccine effectiveness, vaccine safety, and risk of influenza.

DISCUSSION

This study found that there were moderate differences in many sociodemographic and other characteristics between early and later cooperators to a telephone survey about influenza vaccination. For key influenza-related opinions and vaccination status, some differences were found between early and later responders. After restricting the sample to early responders and adjusting the weights by post-stratification to population control totals, these differences were reduced. With 77% of the total respondents classified as early respondents, differences between early and later respondents would need to be larger to result in substantial bias from restriction of the sample to early respondents. Assuming later responders were representative of nonresponders, nonresponse bias of influenza vaccination coverage estimates from the full sample were estimated to be less than two percentage points for the majority of population subgroups examined.

Similar to a previous study using the 2004 Behavioral Risk Factor Surveillance System, this study found early cooperators were more likely to be older, non-Hispanic white and female (45). That study reported a larger difference (7.6 percentage points) in receipt of influenza vaccination between early and later cooperators (defined by number of call attempts), but similarly found a smaller difference (2.6) between early cooperators and all respondents.

This study is among the first to evaluate early responders from a cell phone sample. Fewer differences were found between early and later responders to the cell sample compared to the landline sample, and in some cases the opposite effect was found. In the cell sample, early responders were more likely to be younger and male, and race/ethnicity was not associated with responder status. Influenza vaccination coverage did not differ by responder status for the cell

sample, but there were differences for two of the opinion outcomes, with an opposite early responder effect between cell and landline samples for one of them. These findings underscore the need for further studies to evaluate factors associated with propensity to respond to cell phone surveys, and implications for nonresponse bias.

The 5-week rolling sample design of the NHFS maximized response rates while allowing weekly estimates during the 2009-2010 influenza pandemic. For the 2010-2011, 2011-12 and 2012-13 seasons, the CDC needed estimates for the start of National Influenza Vaccination Week (NIVW) in early December. Because the incidence of influenza vaccination typically changes substantially during October and November, a short survey field period was desired to provide the most up-to-date estimates with results available in time for use during NIVW. Thus, the 2010-11 and 2011-12 season National Flu Surveys were conducted November 1-13, 2011 and November 1-13, 2012. The findings of this NHFS analysis suggest that estimates would not have been substantively different with a longer field period. Similarly, this study also found that restricting to first week respondents would also likely yield similar results to a five week survey field period. Because rapid one or two week influenza vaccination surveys in future influenza seasons may face different response propensities depending on the nature of public perceptions and saliency related to severity of influenza season, shortage of vaccine, or safety issues, they should consider including a subsample followed for a longer time to allow assessment of early responder bias, For repeated cross-section designs like the NHFS, cost could have been reduced by about 13% if restricted to two-week rolling panels; these resources could be redirected to increasing sample size.

Besides providing timely estimates of influenza vaccination coverage, rapid surveys may also be used to test hypothesis about associations between influenza vaccination and key "exposure" variables, or to identify factors independently associated with influenza vaccination. This study examined several logistic regression models and did not find substantive differences in estimated prevalence ratios whether based on all, early weighted or first week weighted

respondent samples. These findings support use of multivariable modeling as needed using data from rapid influenza vaccination surveys.

LIMITATIONS

This report has several limitations. If the NHFS had been designed with a two-week follow-up period, survey operations would likely have been modified, as was done for November 1-13, 2010 National Flu Survey, which would tend to improve the results compared to restricting to early respondents in a longer period survey. While reducing the field period to one or two weeks appeared not to affect results, the bias in estimates based on the full sample is unknown. The nonresponse bias analysis assumed that later respondents were representative of nonrespondents, which may not be true. Thus, further studies comparing NHFS results to external sources are needed to assess overall bias. Because the NHFS was conducted for the purpose of monitoring influenza vaccination during a pandemic, response propensity may have been influenced by topic saliency and altered the early cooperator effects as compared to other general purpose surveys conducted at the same time, or in future inter-pandemic influenza seasons.

CONCLUSIONS

When timely information is needed for decision making during emergency situations, tradeoffs may be necessary with other survey attributes (e.g., response rates). The "fitness for use" of survey estimates in this situation will depend on how the estimates will be used (23), how much potential random and systematic error can be tolerated, and the loss function associated with incorrect conclusions resulting from survey error. This study indicates that shortening the field period of a telephone-based influenza vaccination survey can provide more rapid results without increasing systematic error.

Table 3-1 Comparison of respondent characteristics between early and later responders, by sample source, National 2009 H1N1 Flu Survey (standalone component)

Characteristic	Landline		Cell-Only/Mainly	
	Early Responders (n=35,079)	Later Responders (n=10,520)	Early Responders (n=8,540)	Later Responders (n=2,517)
AGE (years)				
18-24	*7.7	*12.4	†21.2	†15.1
25-29	5.1	6.4	16.2	16.1
30-34	6.3	6.4	12.1	14.2
35-44	*16.5	*19.4	19.1	21.1
45-49	10.0	9.5	9.8	11.7
50-54	10.3	10.7	8.0	8.1
55-64	18.6	17.4	9.6	9.5
≥65	*25.5	*17.8	3.9	4.2
RACE/ETHNICITY				
Hispanic (H)	*9.1	*13.2	20.8	22.0
Non-H, Black Only	9.8	12.2	13.3	15.4
Non-H, White Only	*75.8	*68.9	57.7	54.0
Non-H, Other or Multiple Races	5.3	5.8	8.2	8.6
INTERVIEW LANGUAGE				
English	*96.1	*91.2	†90.0	†80.5
Spanish	*2.8	*6.7	†8.7	†16.3
Other Language	*1.1	*2.2	†1.3	†3.2
SEX				
Male	*42.6	*46.1	†56.8	†52.3
Female	*57.4	*53.9	†43.2	†47.7
CHILD IN HOUSEHOLD				
Yes	*34.8	*40.9	40.0	43.2
No	*65.2	*59.1	60.0	56.8
REGION				
I: CT, ME, MA, NH, RI, VT	5.2	5.3	3.6	3.7
II: NJ, NY	9.8	10.6	†7.7	†11.0
III: DE, DC, MD, PA, VA, WV	9.8	10.5	8.5	10.1
IV: AL, FL, GA, KY, MS, NC, SC, TN	18.9	18.6	22.1	19.6
V: IL, IN, MI, MN, OH, WI	18.1	17.2	15.2	14.1
VI: AR, LA, NM, OK, TX	10.2	10.4	16.1	14.7
VII: IA, KS, MO, NE	*4.7	*3.8	†4.6	†2.8
VIII: CO, MT, ND, SD, UT, WY	3.3	3.0	3.5	3.3
IX: AZ, CA, HI, NV	15.9	16.1	14.7	17.1
X: AK, ID, OR, WA	4.1	4.5	4.2	3.7
METROPOLITAN STATISTICAL AREA				
MSA, Principle City	28.8	29.8	41.4	39.2
MSA, Not Principle City	53.0	54.4	44.6	48.7
Non-MSA	*18.2	*15.8	14.0	12.0
EDUCATION LEVEL				
<12 Years	10.5	11.6	13.9	13.1
12 Years	22.1	22.3	21.2	25.6
Some College	27.2	27.3	30.2	30.4
College Graduate	40.2	38.8	34.7	30.9
HOUSEHOLD POVERTY STATUS				
Above Poverty				
Annual Income >$75,000	29.1	29.7	†22.0	†17.1
Annual Income ≤$75,000	*44.8	*40.2	44.0	41.0
Below Poverty	9.9	10.3	17.5	17.8
Unknown	*16.3	*19.8	†16.4	†24.2
OWN OR RENT DWELLING				
Own	*79.9	*77.9	48.2	50.9

Characteristic	Landline		Cell-Only/Mainly	
	Early Responders (n=35,079)	Later Responders (n=10,520)	Early Responders (n=8,540)	Later Responders (n=2,517)
Rent	17.7	18.3	46.6	45.0
Other	*2.5	*3.8	5.3	4.1
EMPLOYMENT STATUS				
Employed	*50.8	*56.9	65.9	66.6
Out of Work	6.9	7.2	10.2	10.2
Homemaker	8.6	8.0	4.4	5.7
Student	*4.2	*6.8	9.9	8.4
Retired	*23.8	*16.3	4.5	4.6
Unable to Work	5.7	4.7	5.2	4.4
HEALTH INSURANCE STATUS				
Insured	89.0	87.7	72.5	67.1
No Insurance	11.0	12.3	27.5	32.9
CHRONIC MEDICAL CONDITION[§]				
No	*71.7	*74.3	80.5	79.5
Yes	*28.3	*25.7	19.5	20.5
pH1N1 TARGET GROUP[¶]				
No	*63.0	*58.7	49.4	53.4
Yes	*37.0	*41.3	50.6	46.6
SEASONAL TARGET GROUP[**]				
No	*27.5	*33.6	48.7	51.0
Yes	*72.5	*66.4	51.3	49.0
WORKS IN HEALTH CARE SETTING	89.4	89.7	87.0	86.6
No	10.6	10.3	13.0	13.4
Yes				

[*] For landline sample, statistically significant association between responder status (early vs. later) and characteristic (Adjusted Wald F p-value <0.05), and statistically significant difference in prevalence of characteristic level between early and later respondents by post-hoc t-test ($p<0.05$).

[†] For cell-only/mainly sample, statistically significant association between responder status (early vs. later) and characteristic (Adjusted Wald F p-value <0.05), and statistically significant difference in prevalence of characteristic level between early and later respondents by post-hoc t-test ($p<0.05$).

[§] Chronic medical conditions that a health professional has reported to respondent, including current asthma, other lung condition, heart condition, diabetes, kidney condition, sickle cell or other anemia, neurological or neuromuscular condition, liver condition, or weakened immune system.

[¶] Initial H1N1 target group (among persons ≥18 years) included all persons 18-24 years, persons 25-64 years with a chronic medical condition, pregnant women, health care personnel, and persons living with or providing care for infants <6 months.

[**] Seasonal target group (among persons ≥18 years) included persons 19-49 years with a chronic medical condition, pregnant women, health care personnel, persons living with or providing care for infants <6 months and others at high risk for influenza-related complications, and all persons ≥50 years.

Table 3-2a Comparisons of adjusted prevalence[*] (%) of influenza-related outcomes between early and later responders, National 2009 H1N1 Flu Survey (standalone component)

Outcome	Landline Sample			Cell-Only/Mainly Sample		
	Early Resp. (n=30,356)	Later Resp. (n=10,030)	Early - Later	Early Resp. (n=7,576)	Later Resp. (n2,333)	Early – Later
Very concerned about H1N1 flu	17.1	18.1	-1.0	17.2	18.7	-1.5
H1N1 flu vaccination very or somewhat effective in preventing H1N1 flu	72.6	72.8	-0.2	72.1	70.6	1.5
Very or somewhat high chances of H1N1 flu sickness if not vaccinated	25.9	25.8	0.2	28.4	28.5	-0.1
Very or somewhat worried about getting sick from H1N1 flu vaccine	31.0	32.0	-1.0	33.5	36.6	-3.1
Received H1N1 vaccination	21.4	19.8	[†]1.6	16.7	14.8	1.8
Seasonal flu vaccination very or somewhat effective in preventing seasonal flu	82.2	81.3	0.9	77.9	78.3	-0.4
Very or somewhat high chances of seasonal flu sickness if not vaccinated	39.6	37.4	[†]2.2	36.8	41.1	[†]-4.3
Very or somewhat worried about getting sick from seasonal flu vaccine	25.9	27.2	-1.4	28.5	33.9	[†]-5.4
Received seasonal flu vaccination	46.9	44.7	[†]2.2	30.2	30.8	-0.6

[*] Adjusted prevalence determined from predictive marginal of logistic regression model with outcome as dependent variable and main effects for responder status (early vs. later) and week of interview. Excludes first four weeks of interviews.

[†] Statistically significant difference between adjusted prevalence between early and later responders.

Table 3-2b Comparisons of adjusted prevalence[*] (%) of influenza-related outcomes between 1st week and later responders, National 2009 H1N1 Flu Survey (standalone component)

Outcome	Landline Sample			Cell-Only/Mainly Sample		
	1st Week Resp. (n=20,606)	Later Resp. (n=19,780)	1st Week – Later	1st Week Resp. (n=5,255)	Later Resp. (n=4,654)	1st Week – Later
Very concerned about H1N1 flu	17.0	17.8	-0.7	16.6	18.6	-2.0
H1N1 flu vaccination very or somewhat effective in preventing H1N1 flu	72.5	72.8	-0.3	72.1	71.4	-0.7
Very or somewhat high chances of H1N1 flu sickness if not vaccinated	25.8	26.0	-0.2	27.8	29.1	-1.3
Very or somewhat worried about getting sick from H1N1 flu vaccine	30.8	31.7	-0.8	32.3	36.4	†-4.1
Received H1N1 vaccination	21.5	20.4	1.1	18.1	14.3	†3.8
Seasonal flu vaccination very or somewhat effective in preventing seasonal flu	82.4	81.5	1.0	78.2	77.9	0.3
Very or somewhat high chances of seasonal flu sickness if not vaccinated	39.9	38.2	†1.7	35.8	40.0	†-4.2
Very or somewhat worried about getting sick from seasonal flu vaccine	25.3	27.1	†-1.8	27.6	32.2	†-4.6
Received seasonal flu vaccination	47.7	44.9	†2.7	32.2	28.5	†3.7

[*] Adjusted prevalence determined from predictive marginal of logistic regression model with outcome as dependent variable and main effects for responder status (early vs. later) and week of interview. Excludes first four weeks of interviews.

[†] Statistically significant difference between adjusted prevalence between 1st week and later responders.

Table 3-3a Influenza vaccination coverage – pH1N1 - through May 2010 for early vs. later and early weighted vs. all responders, by vaccine and selected respondent characteristics, National 2009 H1N1 Flu Survey (standalone component)

Vaccine and Population Group	Early Responders	Later Responders	Early - Later	Early Weighted	All	Early Wt. – All
pH1N1, CHILDREN	41.7 (±2.4)	39.9 (±3.5)	1.8 (±4.2)	41.7 (±2.4)	41.1 (±1.9)	0.6
By Race/Ethnicity						
Hispanic (H)	49.6 (±6.7)	47.5 (±9.7)	2.1 (±11.8)	49.5 (±6.8)	48.8 (±5.6)	0.7
Non-H, Black Only	35.0 (±8.1)	20.0 (±7.3)	*15.0 (±10.9)	34.9 (±8.1)	29.7 (±5.9)	5.2
Non-H, White Only	40.8 (±2.6)	40.6 (±4.0)	0.2 (±4.8)	40.9 (±2.6)	40.8 (±2.2)	0.1
Non-H, Other	41.8 (±6.8)	48.9 (±11.8)	-7.1 (±13.6)	41.8 (±6.7)	44.0 (±6.0)	-2.2
pH1N1, ADULTS	24.4 (±1.1)	23.1 (±1.8)	1.5 (±2.1)	24.3 (±1.1)	24.1 (±0.9)	0.2
by Race/Ethnicity						
Hispanic (H)	19.6 (±4.2)	22.9 (±7.1)	-3.3 (±8.3)	19.7 (±4.4)	20.7 (±3.7)	-1.0
Non-H, Black Only	16.8 (±3.1)	15.8 (±3.9)	1.0 (±5.0)	16.8 (±3.1)	16.5 (±2.4)	0.3
Non-H, White Only	26.7 (±1.1)	24.2 (±1.8)	*2.6 (±2.1)	26.7 (±1.1)	26.1 (±1.0)	0.6
Non-H, Other	23.0 (±4.7)	27.8 (±6.8)	-4.8 (±8.2)	23.0 (±4.6)	24.3 (±3.8)	-1.3
by Age Group (years)						
18-24	19.8 (±3.1)	19.3 (±4.3)	0.5 (±5.3)	19.7 (±2.5)	19.8 (±3.1)	-0.1
25-29	20.0 (±3.5)	22.4 (±6.7)	-2.4 (±7.6)	20.8 (±3.2)	20.1 (±3.5)	0.7
30-34	22.0 (±3.3)	23.2 (±5.6)	-1.2 (±6.5)	22.4 (±2.8)	21.9 (±3.3)	0.5
35-44	23.8 (±2.6)	19.1 (±3.2)	*4.7 (±4.1)	22.3 (±2.0)	23.7 (±2.6)	-1.4
45-49	26.7 (±5.3)	24.7 (±7.4)	2.0 (±9.1)	26.1 (±4.3)	26.8 (±5.5)	-0.7
50-54	23.1 (±3.1)	19.8 (±3.9)	3.3 (±5.0)	22.1 (±2.4)	23.0 (±3.1)	-0.9
55-64	28.6 (±2.3)	29.1 (±3.8)	-0.5 (±4.4)	28.7 (±2.0)	28.6 (±2.3)	0.1
≥65	27.7 (±2.0)	27.9 (±5.7)	-0.2 (±6.0)	27.9 (±2.1)	27.7 (±2.0)	0.2
by pH1N1 Target Group						
Not in target group	20.1 (±1.1)	20.0 (±2.3)	0.1 (±2.5)	19.9 (±1.2)	20.0 (±1.0)	-0.1
In target group	30.5 (±2.0)	27.3 (±2.9)	3.2 (±3.5)	30.4 (±2.1)	29.6 (±1.7)	0.8
by Health Care Setting (HCS)						
Does not work in HCS	22.1 (±1.1)	21.0 (±2.0)	1.1 (±2.2)	22.0 (±1.1)	21.9 (±0.9)	0.1
Works in HCS	45.8 (±4.9)	41.1 (±5.4)	4.8 (±7.3)	45.8 (±5.1)	44.4 (±3.7)	1.4

* Statistically significant difference in estimated vaccination coverage between early and later respondents, $p<0.05$

Table 3-3b Influenza vaccination coverage – trivalent seasonal - through May 2010 for early vs. later and early weighted vs. all responders, by vaccine and selected respondent characteristics, National 2009 H1N1 Flu Survey (standalone component)

Vaccine and Population Group	Early Responders	Later Responders	Early - Later	Early Weighted	All	Early Wt. – All
SEASONAL, CHILDREN	45.6 (±2.3)	45.9 (±3.6)	-0.3 (±4.2)	45.6 (±2.3)	45.7 (±1.9)	-0.1
By Race/Ethnicity						
Hispanic (H)	51.5 (±7.5)	41.5 (±10.0)	10.0 (±12.5)	51.6 (±7.6)	48.4 (±6.0)	3.2
Non-H, Black Only	39.3 (±8.0)	45.8 (±10.8)	-6.5 (±13.4)	39.2 (±8.0)	41.3 (±6.2)	-2.1
Non-H, White Only	44.4 (±2.2)	45.6 (±3.7)	-1.3 (±4.3)	44.4 (±2.2)	44.7 (±1.9)	-0.3
Non-H, Other	51.9 (±6.8)	59.0 (±11.3)	-7.1 (±13.2)	52.0 (±6.8)	54.0 (±5.9)	-2.0
SEASONAL, ADULTS	43.3 (±1.0)	41.8 (±1.9)	1.5 (±2.1)	42.8 (±1.1)	43.0 (± 0.9)	-0.2
by Race/Ethnicity						
Hispanic (H)	28.1 (±3.5)	35.4 (±6.1)	*-7.3 (±7.0)	27.9 (±3.4)	30.3 (±3.1)	-2.4
Non-H, Black Only	36.4 (±3.8)	32.6 (±5.3)	3.8 (±6.6)	35.9 (±3.8)	35.1 (±3.1)	0.8
Non-H, White Only	47.8 (±1.1)	45.1 (±2.0)	*2.7 (±2.3)	47.4 (±1.1)	47.1 (±1.0)	0.3
Non-H, Other	38.8 (±4.2)	44.8 (±7.2)	-6.1 (±8.3)	38.5 (±4.2)	40.4 (±3.6)	-1.9
by Age Group (years)						
18-24	24.5 (±3.1)	28.7 (±5.5)	-4.2 (±6.3)	24.4 (±3.1)	25.7 (±2.7)	-1.3
25-29	27.5 (±3.7)	30.3 (±6.1)	-2.8 (±7.1)	27.3 (±3.7)	28.3 (±3.2)	-1.0
30-34	35.1 (±3.8)	31.4 (±5.6)	3.6 (±6.8)	34.9 (±3.8)	34.0 (±3.1)	0.9
35-44	35.1 (±2.4)	34.6 (±3.7)	0.4 (±4.4)	34.9 (±2.4)	34.9 (±2.0)	0.0
45-49	36.8 (±3.3)	35.0 (±5.4)	1.8 (±6.3)	36.7 (±3.4)	36.4 (±2.8)	0.3
50-54	41.8 (±3.1)	45.3 (±7.4)	-3.5 (±8.0)	41.8 (±3.1)	42.8 (±3.1)	-1.0
55-64	52.9 (±2.3)	55.3 (±3.9)	-2.4 (±4.5)	52.9 (±2.3)	53.5 (±2.0)	-0.6
≥65	72.5 (±2.0)	69.3 (±3.8)	3.2 (±4.3)	72.5 (±2.1)	71.9 (±1.8)	0.6
by Seasonal Target Group						
Not in target group	25.0 (±1.6)	28.4 (±2.8)	*-3.4 (±3.3)	24.9 (±1.6)	26.0 (±1.4)	-1.1
In target group	53.2 (±1.3)	50.6 (±2.3)	2.6 (±2.7)	52.7 (±1.3)	52.6 (±1.1)	0.1
by Health Care Setting (HCS)						
Does not work in HCS	41.1 (±1.1)	39.6 (±2.0)	1.5 (±2.3)	40.5 (±1.1)	40.8 (±1.0)	-0.3
Works in HCS	62.0 (±3.2)	60.0 (±5.6)	2.1 (±6.4)	61.7 (±3.2)	61.5 (±2.8)	0.2

* Statistically significant difference in estimated vaccination coverage between early and later respondents, $p<0.05$

Table 3-3c Influenza vaccination coverage – pH1N1 - through May 2010 for 1st week vs. later and 1st week weighted vs. all responders, by vaccine and selected respondent characteristics, National 2009 H1N1 Flu Survey (standalone component)

Vaccine and Population Group	1st Week Responders	Later Responders	1st Week - Later	1st Week Weighted	All	1st Week Wt. – All
pH1N1, CHILDREN	41.8 (±2.8)	40.4 (±2.7)	1.4 (±3.9)	41.8 (±2.9)	41.1 (±1.9)	0.7
By Race/Ethnicity						
Hispanic (H)	45.6 (±8.1)	50.8 (±7.5)	-5.2 (±11.1)	45.2 (±8.2)	48.8 (±5.6)	-3.6
Non-H, Black Only	38.6 (±11.1)	23.0 (±5.8)	*15.6 (±12.5)	39.1 (±11.2)	29.7 (±5.9)	9.4
Non-H, White Only	41.0 (±3.0)	40.4 (±3.1)	0.6 (±4.3)	40.9 (±3.0)	40.8 (±2.2)	0.1
Non-H, Other	46.7 (±8.7)	42.1 (±8.2)	4.6 (±11.9)	46.2 (±8.6)	44.0 (±6.0)	2.2
pH1N1, ADULTS	25.3 (±1.2)	22.9 (±1.3)	*2.3 (±1.8)	25.0 (±1.3)	24.1 (±0.9)	0.9
by Race/Ethnicity						
Hispanic (H)	18.3 (±3.9)	22.2 (±5.5)	-3.9 (±6.8)	18.5 (±4.0)	20.7 (±3.7)	-2.2
Non-H, Black Only	18.2 (±4.3)	15.1 (±2.8)	3.1 (±5.1)	18.3 (±4.5)	16.5 (±2.4)	1.8
Non-H, White Only	27.6 (±1.4)	24.5 (±1.3)	*3.1 (±1.9)	27.5 (±1.4)	26.1 (±1.0)	1.4
Non-H, Other	24.7 (±6.2)	24.1 (±4.7)	0.5 (±7.8)	24.9 (±6.3)	24.3 (±3.8)	0.6
by Age Group (years)						
18-24	20.0 (±3.5)	19.3 (±3.6)	0.7 (±5.0)	19.8 (±3.6)	19.8 (±3.1)	0.0
25-29	20.7 (±4.2)	20.7 (±4.6)	0.1 (±6.2)	20.7 (±4.3)	20.1 (±3.5)	0.6
30-34	24.2 (±4.2)	20.7 (±3.7)	3.5 (±5.7)	23.7 (±4.3)	21.9 (±3.3)	1.8
35-44	25.2 (±3.3)	19.8 (±2.5)	*5.3 (±4.1)	24.9 (±3.4)	23.7 (±2.6)	1.2
45-49	24.9 (±4.7)	27.0 (±6.6)	-2.1 (±8.1)	25.2 (±4.9)	26.8 (±5.5)	-1.6
50-54	23.9 (±3.9)	20.5 (±3.0)	3.5 (±4.9)	23.5 (±3.8)	23.0 (±3.1)	0.5
55-64	29.4 (±2.7)	28.2 (±2.8)	1.2 (±3.9)	29.5 (±2.9)	28.6 (±2.3)	0.9
≥65	29.2 (±2.5)	26.4 (±3.5)	2.8 (±4.3)	29.2 (±2.6)	27.7 (±2.0)	1.5
by pH1N1 Target Group						
Not in target group	20.5 (±1.4)	19.6 (±1.5)	1.0 (±2.1)	20.2 (±1.4)	20.0 (±1.0)	0.2
In target group	31.7 (±2.2)	27.6 (±2.4)	*4.0 (±3.3)	31.4 (±2.3)	29.6 (±1.7)	1.8
by Health Care Setting (HCS)						
Does not work in HCS	23.1 (±1.3)	20.7 (±1.3)	*2.4 (±1.9)	22.8 (±1.4)	21.9 (±0.9)	0.9
Works in HCS	45.5 (±4.6)	43.2 (±5.7)	2.3 (±7.4)	45.2 (±4.7)	44.4 (±3.7)	0.8

* Statistically significant difference in estimated vaccination coverage between 1st week and later respondents, $p<0.05$

Table 3-3d Influenza vaccination coverage – trivalent seasonal - through May 2010 for 1st week vs. later and 1st week weighted vs. all responders, by vaccine and selected respondent characteristics, National 2009 H1N1 Flu Survey (standalone component)

Vaccine and Population Group	1st Week Responders	Later Responders	1st Week – Later	1st Week Weighted	All	1st Week Wt. – All
SEASONAL, CHILDREN	45.9 (±2.8)	45.7 (±2.6)	0.2 (±3.8)	45.9 (±2.9)	45.7 (±1.9)	0.2
By Race/Ethnicity						
Hispanic (H)	50.3 (±9.1)	46.9 (±7.9)	3.4 (±12.0)	50.3 (±9.3)	48.4 (±6.0)	1.9
Non-H, Black Only	45.4 (±11.4)	39.0 (±7.5)	6.4 (±13.7)	45.8 (±11.5)	41.3 (±6.2)	4.5
Non-H, White Only	44.2 (±2.7)	45.2 (±2.7)	-1.0 (±3.8)	44.0 (±2.7)	44.7 (±1.9)	-0.7
Non-H, Other	51.6 (±8.6)	55.9 (±8.1)	-4.3 (±11.8)	51.2 (±8.5)	54.0 (±5.9)	-2.8
SEASONAL, ADULTS	44.8 (±1.2)	41.0 (±1.3)	*3.8 (±1.8)	43.8 (±1.3)	43.0 (± 0.9)	0.8
by Race/Ethnicity						
Hispanic (H)	30.6 (±4.6)	29.9 (±4.0)	0.6 (±6.1)	30.2 (±4.7)	30.3 (±3.1)	-0.1
Non-H, Black Only	36.9 (±4.2)	33.4 (±4.3)	3.5 (±6.0)	36.1 (±4.1)	35.1 (±3.1)	1.0
Non-H, White Only	48.7 (±1.3)	45.4 (±1.4)	*3.3 (±1.9)	48.0 (±1.3)	47.1 (±1.0)	0.9
Non-H, Other	41.6 (±5.0)	39.4 (±5.1)	2.2 (±7.2)	41.1 (±5.0)	40.4 (±3.6)	0.7
by Age Group (years)						
18-24	24.2 (±3.6)	26.9 (±3.9)	-2.8 (±5.4)	23.8 (±3.7)	25.7 (±2.7)	-1.9
25-29	28.9 (±4.5)	27.6 (±4.3)	1.3 (±6.3)	28.3 (±4.6)	28.3 (±3.2)	0.0
30-34	38.5 (±4.8)	30.0 (±4.1)	*8.5 (±6.3)	38.2 (±4.9)	34.0 (±3.1)	4.2
35-44	37.0 (±3.0)	33.1 (±2.7)	3.9 (±4.0)	36.7 (±3.1)	34.9 (±2.0)	1.8
45-49	39.6 (±4.3)	33.6 (±3.7)	*6.0 (±5.7)	39.5 (±4.5)	36.4 (±2.8)	3.1
50-54	41.3 (±3.7)	44.0 (±4.7)	-2.7 (±6.0)	40.9 (±3.9)	42.8 (±3.1)	-1.9
55-64	53.0 (±2.7)	53.9 (±2.8)	-0.9 (±3.9)	52.9 (±2.8)	53.5 (±2.0)	-0.6
≥65	73.6 (±2.0)	69.5 (±3.0)	*4.1 (±3.6)	73.6 (±2.1)	71.9 (±1.8)	1.7
by Seasonal Target Group						
Not in target group	26.1 (±2.1)	25.9 (±2.0)	0.2 (±2.8)	25.9 (±2.1)	26.0 (±1.4)	-0.1
In target group	54.4 (±1.5)	50.5 (±1.7)	*3.9 (±2.2)	53.4 (±1.6)	52.6 (±1.1)	0.8
by Health Care Setting (HCS)						
Does not work in HCS	42.5 (±1.3)	39.0 (±1.4)	*3.5 (±1.9)	41.3 (±1.4)	40.8 (±1.0)	0.5
Works in HCS	64.1 (±3.7)	58.7 (±4.1)	5.3 (±5.5)	63.5 (±3.8)	61.5 (±2.8)	2.0

* Statistically significant difference in estimated vaccination coverage between 1st week and later respondents, $p<0.05$

Table 3-4a Comparison of influenza vaccination prevalence ratios from main effects logistic regression models*, child overall sample, early weighted respondents, and 1st week weighted respondents, National 2009 H1N1 Flu Survey (standalone component)

Characteristic	pH1N1			Seasonal		
	Overall (n=8,376)	Early Weighted (n=5,977)	1st Week Weighted (n=3,985)	Overall (n=8,525)	Early Weighted (n=6,085)	1st Week Weighted (n=4,042)
RACE/ETHNICITY						
Hispanic (H)	Referent	Referent	Referent	Referent	Referent	Referent
Non-H, Black Only	0.6 (0.5-0.7)	0.7 (0.5-1.0)	0.7 (0.5-1.0)	0.8 (0.7-1.0)	0.7 (0.5-0.9)	0.7 (0.6-1.0)
Non-H, White Only	0.7 (0.7-0.9)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.9 (0.8-1.1)	0.9 (0.8-1.0)	0.9 (0.7-1.0)
Non-H, Other	0.8 (0.7-1.0)	1.0 (0.7-1.2)	1.0 (0.7-1.2)	1.0 (0.9-1.2)	0.9 (0.8-1.1)	0.9 (0.7-1.2)
SEX						
Male	Referent	Referent	Referent	Referent	Referent	Referent
Female	1.1 (1.0-1.2)	1.1 (0.9-1.2)	1.1 (0.9-1.2)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.0 (0.9-1.1)
REGION						
I: CT, ME, MA, NH, RI, VT	Referent	Referent	Referent	Referent	Referent	Referent
II: NJ, NY	0.8 (0.7-1.0)	0.7 (0.5-0.9)	0.7 (0.5-0.9)	1.1 (0.9-1.2)	1.1 (0.9-1.3)	1.0 (0.8-1.3)
III: DE, DC, MD, PA, VA, WV	0.9 (0.8-1.1)	0.8 (0.6-1.0)	0.8 (0.6-1.0)	0.9 (0.8-1.1)	1.0 (0.8-1.2)	0.9 (0.7-1.1)
IV: AL, FL, GA, KY, MS, NC, SC, TN	0.7 (0.6-0.8)	0.6 (0.5-0.8)	0.6 (0.5-0.8)	0.9 (0.8-1.0)	0.9 (0.8-1.1)	0.9 (0.7-1.1)
V: IL,IN,MI,MN,OH,WI	0.7 (0.6-0.9)	0.7 (0.6-0.9)	0.7 (0.6-0.9)	0.8 (0.7-0.9)	0.9 (0.7-1.0)	0.8 (0.7-1.0)
VI: AR,LA,NM,OK,TX	0.5 (0.4-0.7)	0.6 (0.5-0.8)	0.6 (0.5-0.8)	0.9 (0.7-1.0)	0.8 (0.7-1.0)	0.8 (0.6-1.0)
VII: IA,KS,MO,NE	0.7 (0.6-0.9)	0.7 (0.5-0.9)	0.7 (0.5-0.9)	0.9 (0.7-1.0)	0.9 (0.7-1.1)	0.9 (0.7-1.1)
VIII: CO,MT,ND,SD,UT,WY	0.7 (0.6-0.9)	0.7 (0.5-0.9)	0.7 (0.5-0.9)	1.0 (0.8-1.1)	1.0 (0.8-1.2)	1.0 (0.8-1.3)
IX: AZ,CA,HI,NV	0.7 (0.5-0.8)	0.6 (0.4-0.8)	0.6 (0.4-0.8)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.9 (0.7-1.1)
X: AK,ID,OR,WA	0.7 (0.6-0.8)	0.7 (0.6-1.0)	0.7 (0.6-1.0)	0.8 (0.7-1.0)	0.8 (0.6-1.0)	0.8 (0.6-1.1)
METROPOLITAN STATISTICAL AREA						
MSA, Principle City	Referent	Referent	Referent	Referent	Referent	Referent
MSA, Not Prin. City	0.9 (0.8-1.0)	0.9 (0.7-1.0)	0.9 (0.7-1.0)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	0.9 (0.8-1.1)
Non-MSA	0.9 (0.8-1.1)	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.8 (0.7-1.0)
HOUSEHOLD POVERTY STATUS						
> Poverty, Annual Income >$75,000	Referent	Referent	Referent	Referent	Referent	Referent
> Poverty, Annual Income ≤$75,000	0.8 (0.8-0.9)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.9 (0.8-0.9)	0.8 (0.8-0.9)	0.9 (0.8-1.0)
Below Poverty	0.9 (0.8-1.1)	0.9 (0.7-1.2)	0.9 (0.7-1.2)	0.9 (0.8-1.0)	0.9 (0.7-1.1)	0.8 (0.6-1.0)
Unknown	0.8 (0.7-1.0)	0.9 (0.6-1.1)	0.9 (0.6-1.1)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.9 (0.7-1.1)
OWN OR RENT DWELLING						
Own	Referent	Referent	Referent	Referent	Referent	Referent
Rent	0.9 (0.8-1.0)	1.0 (0.8-1.2)	1.0 (0.8-1.2)	1.0 (0.9-1.2)	1.1 (0.9-1.2)	1.1 (1.0-1.3)
Other	0.9 (0.6-1.2)	1.0 (0.6-1.5)	1.0 (0.6-1.5)	0.8 (0.6-1.1)	0.9 (0.6-1.3)	0.7 (0.5-1.2)

* Sample restricted to respondents interviewed January-June 2010.

Table 3-4b Comparison of influenza vaccination prevalence ratios from main effects logistic regression models*, adult overall sample, early weighted respondents, and 1st week weighted respondents, National 2009 H1N1 Flu Survey (standalone component)

Characteristic	pH1N1			Seasonal		
	Overall (n=32,470)	Early Weighted (n=24,620)	1st Week Weighted (n=17,041)	Overall (n=33,035)	Early Weighted (n=25,045)	1st Week Weighted (n=17,322)
AGE (years)						
18-24	Referent	Referent	Referent	Referent	Referent	Referent
25-29	1.4 (1.1-1.7)	1.3 (1.0-1.7)	1.4 (1.1-2.0)	1.1 (0.9-1.2)	1.0 (0.9-1.3)	1.2 (0.9-1.5)
30-34	1.4 (1.1-1.7)	1.3 (1.0-1.7)	1.5 (1.1-2.1)	1.2 (1.0-1.4)	1.2 (1.0-1.4)	1.4 (1.2-1.8)
35-44	1.4 (1.1-1.7)	1.4 (1.1-1.8)	1.6 (1.2-2.1)	1.1 (1.0-1.3)	1.1 (0.9-1.3)	1.2 (1.0-1.5)
45-49	1.5 (1.2-1.9)	1.6 (1.2-2.0)	1.6 (1.1-2.1)	1.2 (1.1-1.4)	1.3 (1.1-1.5)	1.4 (1.1-1.7)
50-54	1.4 (1.2-1.8)	1.5 (1.2-1.9)	1.5 (1.1-2.1)	1.1 (1.0-1.3)	1.1 (1.0-1.3)	1.2 (0.9-1.5)
55-64	1.9 (1.6-2.3)	1.9 (1.5-2.4)	1.9 (1.5-2.5)	1.4 (1.2-1.6)	1.4 (1.2-1.7)	1.5 (1.3-1.9)
≥65	2.3 (1.8-2.8)	2.3 (1.8-2.9)	2.4 (1.8-3.2)	1.9 (1.6-2.1)	1.9 (1.6-2.2)	2.1 (1.7-2.5)
RACE/ETHNICITY						
Hispanic (H)	Referent	Referent	Referent	Referent	Referent	Referent
Non-H, Black Only	0.8 (0.7-1.0)	0.9 (0.7-1.1)	0.9 (0.7-1.3)	0.9 (0.8-1.0)	1.0 (0.8-1.1)	0.9 (0.8-1.1)
Non-H, White Only	1.2 (1.0-1.4)	1.2 (1.0-1.5)	1.3 (1.1-1.7)	1.1 (1.0-1.2)	1.2 (1.0-1.3)	1.2 (1.0-1.3)
Non-H, Other	1.2 (1.0-1.5)	1.2 (0.9-1.5)	1.3(0.9-1.7)	1.1 (1.0-1.3)	1.2 (1.0-1.4)	1.2 (1.0-1.5)
SEX						
Male	Referent	Referent	Referent	Referent	Referent	Referent
Female	1.0 (1.0-1.1)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.1 (1.1-1.2)	1.1 (1.1-1.2)	1.1 (1.0-1.2)
CHILD IN HOUSEHOLD						
Yes	Referent	Referent	Referent	Referent	Referent	Referent
No	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.9 (0.9-1.0)	0.9 (0.9-1.0)	0.9 (0.9-1.0)
REGION						
I: CT, ME, MA, NH, RI, VT	Referent	Referent	Referent	Referent	Referent	Referent
II: NJ, NY	0.7 (0.6-0.8)	0.7 (0.6-0.8)	0.7 (0.5-0.8)	0.9 (0.8-1.0)	0.9 (0.8-1.0)	0.9 (0.8-1.0)
III: DE, DC, MD, PA, VA, WV	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.9 (0.9-1.0)	0.9 (0.8-1.0)	0.9 (0.8-1.0)
IV: AL, FL, GA, KY, MS, NC, SC, TN	0.7 (0.6-0.8)	0.7 (0.6-0.8)	0.8 (0.7-0.9)	0.9 (0.8-0.9)	0.8 (0.8-0.9)	0.8 (0.8-0.9)
V: IL,IN,MI,MN,OH,WI	0.8 (0,7-0.9)	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.9 (0.8-0.9)	0.9 (0.8-0.9)	0.9 (0.8-1.0)
VI: AR,LA,NM,OK,TX	0.7 (0.6-0.8)	0.7 (0.6-0.8)	0.8 (0.7-1.0)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.0 (0.9-1.1)
VII: IA,KS,MO,NE	0.7 (0.7-0.9)	0.8 (0.7-0.9)	0.8 (0.7-1.0)	1.0 (0.9-1.1)	0.9 (0.9-1.0)	1.0 (0.9-1.1)
VIII: CO,MT,ND,SD,UT,WY	0.8 (0.7-0.9)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.0 (0.9-1.1)
IX: AZ,CA,HI,NV	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.8 (0.6-1.0)	0.8 (0.7-0.9)	0.7 (0.7-0.8)	0.7 (0.6-0.9)
X: AK,ID,OR,WA	0.8 (0.7-0.9)	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.9 (0.8-1.0)	0.8 (0.7-0.9)	0.8 (0.7-1.0)

Characteristic	pH1N1			Seasonal		
	Overall (n=32,470)	Early Weighted (n=24,620)	1st Week Weighted (n=17,041)	Overall (n=33,035)	Early Weighted (n=25,045)	1st Week Weighted (n=17,322)
METROPOLITAN STATISTICAL AREA						
MSA, Principle City	Referent	Referent	Referent	Referent	Referent	Referent
MSA, Not Prin. City	1.0 (0.9-1.0)	1.0 (0.9-1.1)	1.0 (0.8-1.1)	1.0 (0.9-1.0)	1.0 (0.9-1.0)	0.9 (0.9-1.0)
Non-MSA	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.0 (0.9-1.0)	0.9 (0.9-1.0)	0.9 (0.8-1.0)
EDUCATION LEVEL						
<12 Years	Referent	Referent	Referent	Referent	Referent	Referent
12 Years	1.1 (0.9-1.3)	1.1 (0.9-1.3)	1.1 (0.9-1.4)	1.1 (1.0-1.2)	1.1 (1.0-1.3)	1.1 (1.0-1.3)
Some College	1.0 (0.9-1.2)	1.1 (0.9-1.4)	1.1 (0.9-1.4)	1.2 (1.1-1.3)	1.1 (1.0-1.3)	1.1 (1.0-1.3)
College Graduate	1.3 (1.1-1.6)	1.4 (1.1-1.7)	1.4 (1.1-1.7)	1.3 (1.2-1.4)	1.3 (1.1-1.4)	1.2 (1.1-1.4)
HOUSEHOLD POVERTY STATUS						
Above Poverty						
Annual Income >$75,000	Referent	Referent	Referent	Referent	Referent	Referent
Annual Income ≤$75,000	0.8 (0.8-0.9)	0.8 (0.8-0.9)	0.8 (0.7-0.9)	0.9 (0.8-0.9)	0.9 (0.8-0.9)	0.9 (0.8-1.0)
Below Poverty	0.8 (0.7-1.0)	0.8 (0.7-1.0)	0.9 (0.7-1.1)	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.8 (0.7-0.9)
Unknown	0.7 (0.6-0.8)	0.7 (0.6-0.8)	0.6 (0.5-0.8)	0.8 (0.7-0.9)	0.8 (0.7-0.9)	0.8 (0.7-0.9)
OWN OR RENT DWELLING						
Own	Referent	Referent	Referent	Referent	Referent	Referent
Rent	1.0 (0.9-1.1)	1.0 (0.9-1.2)	1.1 (0.9-1.2)	0.9 (0.9-1.0)	1.0 (0.9-1.0)	1.0 (0.9-1.1)
Other	0.9 (0.7-1.1)	0.9 (0.7-1.1)	1.0 (0.7-1.3)	1.0 (0.8-1.1)	0.9 (0.8-1.1)	0.9 (0.8-1.1)
EMPLOYMENT STATUS						
Employed	Referent	Referent	Referent	Referent	Referent	Referent
Out of Work	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.9 (0.8-1.0)	0.8 (0.7-1.0)	0.9 (0.7-1.0)
Homemaker	1.1 (1.0-1.3)	1.1 (0.9-1.3)	1.1 (0.9-1.3)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	0.9 (0.8-1.1)
Student	1.1 (0.9-1.3)	1.0 (0.8-1.3)	1.1 (0.9-1.5)	1.0 (0.9-1.1)	1.0 (0.8-1.1)	1.0 (0.9-1.2)
Retired	1.1 (1.0-1.3)	1.1 (1.0-1.3)	1.2 (1.0-1.3)	1.2 (1.1-1.2)	1.2 (1.1-1.3)	1.2 (1.1-1.3)
Unable to Work	1.2 (1.0-1.4)	1.1 (0.9-1.3)	1.2 (1.0-1.5)	1.3 (1.2-1.4)	1.2 (1.1-1.4)	1.2 (1.1-1.4)
TARGET GROUP†						
No	Referent	Referent	Referent	Referent	Referent	Referent
Yes	1.8 (1.7-1.9)	1.9 (1.7-2.1)	1.9 (1.7-2.1)	1.5 (1.4-1.6)	1.5 (1.4-1.6)	1.5 (1.3-1.6)

* Sample restricted to respondents interviewed January-June 2010.

† For pH1N1, target group refers to the initial H1N1 target group (among persons ≥18 years), including all persons 18-24 years, persons 25-64 years with a chronic medical condition, pregnant women, health care personnel, and persons living with or providing care for infants <6 months. For seasonal influenza vaccination, target group refers to persons 19-49 years with a chronic medical condition, pregnant women, health care personnel, persons living with or providing care for infants <6 months and others at high risk for influenza-related complications, and all persons ≥50 years.

Table 3-4c Comparison of influenza vaccination prevalence ratios from logistic regression models with opinion covariates*, adult overall sample, early weighted respondents, and 1st week weighted respondents, National 2009 H1N1 Flu Survey (standalone component)

Characteristic		pH1N1			Seasonal		
		Overall (n=33,594)	Early Weighted (n=25,427)	1st Week Weighted (n=17,575)	Overall (n=34,209)	Early Weighted (n=25,880)	1st Week Weighted (n=17,873)
RACE/ETHNICITY	**Hispanic (H)**	Referent	Referent	Referent	Referent	Referent	Referent
	Non-H, Black Only	1.1 (0.9-1.3)	1.2 (1.0-1.6)	1.2 (0.9-1.7)	1.1 (1.0-1.3)	1.3 (1.1-1.5)	1.2 (0.9-1.4)
	Non-H, White Only	1.6 (1.4-1.9)	1.8 (1.5-2.2)	1.9 (1.5-2.4)	1.3 (1.2-1.4)	1.5 (1.3-1.7)	1.4 (1.2-1.6)
	Non-H, Other	1.5 (1.2-1.8)	1.6 (1.2-2.0)	1.6 (1.2-2.2)	1.3 (1.1-1.5)	1.4 (1.2-1.7)	1.4 (1.2-1.8)
SEX	**Male**	Referent	Referent	Referent	Referent	Referent	Referent
	Female	1.0 (0.9-1.0)	0.9 (0.9-1.0)	0.9 (0.9-1.0)	1.0 (1.0-1.1)	1.1 (1.0-1.1)	1.0 (1.0-1.1)
EDUCATION LEVEL	**<12 Years**	Referent	Referent	Referent	Referent	Referent	Referent
	12 Years	1.0 (0.9-1.2)	1.1 (0.9-1.3)	1.1 (0.9-1.4)	1.0 (0.9-1.1)	1.0 (0.9-1.2)	1.1 (0.9-1.2)
	Some College	1.1 (0.9-1.3)	1.2 (1.0-1.4)	1.2 (1.0-1.5)	1.1 (1.0-1.2)	1.1 (1.0-1.2)	1.1 (0.9-1.2)
	College Graduate	1.4 (1.1-1.6)	1.4 (1.2-1.7)	1.4 (1.2-1.7)	1.2 (1.1-1.3)	1.2 (1.1-1.4)	1.2 (1.1-1.4)
HOUSEHOLD POVERTY STATUS							
> Poverty, Annual Income >$75,000		Referent	Referent	Referent	Referent	Referent	Referent
> Poverty, Annual Income ≤$75,000		0.9 (0.8-1.0)	0.9 (0.8-1.0)	0.9 (0.8-1.0)	0.9 (0.9-1.0)	1.0 (0.9-1.0)	1.0 (0.9-1.1)
	Below Poverty	0.8 (0.6-0.9)	0.8 (0.7-1.0)	0.9 (0.7-1.0)	0.8 (0.7-0.9)	0.8 (0.8-0.9)	0.8 (0.7-0.9)
	Unknown	0.9 (0.8-1.0)	0.9 (0.8-1.0)	0.8 (0.7-1.0)	1.0 (0.9-1.1)	1.0 (0.9-1.1)	1.0 (0.9-1.1)
TARGET GROUP†	**No**	Referent	Referent	Referent	Referent	Referent	Referent
	Yes	1.2 (1.2-1.3)	1.3 (1.2-1.4)	1.3 (1.2-1.4)	1.7 (1.6-1.8)	1.7 (1.6-1.8)	1.6 (1.5-1.8)
OPINIONS							
Vaccine not effective							
Risk of flu low, vaccine worries		Referent	Referent	Referent	Referent	Referent	Referent
Risk of flu low, no vaccine worries		1.6 (1.1-2.1)	1.4 (1.0-2.0)	1.5 (1.0-2.3)	0.9 (0.7-1.3)	0.9 (0.6-1.3)	0.9 (0.6-1.6)
Risk of flu high, vaccine worries		3.3 (2.4-4.6)	3.5 (2.3-5.1)	3.9 (2.6-5.8)	2.8 (2.2-3.5)	2.5 (1.8-3.3)	2.9 (2.0-4.1)
Risk of flu high, no vaccine worries		3.9 (2.9-5.2)	3.6 (2.6-4.9)	4.5 (3.2-6.3)	2.1 (1.6-3.0)	2.1 (1.4-3.2)	2.7 (1.7-4.4)
Vaccine effective							
Risk of flu low, vaccine worries		2.3 (1.9-2.7)	2.1 (1.8-2.6)	2.3 (1.9-2.8)	2.4 (2.1-2.8)	2.4 (2.1-2.8)	2.6 (2.2-3.1)
Risk of flu low, no vaccine worries		3.3 (2.7-4.0)	2.9 (2.3-3.6)	2.9 (2.3-3.7)	2.1 (1.8-2.5)	2.0 (1.7-2.4)	2.0 (1.6-4.5)
Risk of flu high, vaccine worries		7.2 (6.1-8.5)	6.9 (5.8-8.4)	7.4 (6.1-9.0)	4.9 (4.3-5.5)	4.8 (4.1-5.6)	5.1 (4.3-6.1)
Risk of flu high, no vaccine worries		7.0 (6.0-8.3)	6.9 (5.8-8.3)	7.3 (6.0-8.9)	4.2 (3.7-4.8)	4.1 (3.5-4.8)	4.4 (3.7-5.3)

* Sample restricted to respondents interviewed January-June 2010; this model was included in reference 86.

† For pH1N1, target group refers to the initial H1N1 target group (among persons ≥18 years), including all persons 18-24 years, persons 25-64 years with a chronic medical condition, pregnant women, health care personnel, and persons living with or providing care for infants <6 months. For seasonal influenza vaccination, target group refers to persons 19-49 years with a chronic medical condition, pregnant women, health care personnel, persons living with or providing care for infants <6 months and others at high risk for influenza-related complications, and all persons ≥50 years.

Figure 3-1 Distribution of Total, Landline and Cell Phone Completed Interviews by Week Since Release, National 2009 H1N1 Flu Survey

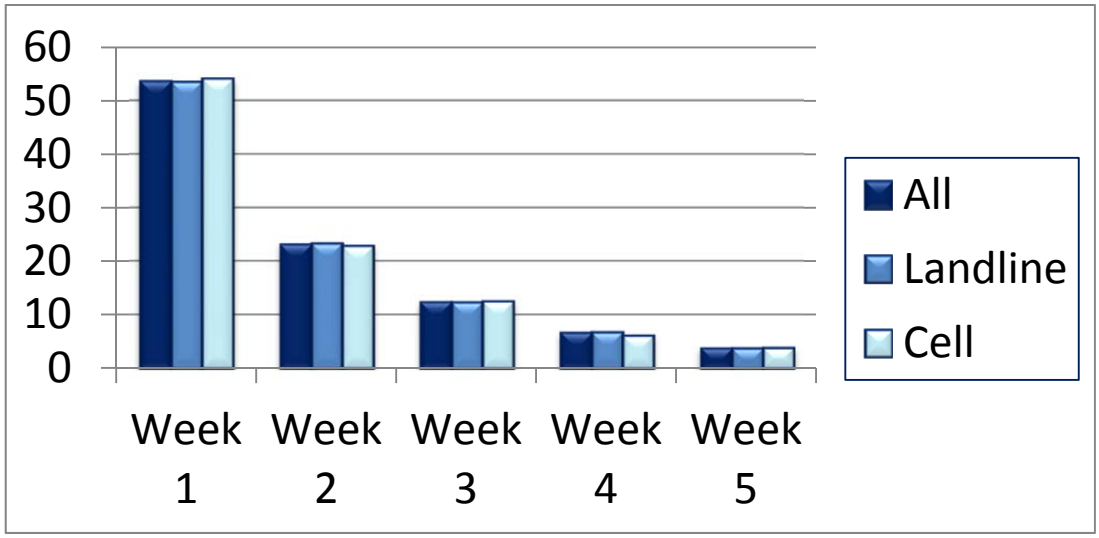
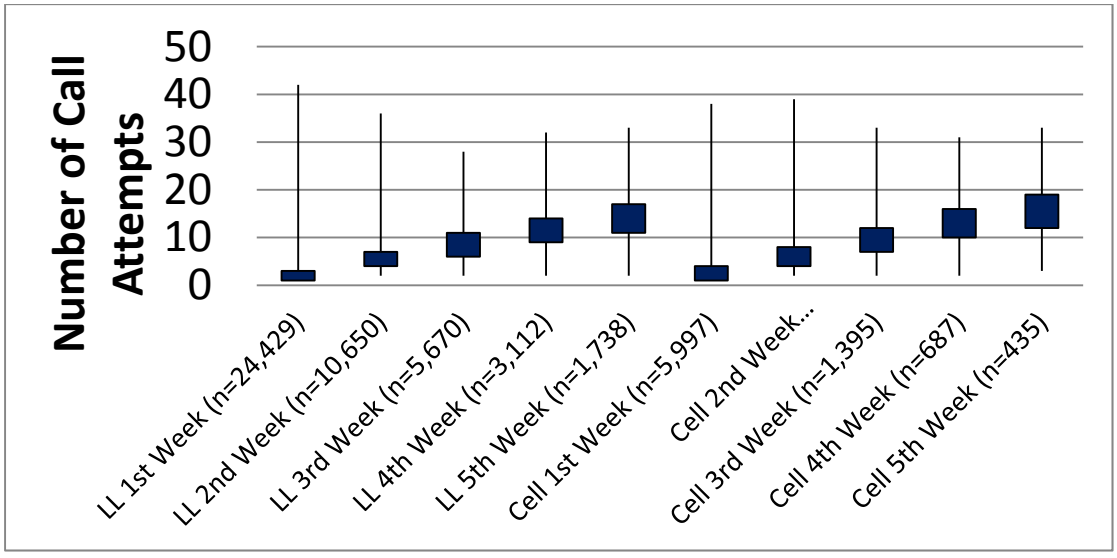


Figure 3-2 Distribution of Call Attempts by Sample Source (Landline or Cell Only/Mainly) and Weeks Since Release, National 2009 H1N1 Flu Survey



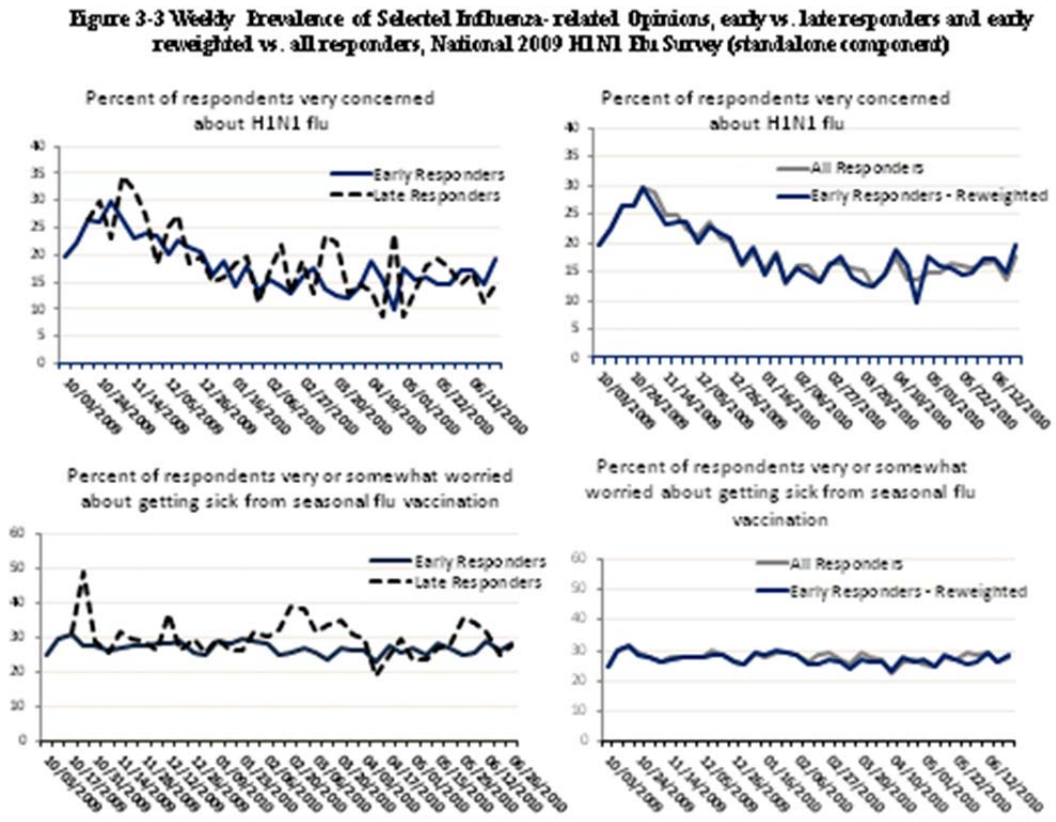
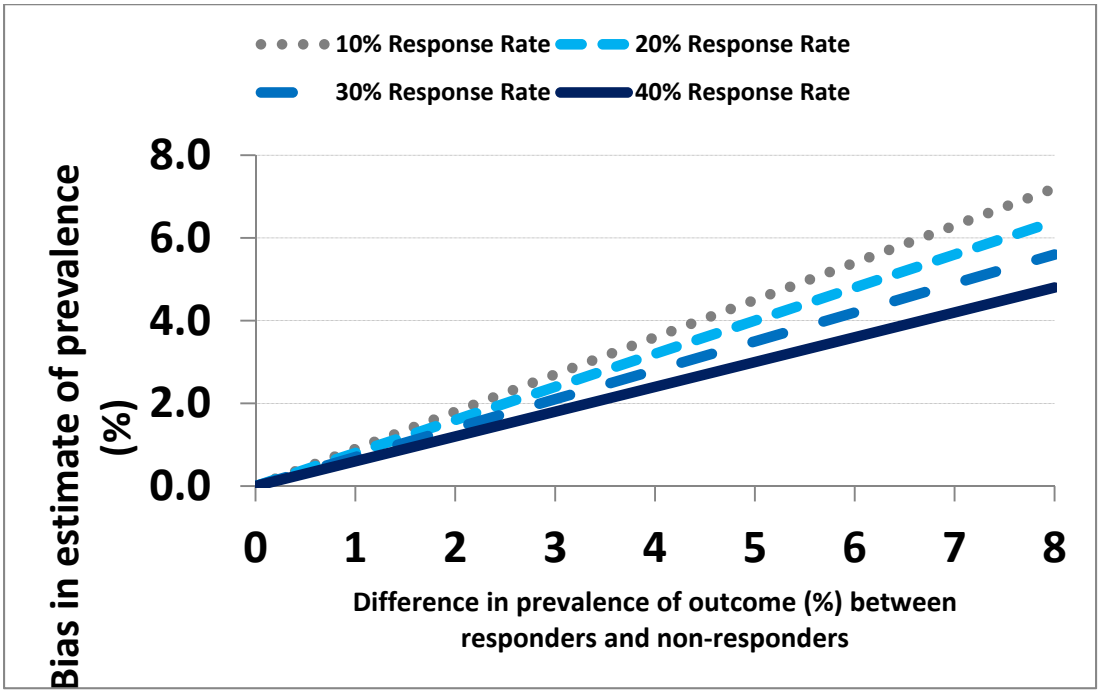


Figure 3-4 Potential Non-Response Bias in NHFS Based on Findings from Early Responder Analysis



Chapter 4 EVALUATING NONRESPONSE AND NONCOVERAGE BIAS IN A TELEPHONE SURVEY OF INFLUENZA VACCINATION BY COMPARISON TO THE NATIONAL HEALTH INTERVIEW SURVEY (NHIS)[1]

ABSTRACT

In response to the influenza A(H1N1)pdm09 (pH1N1) pandemic, the Centers for Disease Control and Prevention (CDC) developed the National 2009 H1N1 Flu Survey (NHFS) to provide weekly estimates of pH1N1 and trivalent seasonal influenza vaccination coverage and related opinions about influenza and influenzas vaccination. The NHFS was a dual landline and cell telephone RDD survey conducted October 2009 – June 2010. The purpose of this study is to assess potential differential bias of NHFS estimates of influenza vaccination coverage in comparison to the National Health Interview Survey (NHIS), an ongoing health survey with higher response rates than telephone surveys.

Respondents interviewed January-June 2010 from NHFS and NHIS were selected for analysis. Influenza vaccination coverage was estimated using stratified non-parametric survival analysis of time to vaccination. Results were stratified by sample source (landline and cell samples) for NHFS, and by selected sociodemographic and other health-reltated characteristics for both surveys.

Weighted distributions were similar between NHFS and NHIS for some but not all characteristics examined. Compared to estimates of pH1N1 and seasonal influenza vaccination coverage from NHIS, estimates from NHFS for children and adults were six to nine percentage

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[1] This chapter expands on a paper submitted for publication in the proceedings of the 2010 Joint Statistical Meetings, based on a presentation August 2, 2010 in Vancouver, BC: Comparison of influenza vaccination rates in cell-only, cell-mostly, and landline households in the National 2009 H1N1 Flu Survey, by Nicholas Davis, Margrethe Montgomery, and Kennon R. Copeland, NORC at the University of Chicago, and James A. Singleton, Centers for Disease Control and Prevention.

points higher. There was evidence of differential nonresponse bias for some characteristics. Relative bias (dividing by vaccination rate from NHIS) was higher for adults compared to children and for pH1N1 compared to trivalent seasonal influenza vaccination (child pH1N1 – 25%; child seasonal – 16%; adult pH1N1 – 31%; adult seasonal – 20%).

Landline telephone RDD surveys have been replaced by dual landline and cell telephone RDD surveys, but these surveys need to assess potential nonresponse bias as response rates to cell phone samples are low. Some bias in estimates is tolerable for assessment of trends if bias is relatively constant over time and across population subgroups, while for other uses such as evaluating vaccine safety or estimating disease burden averted by vaccination, unbiased estimates are needed. In the case of influenza vaccination coverage estimates during the 2009-10 pandemic, dual frame estimates from the NHFS were five to seven percentage points higher than those from the NHIS, a presumably more representative survey. Continued seasonal comparisons should be made of more timely influenza vaccination coverage estimates with estimates from NHIS.

INTRODUCTION

By the 1980's, random digit dialing (RDD) landline telephone surveys had become a standard approach for collecting health and other data on the U.S. non-institutionalized population (88). Large RDD surveys were implemented for public health surveillance (89-91). This approach is often used to identify and recruit subjects for epidemiologic case-control studies (92-93), and is a cost-efficient approach for collecting timely data in public health emergencies (8, 84). In recent decades, the validity of estimates from these telephone surveys has been increasingly threatened by declining response rates (39) and increasing prevalence of households with only wireless telephone service.

From mid-2003 to mid-2011, the percentage of adults and children living in households with only wireless telephone service increased from less than 5% to 30% and 36%, respectively;

the percentage living in households with no telephone service remained below 2% (94). Among adults, factors associated with higher wireless-only prevalence included living only with other unrelated adult roommates (71.3%), younger age (e.g., 58.1% for those age 25-29 years), renting home (52.5%), living below the poverty level (46.8%), and Hispanic ethnicity (40.8%); prevalence also varied by region of residence (e.g. 33.6% in the South and 18.8% in the Northeast) (94).

Landline RDD surveys are subject to a selection bias in estimates intended to represent the target population of all households, induced by choice of sampling frame. In the study population represented by the landline telephone sampling frame, this undercoverage bias is a function of the prevalence of non-landline households and the difference in the outcome of interest between landline and non-landline households. Increasing undercoverage of landline RDD surveys reduces the ability of weighting to the target population to mitigate bias, and strains credibility of the survey.

Many landline telephone surveys have supplemented their frames with cell phone samples, and this dual frame RDD design has become "the accepted approach to conducting a general population survey in the United States", although there are many challenges for optimum implementation (95). Studies have evaluated the effect of these dual frame designs by comparing characteristics and outcomes of interest between landline and cell phone respondents (89, 34-37). However, response rates to cell phone samples are typically lower than for landline samples, and little is known about nonresponse bias of cell phone surveys nor differential nonresponse bias to landline and cell phone components of the same survey (37, 38, 95, 96). Although dual frame RDD surveys resolve the undercoverage problem, additional research is needed to evaluate their nonresponse bias, to ensure that reductions in selection bias by expanding the sample frame are not offset by increased nonresponse bias.

One approach for evaluating nonresponse bias of dual frame RDD surveys is to compare estimated outcomes of interest with those based on another data source or survey known or

presumed to have no or low undercoverage and nonresponse bias (40). The purpose of this paper is to evaluate potential nonresponse bias in the National 2009 H1N1 Flu Survey (NHFS), a dual frame RDD telephone survey. The NHFS was implemented in 2009-10 by CDC to monitor influenza vaccination coverage during the vaccination campaign to prevent pandemic influenza A(H1N1)pdm09 (pH1N1) (4, 7, 8). Characteristics and key outcomes from the NHFS are compared between respondents reached via the landline and cellular sample frames, and NHFS estimates of influenza vaccination coverage are compared to estimates from the National Health Interview Survey (NHIS). The NHIS also collects self and parental reported influenza vaccination status, but uses an area-based sampling frame with in-person interviews, and achieves higher response rates than typical RDD telephone surveys.

METHODS

DATA SOURCES

National 2009 H1N1 Flu Survey (NHFS)

The NHFS was an RDD dual landline and cellular telephone frame survey conducted by CDC October 2009 – June 2010 (see Chapter 2 for a detailed description). Because the NHIS did not start asking separately about pH1N1 vaccination until January 2010, only NHFS data collected January-June 2010 were used for this analysis (36,957 completed adult interviews and 9,095 completed interviews for children). This included 7,131 child and 29,714 adult respondents from the landline frame and 1,964 child and 7,243 adult respondents from the cell phone frame. Children were included if they were at least 6 months of age at the time of the interview. The youngest children, 6 months of age in June 2010, were born in December 2009.

National Health Interview Survey (NHIS)

The NHIS has been conducted by the CDC since 1957 to monitor the health of the civilian, non-institutionalized U.S. population (69) (see Chapter 2 for a detailed description). It

uses an area sample frame and in-person household interviews. The NHIS added questions to determine pH1N1 vaccination status in sample children and adults starting in January 2010. Thus, for comparison to the NHFS, this analysis uses NHIS 2010 data from January-June 2010 interviews, including 14,021 sample adults and 5,115 sample children. Children born after December 2009 were excluded.

ANALYSIS

Influenza vaccine-related outcomes examined from NHFS and NHIS include receipt of pH1N1 vaccination since October 2009, receipt of seasonal influenza vaccination since August 2009, and for adults from NHFS, opinions about safety and effectiveness of influenza vaccines, risk of influenza illness if not vaccinated, and level of concern about "swine flu". For direct prevalence estimates from NHFS, positive responses to questions about receipt of flu vaccination since September 2009 for pH1N1 and since August 2009 for trivalent seasonal influenza vaccination were used; the NHFS asked about receipt of pH1N1 vaccination since September 2009, but distribution of this vaccine did not start until October 2009 (7). For children and adults, the NHIS asked separate questions about receipt of seasonal influenza vaccination in the past 12 months for "flu shot" and "flu vaccine sprayed in the nose"; final influenza vaccination status was determined based on receipt of either of these types of influenza vaccination. Persons with missing, refused or "don't know" responses to the initial questions about influenza vaccination since the beginning of the vaccination period or (for NHIS seasonal influenza vaccination, receipt in the past 12 months) were excluded from analyses of influenza vaccination outcomes. For estimates of influenza vaccination based on time-to-event analysis (described below), reported month and year of vaccination were used to determine pH1N1 vaccinations since October 2009 and seasonal vaccinations since August 2009.

Respondent characteristics common to both NHFS and NHIS were examined, including age group (for children, based on age as of November 2009), race/ethnicity, language of

interview (English, Spanish, other), sex, whether at least one child was residing with the family (for adults), region of residence, level of education (for adults), poverty status, housing tenure, employment status (for adults), health insurance status, having one or more chronic conditions associated with high risk of complications from influenza, working in a health-care facility (for adults). Age as of November 2009 was chosen to reflect age when influenza vaccination typically peaks; the youngest children were a month from being born in November 2009 and had limited opportunity to be vaccinated very late in the season after they reached age 6 months, the minimum licensed age for receipt of inactivated influenza vaccination.

For NHIS, telephone status was examined by the following levels: dual landline and cell phone users with cell phone use classified as "cell mostly"; other dual landline and cell phone users; landline only in family; only cell phones in family; and no telephone service used by the family. The definition of "cell mostly" was based on reporting that "all or almost all calls are received on cell phones", among those reporting having both landline and cellular phones in the family. This definition differs from the NHFS, which defined "cell mainly" based on likelihood of answering a landline phone if it rang. Thus, direct comparisons of the NHFS cell phone sample consisting of households with only or "mainly" cellular telephone usage with the NHIS are not possible.

Definitions of chronic high-risk conditions differed for children and adults and somewhat across surveys. For children from NHFS, chronic high-risk status was determined based on questions about the child still having asthma or still having one or more of a list of conditions: "Has a doctor, nurse, or other health professional ever said that [S.C.] has <u>any</u> of the following health conditions? A heart problem, including congenital heart disease, blood problems such as anemia or sickle cell disease, cerebral palsy, muscular dystrophy, kidney problems, liver problems, cancer, diabetes, lung problems, a weakened immune system caused by a chronic illness or by medicines taken for a chronic illness…". For children from NHIS, high-risk status was based on responses to separate questions ever having been told that the child had: cerebral

palsy, multiple sclerosis, sickle cell anemia, diabetes, congenital heart disease, other heart disease, or asthma. Asthma was included only if the child still had asthma. For adults from NHFS, high-risk status was based on the respondent still having asthma or still having one or more of a list of conditions: "Has a doctor, nurse, or other health professional ever said that you have any of the following health conditions? A lung condition other than asthma, a heart condition, diabetes, a kidney condition, sickle cell anemia or other anemia, a neurological or neuromuscular condition, a liver condition, or a weakened immune system caused by a chronic illness or by medicines taken for a chronic illness…" For adults from NHIS, high-risk status was based on responses to separate questions about the respondent: still having asthma; ever having coronary heart disease, angina pectoris, heart attack, emphysema, diabetes, seizure disorder or epilepsy, chronic or long term liver condition; having chronic bronchitis, weak or failing kidneys, or liver condition in the past 12 months; having a diagnosis of cancer (excluding non-melanoma skin cancer) in the past year; or ever having a cancer diagnosis of blood, leukemia or lymphoma.

Data analyses were conducted using SAS version 9.2 for data management, and SAS-callable SUDAAN release 10.0.1 for statistical analyses to the complex survey designs of NHFS and NHIS (70).

Comparison of characteristics across sample sources and surveys

The weighted distributions of characteristics were compared within the NHFS sample, stratified by sample source (landline or cell phone). Characteristics in the full sample were also compared to the subset of respondents from the landline sample, with new weights applied to this landline sample subset so that their new weighted totals summed to the population control totals used for the target population. This latter comparison simulates the scenario in which only a landline sample had been used for the survey, and comparison of landline weighted estimates to the overall dual frame estimates allows assessment of the change in estimates resulting from using a dual frame design. To create the new landline weights, base weights for landline

respondents that adjusted for probability of selection and multiple phone lines per household were further adjusted using the same post-stratification steps applied to the complete dual frame sample.

Because NHFS weighting included control totals for age, sex, race/ethnicity and state of residence, comparisons of weighted distributions of these characteristics of overall NHFS respondents are expected to be very similar to those from NHIS, though may differ somewhat due to differences in population control totals used across surveys and different age groupings used in weighting and analysis. Associations between characteristics of NHFS respondents and sample source (landline or cell phone) were assessed by Chi-square tests.

Prevalence of selected influenza-related outcomes by NHFS sample source

With NHFS data, crude and adjusted comparisons were made for the prevalence of influenza-related opinions and vaccination outcomes by sample source (landline and cell phone). For children, only vaccination outcomes were compared. Comparisons were made using estimated prevalence differences (cell – landline). Adjusted comparisons for each outcome (dichotomized variables for influenza-related opinions, receipt of influenza vaccination) used logistic regression via the SUDAAN Multilog procedure (70) with sample design (landline, cell phone) and selected characteristics as predictors. No interaction terms among predictor variables were assessed. Adjusted differences in outcome proportions were estimated from predictive marginals obtained from the logistic regression models.

In the target population, undercoverage bias of a landline RDD telephone survey can be expressed as the proportion of the population in non-landline households times the difference in prevalence of an outcome between landline and non-landline households (see Appendix 4.1). Because differential nonresponse bias may exist for landline and cell phone samples, even after weighting, estimated differences in prevalence of adjusted and unadjusted outcomes based on landline and cell sample respondents may provide biased estimates of the difference in prevalence

between landline and cell only/mainly households in the target population. Thus, sample estimates of undercoverage bias may be distorted.

Time-to-event analysis of influenza vaccination coverage

Influenza vaccination coverage was estimated as the cumulative proportion vaccinated as of the end of May 2010 using the Kaplan-Meier procedure KAPMEIR in SUDAAN (70). The event for analysis was earliest reported influenza vaccination during the vaccination period (August 2009-May 2010 for seasonal and October 2009 through May 2010 for pH1N1). Time-to-event was measured by the month of reported vaccination. Persons reporting they had not received influenza vaccination by date of interview were assigned a time value of the month prior to their month of interview, since vaccination could have occurred between date of interview and end of the month. Persons reporting vaccination in a month prior to month of interview were assigned a time value of the month of vaccination. Persons reporting vaccination in the same month as interviewed were classified as not having the event and assigned a time value of the month prior to month of interview, because persons not vaccinated by date of interview were interval-censored. Vaccination coverage was estimated as one minus the cumulative proportion without vaccination directly produced by the KAPMEIR procedure.

To avoid possible differential downward bias from NHFS and NHIS in estimated vaccination coverage that could result by excluding persons reporting influenza vaccination but did not report the month of vaccination, the month of vaccination for these cases was imputed. Missing month of vaccination was determined using a hot-deck imputation method with non-missing donors with the same or close interview week, state (for NHFS) or region (for NHIS) of residence, race/ethnicity and age group (23, 97). For NHFS, from 0.4% (adult pH1N1) to 1.5% (child pH1N1) of the study cohort were excluded because of missing responses to receipt of seasonal or pH1N1 vaccination, and from 1.9% (adult seasonal) to 2.8% (child seasonal) had month and year of most recent influenza vaccination imputed. for NHIS, from 1.9% (adult

pH1N1, seasonal) to 3.0% (child seasonal) of the study cohort were excluded because of missing responses to receipt of seasonal or pH1N1 vaccination, and from 0.7% (adult pH1N1) to 2.3% (child seasonal) had month and year of most recent influenza vaccination imputed.

The primary analysis compares Kaplan-Meier estimates of influenza vaccination coverage as of the end of May 2010 from NHFS and NHIS, overall and stratified by respondent characteristics. Cox proportional hazards models were not considered for this study as the main purpose is to evaluate potential bias in stratified estimates used to evaluate influenza vaccination efforts and identify potential disparities in key population subgroups. The estimated difference in influenza vaccination coverage between NHFS and NHIS approximate the nonresponse bias of the NHFS estimates under the assumption that the NHIS estimates have zero nonresponse bias, or relatively smaller magnitude of bias compared to NHFS. Under the assumption that NHFS estimates are always further from actual than NHIS, the difference of NHFS minus NHIS estimates will provide an overly favorable assessment of nonresponse bias of NHFS estimates. The nonresponse bias of influenza vaccination coverage estimates from NHIS is unknown, but presumed lower than for typical telephone surveys given its substantially higher response rates. In practice, the NHIS provides a useful benchmark for evaluating the performance of telephone surveys.

Estimates from NHFS are also further stratified by sample source (landline and cell phone). NHFS estimates for the landline weighted subsample are also presented and compared to the overall NHFS estimates to assess the change in estimates attributable to switch from landline only sample to dual frame sample.

RESULTS

For each of the adult characteristics examined, weighted distributions of January-June 2010 NHFS respondents differed significantly ($p<0.05$) by sample source (Table 4-1). Compared to landline respondents, cell only/mainly respondents were more likely to be younger, in a

racial/ethnic minority group, have the interview conducted in Spanish, male, have a child in the household, live in the South, have less than 12 years of education, live below the poverty level, rent their dwelling, be employed, out of work or a student, have no health insurance, not have a chronic medical condition, and work in a health care setting. After weighting the landline subsample, distributions by age, race/ethnicity, sex and region were very similar to the total NHFS weighted sample as expected since these variables were used in post-stratification weighting adjustments (Table 4-1). Distributions were also similar between weighted landline subsample and total NHFS samples for interview language, education, employment status, chronic condition and working in a health care setting. Compared to the total adult sample, the weighted landline subsample of adults had higher prevalence of children living in the household (41.5% vs. 37.2%), living above poverty with annual household income of at least $75,000 (28.3% vs. 25.8%), owning residence (75.8% vs. 68.6%), and having health insurance (85.3% vs. 82.7%).

For children, weighted distributions of respondent characteristics differed significantly ($p<0.05$) between those from cell only/mainly and landline samples for all characteristics examined except sex and chronic condition (Table 4-2). Compared to the landline sample, cell only/mainly children were more likely to be age <2 years, Hispanic, have interview conducted in Spanish, live in the South, live below the poverty level, live in a rented residence, and have no health insurance or are covered by Medicaid or SCHIP. Compared to the total sample, the weighted landline subsample of children was more likely to live above poverty with annual household income of $75,000 or greater (37.8% vs. 34.1%), live in an owned residence (75.0% vs. 66.5%), and have health insurance other than Medicaid or SCHIP (67.2% vs. 62.8%).

For adults, the weighted distributions of characteristics of the January-June 2010 NHFS total and January-June 2010 NHIS samples were very similar for variables used in weighting the NHFS (age, race/ethnicity, sex and region), and for some other characteristics (having child in household, housing tenure, and health insurance status) (Table 4-1). Compared to NHIS, NHFS

respondents were more likely to have an interview in Spanish (6.6% vs. 5.2%), have some college education (28.1% vs. 20.4%; and less likely to have 12 years of education, 22.9% vs. 29.0%), not have a chronic condition (74.8% vs. 70.5%), and work in a health care setting (11.3% vs. 7.8%). A higher proportion of NHFS respondents (17.8%) had missing poverty and income status than NHIS respondents (8.8%), but distributions were similar after restricting to those with known status. For employment status, NHFS respondents were more likely to be homemakers (7.2% vs. 5.9%) or students (6.4% vs. 2.9%) and less likely to be employed (57.2% vs. 61.5%) or unable to work (5.3% vs. 6.4%). For characteristics differing for adults between NHFS weighted landline subsample and total samples (children living in the household, living above poverty with annual household income of at least $75,000, owning residence, and having health insurance), the distributions from the total NHFS sample were closer to the NHIS distributions except for poverty status. From NHIS, 73.2% of adults were in families with a landline telephone, 25.6% with cell phones only, and 1.2% with no telephones.

For children, weighted distributions were similar for NHFS and NHIS samples for all characteristics except for household poverty status and health insurance status (Table 4-2). Poverty status was unknown for more NHFS than NHIS sample children (9.5% vs. 6.8%). Children from NHFS were more likely to have health insurance other than Medicaid or SCHIP compared to children from NHIS (62.8% vs. 58.2%). For characteristics differing for children between NHFS weighted landline subsample and total samples (living above poverty with annual household income of $75,000 or greater, living in an owned residence, having health insurance other than Medicaid or SCHIP), the distributions from the total NHFS sample were closer to the NHIS distributions. From NHIS, 71.2% of children were in families with a landline telephone, 27.7% with cell phones only, and 1.2% with no telephones.

Prevalence of selected outcomes of interest for NHFS landline and cell only/mainly respondents were compared. For adults, cell only/mainly respondents were more likely to report that they thought they had a very high chance of H1N1 flu sickness if not vaccinated and to be

very or somewhat worried about getting sick from H1N1 or seasonal flu vaccination, but less likely to report having received H1N1 or seasonal flu vaccination (Table 4-3). They were also less likely to think that seasonal flu vaccination is very or somewhat effective in preventing seasonal flu. After adjusting for sociodemographic characteristics, these differences were reduced, though some remained statistically significant (e.g., the crude difference in receipt of seasonal influenza vaccination between cell only/mainly and landline respondents was -17.1 percentage points, and was -4.4 percentage points after adjustment for sociodemographic characteristics) (Table 4-3) For children, differences in prevalence of receipt of pH1N1 and seasonal influenza vaccination by sample source were not statistically significant (Table 4-4).

The primary outcomes of interest for this study are pH1N1 and seasonal influenza vaccination coverage estimated using survival analysis. For adults, pH1N1 coverage was 6.2 percentage points lower for NHFS cell only/mainly compared to landline respondents (Table 4-5). Magnitude of differences in estimated vaccination coverage (cell only/mainly minus landline) varied across levels of each characteristic (e.g. for age, differences ranged from 0.0 percentage points for persons ≥65 years to -8.5 percentage points for persons 30-34 years). For the total NHFS sample, pH1N1 coverage was 26.1%, with coverage based on the weighted landline subsample at 27.2%. In stratified analysis, differences between estimates based on the weighted landline subsample and all respondents that were not within the 95% confidence interval half-width of the total NHFS estimate included higher pH1N1 coverage for weighted landline subsample respondents age 18-24 years, Hispanic, with interview in Spanish, male, living in the Midwest, living below poverty level, being employed or a student, having no health insurance, not having a chronic condition, and not working in a health care setting (Table 4-5).

Estimated pH1N1 coverage among adults from NHFS (26.1%) was 6.2 percentage points higher than from NHIS (19.8%). Across levels of the characteristics, differences in pH1N1 coverage (NHFS minus NHIS) ranged from 0.6 percentage points for students to 10.6 percentage points for persons age 45-49 years. In comparison of potential differential non-response bias

across levels of each subgroup, three statistically significant findings were identified. The NHFS-NHIS differences were 5.1 for females and 7.9 for males, for a differential nonresponse bias estimate of -2.8 percentage points with a 95% confidence interval half width (CI) of ±2.7. For persons with unknown poverty status compared to persons living above poverty with annual household income greater than $75,000, the NHFS-NHIS differences were 3.0 and 7.3 for these two groups, respectively, for a differential non-response bias of -4.4 percentage points with CI of ±4.3. For persons with health insurance compared to those without, the NHFS-NHIS differences were 3.4 and 6.9 respectively, for a differential estimate of 3.5 (CI ±3.2).

For seasonal influenza vaccination among adults, coverage was 17.1 percentage points lower for cell only/mainly compared to landline respondents, and seasonal coverage from the weighted landline subsample was 1.7 percentage points higher than the 42.9% coverage for NHFS total sample (Table 4-6). The total NHFS estimate was 7.3 percentage points higher than the NHIS estimate. This difference was fairly consistent across levels of the characteristics. Statistically significant exceptions included differential non-response bias estimates for: the other/multiple race group (-5.9 ±5.7) compared to non-Hispanic whites; females (-3.0 ±2.8) compared to males; persons with unknown poverty status (-4.9 ±4.8) compared to persons living above poverty with annual household income greater than $75,000; persons without health insurance (-4.0 ±3.2); and persons working in health care settings (-6.0 ±5.0). Estimated non-response bias (difference in estimates from NHFS minus NHIS) for these subgroups was lower than average, ranging from 1.2 for persons working in a health care setting to 6.3 for females. The highest non-response bias was observed for homemakers (13.9).

For children, estimated pH1N1 and seasonal influenza vaccination coverage was lower for NHFS cell only/mainly compared to landline respondents (Tables 4-3, 4-4), but differences were lower than observed for adults. Estimates based on the weighted landline subsample were 0.9 and 1.0 percentage points higher than the total NHFS samples for pH1N1 and seasonal

coverage, respectively. Non-response bias estimated by the difference in NHFS minus NHIS estimates was 8.7 percentage points for pH1N1 and 6.5 for seasonal coverage.

For pH1N1 coverage among children, differential non-response bias was found for Hispanic (12.7 ±7.3) and other/multiple race children (-14.3 ±11.0) compared to non-Hispanic white only children, and for interviews conducted in Spanish compared to English (11.8 ± 10.6). Compared to NHIS, these represent an over-estimation by 20.7 percentage points for Hispanics and 19.5% for interviews in Spanish, and 6.3 percentage point under-estimate for children with other/multiple race. For seasonal coverage among children, no statistically significant estimates of differential non-response bias were identified. Unlike for pH1N1 coverage, estimated non-response bias for seasonal coverage among Hispanic children (9.7) was similar to non-Hispanic white children (7.1). For both pH1N1 and seasonal coverage, differences in vaccination coverage between NHFS and NHIS for non-Hispanic black children were 2-3 percentage points, but 95% confidence intervals were ± 7-8.

Potential selection bias induced by a theoretical survey that has a sampling frame restricted to landline telephones may be best evaluated with NHIS given its higher response rates compared to telephone surveys. From Tables 4-5 through 4-8, estimated influenza vaccination coverage for adults and children from NHIS by family telephone status tended to be lower for those in cell-only and phoneless families, and among those with a landline telephone available to the family, vaccination coverage was lower for dual landline and cell phone users who mostly used their cell phone to answer calls, compared to other dual users and landline only users. Although not directly comparable because of inclusion of cell mainly households, NHFS estimates of influenza vaccination coverage from the cell only/mainly respondents tended to be higher than NHIS estimates for the cell only respondents.

DISCUSSION

This is among the first studies to evaluate potential nonresponse bias in dual landline and cell telephone frame surveys. Compared to estimates from the same time period from the NHIS and using the same analytic methods, estimates of influenza vaccination coverage for the 2009-10 influenza season from NHFS were biased upwards by 6-9 percentage points. Relative bias (dividing by vaccination rate from NHIS) was higher for adults compared to children and for pH1N1 compared to trivalent seasonal influenza vaccination (child pH1N1 – 25%; child seasonal – 16%; adult pH1N1 – 31%; adult seasonal – 20%).

Final estimates released by the CDC combined data from the NHFS standalone survey with estimates from the Behavioral Risk Factor Surveillance System (BRFSS) for children and adults, and from the National Immunization Survey (NIS) influenza vaccination module for children (98). These final estimates were closer to the NHIS estimates than the standalone NHFS estimates presented in this paper, with relative bias of 16% - child pH1N1, 8% child seasonal, 15% - adult pH1N1, and 13% - adult seasonal. This suggests that NHFS estimates had higher nonresponse bias than the BRFSS for adults and combined NIS and BRFSS for children. One possible explanation is that propensity to respond to the NHFS was influenced by the survey being identified as related to influenza vaccination at the beginning, while the BRFSS is a general health survey, and this propensity to respond was associated with higher likelihood of vaccination (41, 42, 99). This may also explain why NHFS nonresponse bias was higher for pH1N1 compared to seasonal influenza vaccination, given the media attention on “swine flu” during the survey period.

This study also identified potential population subgroups with differential nonresponse bias in NHFS estimates. This can create bias in comparisons of estimates across subgroups. For pH1N1 vaccination of children, estimated nonresponse bias was higher than average for Hispanic compared to non-Hispanic white children. For pH1N1 vaccination of children, NHFS estimates indicated higher coverage for Hispanics compared to non-Hispanic whites, and higher coverage for non-Hispanic whites compared to non-Hispanic blacks. In contrast, NHIS estimates indicate

no statistically significant differences among these three racial/ethnic groups, although non-Hispanic black children had 5.3 percentage point lower coverage than non-Hispanic white children from NHIS (compared to 10.7 percentage points lower from NHFS). For seasonal vaccination, both surveys would conclude there were no statistically significant differences among these racial/ethnic groups. Seasonal and pH1N1 coverage for children of other or multiple race was higher than the other racial/ethnic groups for both NHFS and NHIS. The higher nonresponse bias for Hispanics from NHFS might reflect a higher saliency of the survey compared to other racial/ethnic groups given the reports of swine flu in Mexico.

For adults, differential nonresponse bias in seasonal influenza vaccination coverage estimates from NHFS was identified for many characteristics (race/ethnicity, sex, poverty status, health insurance status, and working in a health care setting). This at least partly reflects the narrower confidence intervals for the estimates from both surveys as compared to children. In most cases, the direction of associations between levels of the characteristics were in the same direction for both surveys, with estimated risk ratios differing somewhat. There was little difference between NHFS and NHIS estimates for persons working in a health care setting, which may indicate a higher propensity for health care personnel to respond to a telephone survey regardless of their vaccination status (prevalence of work in a health care setting was higher in NHFS).

The addition of a cell telephone frame improved the validity of NHFS results. Characteristics of the cell only/mainly sample differed from those of the landline sample as expected based on prior NHIS analysis by telephone service (94), and dual frame NHFS estimates were closer to the NHIS estimates compared to estimates from the reweighted landline sample. The apparent reduction in bias of dual frame vs. reweighted landline sample was modest, and weighted distributions of many characteristics from the landline sample were similar to those of the dual frame and NHIS samples. As found in other studies, differences in health outcomes

between cell and landline respondents can be mitigated but not always eliminated after controlling for sociodemographic factors (33, 89).

Because there may be differential nonresponse bias in landline and cell telephone samples, evaluation of potential reduction in bias attributable to addition of a cell telephone sampling frame that relies solely on within-survey comparisons may also be biased. For example, if cell telephone respondents are so unique that their responses to key survey questions are very different from the target population of persons with only cellular telephones, dual frame estimates might actually be more biased than landline frame estimates. Thus when possible, comparisons to external benchmarks and other approaches should be utilized to evaluate nonresponse bias in dual frame telephone surveys.

The NHFS landline weighted subsample still differed from the dual frame on distributions for having a child in the household, poverty status, housing tenure and health insurance status, indicating that actual cell sample is needed to improve representativeness of sample characteristics. Even for characteristics that matched in weighted distribution with the dual frame NHFS and NHIS samples, there were still differences in vaccination coverage estimates stratified by levels of these characteristics.

Overall, for certain health outcomes such as influenza vaccination, past landline RDD telephone surveys likely resulted in relatively minor bias due to undercoverage of the sampling frame. However, as prevalence of wireless-only households increases, bias attributable to undercoverage may increase. Further, the credibility of landline surveys would be increasingly questioned regardless of evidence that may be available to measure undercoverage bias. As the shift to dual frame RDD telephone surveys continues, additional efforts are needed to identify cost-efficient ways of conducting cell phone interviews, factors associated with propensity to respond to surveys dialed to cell phones, and ways to improve and assess validity of survey estimates. Assessment of nonresponse bias in dual frame RDD telephone surveys is needed

across a wide spectrum of health outcomes, overall and stratified by type of phone service and usage.

LIMITATIONS

This report estimated potential nonresponse bias of a telephone survey by comparison to the NHIS, a survey with an address-based sampling frame, in-person mode of interviewing, and higher response rates than the telephone survey. However, response rates for the 2010 NHIS were 61% for adults and 71% for children. While these are higher than the 26% to 33% NHFS response rates, different assumptions are made in constructing response rates for area-based and RDD telephone surveys, and nonresponse bias is not necessarily directly correlated with lower response rates (40). There are no further "gold standards" with which to assess nonresponse bias of NHIS with respect to influenza vaccination. Aside from possible differential nonresponse bias between NHIS and NHFS, differences in survey estimates may also reflect other differences between the surveys, such as mode of interview (in-person vs. by telephone), experience of interviewers, question wording, and methods of weighting the data.

There may be differences in cognitive processes used to recall influenza vaccination in telephone and in-person interviews. For example, some people may be more engaged when there is an interviewer in-person and thus work harder to provide accurate answers. Other persons may be more likely to provide a social desirable response with a face-to-face interview, thus having less accurate recall. Accuracy of recall of influenza vaccination in NHIS and NHFS has not been assessed, and it is possible that some of the differences in estimates could result from differential misclassification bias.

The way questions are worded can also affect comparisons. For example, the questions used to determine chronic medical conditions were asked with different approaches and prevalence of one or more conditions was higher in NHIS for adults. Prevalence of unknown poverty status among adults was twice as high for NHFS (18% vs. 9%).

This study did not directly assess factors associated with propensity to respond to landline and cell phone surveys. This can be done directly by comparing distributions of factors stratified by telephone status between NHIS final weighted distributions and distributions from NHFS or other dual frame telephone surveys weighted to account for probability of selection but not post-stratified to Census population control totals.

The NHFS screened the cell phone sample and included persons in households with only cell phone service or had both cell and landline phones but were not likely to answer their landline if it rang. The NHIS asked dual cell and landline telephone users questions related to the relative frequency of cell and landline use. These concepts of cell "mainly" and "mostly" are not compatible, and thus this study could not assess potential nonresponse bias stratified by sample source. Comparisons could be made for the cell only subset of the NHFS cell sample. More complete comparisons with NHIS can be made for dual frame RDD telephone surveys that screen based on the "cell mostly" concept or use a "take all" approach to the cell phone sample, considering all adults reached by cell phone as eligible regardless of telephone status.

Both NHIS and NHFS are subject to information bias, specifically to misclassification of influenza vaccination status by self or parental report (56, 65). If there were differential misclassification of vaccination status across the two surveys, that could distort the potential nonresponse bias comparisons in this study. For example, there could have been confusion between pH1N1 and seasonal influenza vaccinations, and possibly more confusion via a telephone survey or subtle differences in the way the questions about the two vaccinations were worded or cognitively processed by respondents. One study of children with fever or respiratory symptoms presenting to emergency departments and a pediatric hospital during the pH1N1 vaccination period did not find major differences in sensitivity and specificity of parental recall of pH1N1 and seasonal influenza vaccinations (100).

CONCLUSIONS

Dual landline and cell telephone RDD surveys have replaced landline RDD as the standard for surveys based on telephone sampling frames. However, with decreasing response rates to surveys in general and lower response rates to cell phone samples, it is critical for these dual frame surveys to assess validity of their estimates, and evaluate the possibility that solving one problem (undercoverage of the sampling frame) may be offset to some extent by overall decreased validity due to nonresponse bias. In the case of influenza vaccination coverage estimates during the 2009-10 pandemic, dual frame estimates from the NHFS were six to nine percentage points higher than those from the NHIS, a presumably more representative survey. Combined estimates from BRFSS, NHFS and NIS were closer to the NHIS estimates, from 3 to 6 percentage points higher than NHIS.

The primary advantages of available telephone surveys (NIS for children, BRFSS for adults) for assessing influenza vaccination coverage, compared to the NHIS, are timeliness, larger sample size allowing state-specific estimates both during and after the seasonal vaccination period, and lower cost of telephone surveys compared to in-person household surveys. These advantages must be weighed against the probable over-estimation of vaccination coverage from the telephone surveys. To guard against public health responses generated by false signals from the telephone surveys, estimates from the telephone surveys should continue to be compared each season overall and by key subgroups to determine patterns of consistency and inconsistency in trends between estimates from the different data sources.

When using influenza vaccination coverage estimates for purposes such as estimating the amount of influenza cases, hospitalizations or deaths averted by influenza vaccination, the most valid estimates are needed, and should be based on NHIS data if possible, or based on NIS and BRFSS estimates adjusted for their estimated level of bias as compared to NHIS. For monitoring influenza vaccination coverage via surveys in possible future pandemic vaccination campaigns,

the potential level of bias in telephone surveys must be weighed against the level of validity that is needed, which will depend on how such estimates would be used for public health action.

Table 4-1 Comparison of adult respondent characteristics* by sample source, National 2009 H1N1 Flu Survey (NHFS) (standalone component) and National Health Interview Survey (NHIS), January-June 2010 interview data

	NHFS				NHIS
Characteristic	Landline (n=29,714)	Cell Only/Mainly† (n=7,243)	Landline Weighted (n=29,714)	All (n=36,957)	All (n=13,496)
AGE (years)					
18-24	8.9 (8.1-9.7)	19.8 (18.3-21.5)	12.9 (11.8-14.0)	12.7 (12.0-13.5)	12.8 (12.0-13.7)
25-29	5.4 (4.9-6.0)	16.1 (14.7-17.7)	8.9 (8.1-9.8)	9.1 (8.5-9.8)	9.2 (8.6-9.8)
30-34	6.4 (5.9-6.9)	12.5 (11.2-13.9)	8.5 (7.8-9.2)	8.5 (8.0-9.1)	8.7 (8.1-9.2)
35-44	17.2 (16.4-18.0)	19.7 (18.1-21.4)	18.1 (17.2-19.0)	18.1 (17.3-18.9)	17.3 (16.5-18.1)
45-49	9.7 (9.1-10.2)	10.6 (9.4-12.1)	10.0 (9.4-10.6)	10.0 (9.4-10.6)	9.9 (9.4-10.6)
50-54	10.3 (9.8-10.9)	8.0 (7.0-9.1)	9.6 (9.0-10.2)	9.5 (9.0-10.1)	9.5 (9.0-10.1)
55-64	18.6 (17.9-19.3)	9.2 (8.2-10.3)	15.4 (14.7-16.0)	15.3 (14.7-15.9)	15.5 (14.7-16.3)
≥65	23.5 (22.8-24.3)	4.0 (3.3-4.8)	16.7 (16.1-17.3)	16.7 (16.1-17.3)	17.0 (16.2-17.9)
RACE/ETHNICITY					
Hispanic (H)	9.7 (9.0-10.6)	22.3 (20.4-24.4)	14.7 (13.5-15.9)	14.1 (13.3-15.1)	14.1 (13.2-15.0)
Non-H, Black Only	10.4 (9.8-11.0)	13.9 (12.4-15.5)	11.4 (10.7-12.2)	11.6 (11.0-12.3)	11.6 (10.7-12.5)
Non-H, White Only	74.4 (73.3-75.3)	55.4 (53.3-57.5)	67.6 (66.3-68.8)	67.7 (66.7-68.7)	67.9 (66.5-69.3)
Non-H, Other or Multiple Races	5.5 (5.0-6.0)	8.3 (7.3-9.5)	6.4 (5.8-6.9)	6.5 (6.0-7.0)	6.4 (5.8-7.1)
INTERVIEW LANGUAGE					
English	94.5 (93.8-95.1)	86.5 (84.8-88.1)	92.6 (91.6-93.4)	91.7 (90.0-92.4)	94.3 (93.6-94.8)
Spanish	4.0 (3.5-4.6)	11.4 (9.9-13.0)	5.8 (5.0-6.7)	6.6 (5.9-7.3)	5.2 (4.7-5.8)
Other Language	1.6 (1.3-1.9)	2.1 (1.5-3.0)	1.6 (1.3-2.0)	1.7 (1.4-2.1)	0.5 (0.4-0.6)
SEX					
Male	44.5 (43.5-45.5)	56.0 (53.8-58.0)	48.5 (47.3-49.7)	48.4 (47.4-49.4)	48.2 (47.1-49.2)
Female	55.5 (54.5-56.5)	44.0 (42.0-46.2)	51.5 (50.3-52.7)	51.6 (50.6-52.6)	51.8 (50.8-52.9)
CHILD IN HOUSEHOLD					
Yes	36.2 (35.2-37.2)	39.2 (37.2-41.3)	41.5 (40.3-42.7)	37.2 (36.2-38.2)	36.4 (35.2-37.5)
No	63.8 (62.8-64.8)	60.8 (58.7-62.8)	58.5 (57.3-59.7)	62.8 (61.8-63.8)	63.6 (62.5-64.8)
REGION OF RESIDENCE§					
Northeast	19.7 (19.0-20.4)	15.5 (14.1-16.9)	17.7 (17.0-18.5)	18.2 (17.6-18.8)	18.1 (16.6-19.6)
Midwest	23.0 (22.4-23.7)	19.0 (17.8-20.4)	22.0 (21.3-22.8)	21.7 (21.1-22.2)	23.1 (21.6-24.7)
South	33.9 (33.2-34.7)	42.2 (40.2-44.2)	37.1 (36.1-38.1)	36.8 (36.0-37.6)	35.3 (33.6-37.1)
West	23.3 (22.4-24.3)	23.3 (21.5-25.2)	23.2 (22.1-24.2)	23.3 (22.5-24.2)	23.4 (21.9-25.1)
EDUCATION LEVEL					
<12 Years	10.4 (9.8-11.1)	13.6 (12.0-15.3)	11.1 (10.3-12.0)	11.5 (10.8-12.3)	12.5 (11.7-13.4)
12 Years	22.7 (21.8-23.6)	23.3 (21.5-25.1)	23.0 (21.9-24.0)	22.9 (22.1-23.7)	29.0 (28.1-30.1)
Some College	27.2 (26.3-28.2)	29.7 (27.8-31.6)	28.1 (27.0-29.1)	28.1 (27.2-29.0)	20.4 (19.6-21.3)
College Graduate	39.6 (38.7-40.6)	33.5 (31.6-35.4)	37.8 (36.7-39.0)	37.5 (36.6-38.5)	38.0 (36.8-39.2)
HOUSEHOLD POVERTY STATUS					
Above Poverty					
Annual Income >$75,000	28.8 (27.9-29.7)	20.3 (18.8-21.9)	28.3 (27.3-29.4)	25.8 (25.0-26.7)	31.3 (29.9-32.8)
Annual Income ≤$75,000	43.6 (42.7-44.6)	43.1 (41.1-45.1)	42.6 (41.5-43.7)	43.4 (42.5-44.4)	48.0 (46.7-49.3)
Below Poverty	9.8 (9.2-10.5)	18.8 (17.1-20.5)	11.7 (10.8-12.6)	13.0 (12.2-13.7)	12.1 (11.2-13.0)
Unknown	17.7 (16.9-18.5)	17.9 (16.4-19.5)	17.4 (16.5-18.3)	17.8 (17.0-18.5)	8.8 (8.3-9.5)
OWN OR RENT DWELLING					
Own	79.1 (78.2-80.0)	48.2 (46.0-50.3)	75.8 (74.6-76.9)	68.6 (67.5-69.6)	68.0 (66.6-69.4)
Rent	17.7 (16.9-18.6)	46.8 (44.6-48.9)	20.6 (19.5-21.7)	27.6 (26.7-28.6)	29.7 (28.4-31.1)
Other	3.2 (2.8-3.6)	5.1 (4.2-6.1)	3.6 (3.1-4.2)	3.8 (3.4-4.3)	2.2 (2.0-2.6)
EMPLOYMENT STATUS					
Employed	52.7 (51.7-53.7)	65.9 (63.8-67.9)	55.8 (54.7-57.0)	57.2 (56.2-58.2)	61.5 (60.3-62.7)
Out of Work	6.8 (6.2-7.4)	10.4 (9.1-12.0)	8.0 (7.3-8.8)	8.0 (7.4-8.7)	7.7 (7.2-8.3)
Homemaker	8.3 (7.8-8.9)	5.0 (4.1-6.1)	8.0 (7.4-8.6)	7.2 (6.7-7.7)	5.9 (5.4-6.5)
Student	4.8 (4.2-5.4)	9.5 (8.3-10.8)	6.4 (5.6-7.2)	6.4 (5.8-7.0)	2.9 (2.5-3.3)
Retired	22.0 (21.3-22.8)	4.2 (3.4-5.1)	16.4 (15.8-17.1)	15.9 (15.4-16.5)	15.6 (14.8-16.4)
Unable to Work	5.4 (4.9-5.8)	5.0 (4.2-6.0)	5.4 (4.9-5.9)	5.3 (4.8-5.7)	6.4 (5.9-7.0)
HEALTH INSURANCE STATUS					
Insured	88.7 (87.9-89.4)	71.2 (68.9-73.4)	85.3 (84.1-86.4)	82.7 (81.7-83.6)	82.0 (81.0-83.0)
No Insurance	11.3 (10.6-12.1)	28.8 (26.6-31.1)	14.7 (13.6-15.9)	17.3 (16.4-18.3)	18.0 (17.0-19.0)
CHRONIC MEDICAL CONDITION					
No	71.9 (71.0-72.7)	80.3 (78.6-81.8)	74.2 (73.3-75.2)	74.8 (74.0-75.6)	70.5 (69.5-71.5)
Yes	28.1 (27.3-29.0)	19.7 (18.2-21.4)	25.8 (24.8-26.7)	25.2 (24.4-26.0)	29.5 (28.5-30.5)

Characteristic	NHFS				NHIS
	Landline (n=29,714)	Cell Only/Mainly† (n=7,243)	Landline Weighted (n=29,714)	All (n=36,957)	All (n=13,496)
WORKS IN HEALTH CARE SETTING					
No	89.5 (88.8-90.1)	87.1 (85.7-88.4)	89.7 (89.0-90.4)	88.7 (88.0-89.3)	92.2 (91.6-92.7)
Yes	10.5 (9.9-11.2)	12.9 (11.6-14.3)	10.3 (9.6-11.0)	11.3 (10.7-12.0)	7.8 (7.3-8.4)
FAMILY TELEPHONE STATUS					
Dual, Cell Mostly	NA	NA	NA	NA	18.0 (17.1-18.9)
Dual, Other	NA	NA	NA	NA	44.4 (43.1-45.7)
Landline Only	NA	NA	NA	NA	10.8 (10.1-11.5)
Cell Only	NA	NA	NA	NA	25.6 (24.4-26.8)
Phoneless	0.0	0.0	0.0	0.0	1.2 (1.0-1.5)

***** Weighted percent by levels of each characteristic are shown with 95% confidence intervals. The landline weighted estimates are based on the subsample of landline respondents weighted back to the target population controls.

† The association of characteristic and sample source (landline, cell only/mainly) was statistically significant ($p<0.05$) by Chi-square test for each characteristic.

§ In the geographic classification of the U.S. population, states are grouped into the following four regions used by the U.S. Census Bureau. Northeast includes Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania. Midwest includes Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, and Nebraska. South includes Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Oklahoma, Arkansas, and Texas. West includes Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii.

Table 4-2 Comparison of child characteristics* by sample source, National 2009 H1N1 Flu Survey (NHFS) (standalone component) and National Health Interview Survey (NHIS), January-June 2010 interview data

Characteristic	NHFS				NHIS
	Landline (n=7,131)	Cell Only/Mainly† (n=1,964)	Landline Weighted (n=7,131)	All (n=9,095)	All (n=5,115)
AGE AS OF NOVEMBER 2009					
<2 years	11.2 (10.0-12.4)	14.5 (12.4-16.8)	12.2 (10.9-13.6)	12.3 (11.3-13.5)	12.5 (11.4-13.8)
2-4 years	18.5 (17.1-20.0)	21.2 (18.5-24.3)	19.4 (17.9-21.0)	19.5 (18.2-20.9)	17.9 (16.6-19.3)
5-12 years	46.7 (44.7-48.6)	42.0 (38.3-45.9)	45.5 (43.5-47.5)	45.0 (43.2-46.9)	43.8 (42.2-45.5)
13-17 years	23.6 (22.1-25.2)	22.3 (19.1-25.8)	22.9 (21.4-24.5)	23.2 (21.6-24.7)	25.7 (24.3-27.2)
RACE/ETHNICITY					
Hispanic (H)	15.8 (14.2-17.5)	30.0 (26.3-33.9)	21.4 (19.5-23.4)	20.8 (19.1-22.7)	23.2 (21.5-25.0)
Non-H, Black Only	12.0 (10.6-13.5)	14.7 (12.1-17.7)	12.8 (11.4-14.4)	12.9 (11.6-14.4)	14.4 (13.1-15.8)
Non-H, White Only	64.2 (62.2-66.1)	46.9 (43.2-50.6)	57.0 (54.9-59.0)	58.0 (56.1-59.9)	54.1 (52.0-56.1)
Non-H, Other or Multiple Races	8.1 (7.1-9.1)	8.4 (6.6-10.7)	8.8 (7.8-9.9)	8.2 (7.3-9.2)	8.3 (7.2-9.5)
INTERVIEW LANGUAGE					
English	92.2 (90.7-93.4)	86.4 (83.5-88.9)	90.2 (88.6-91.7)	90.1 (88.7-91.3)	90.8 (89.6-91.9)
Spanish	6.4 (5.3-7.8)	12.2 (9.8-15.1)	8.4 (7.0-10.0)	8.5 (7.3-9.8)	8.6 (7.5-9.8)
Other Language	1.4 (1.0-2.0)	1.4 (0.8-2.5)	1.4 (1.0-1.9)	1.4 (1.0-1.9)	0.6 (0.4-0.9)
SEX					
Male	51.7 (49.8-53.7)	51.0 (47.2-54.8)	52.4 (50.4-54.4)	51.5 (49.6-53.3)	51.1 (49.4-52.9)
Female	48.3 (46.3-50.2)	49.0 (45.2-52.8)	47.6 (45.6-49.6)	48.5 (46.7-50.4)	48.9 (47.1-50.6)
REGION OF RESIDENCE§					
Northeast	19.7 (18.2-21.3)	11.9 (9.8-14.3)	17.7 (16.3-19.2)	16.9 (15.7-18.2)	15.8 (14.0-17.8)
Midwest	22.1 (20.7-23.5)	22.5 (19.7-25.4)	21.2 (19.9-22.6)	22.2 (20.9-23.6)	23.0 (21.1-25.1)
South	33.5 (31.8-35.2)	42.6 (38.9-46.3)	36.9 (35.1-38.7)	36.7 (35.0-38.4)	36.2 (33.9-38.5)
West	24.8 (22.9-26.7)	23.1 (19.8-26.7)	24.2 (22.4-26.0)	24.2 (22.5-25.9)	25.0 (22.9-27.3)
HOUSEHOLD POVERTY STATUS					
Above Poverty					
Annual Income >$75,000	39.9 (38.0-41.8)	23.6 (20.6-26.9)	37.8 (36.0-39.7)	34.1 (32.4-35.6)	33.1 (31.0-35.2)
Annual Income ≤$75,000	36.0 (34.2-37.9)	38.4 (34.8-42.0)	36.4 (34.5-38.3)	36.9 (35.1-38.6)	40.1 (38.3-42.0)
Below Poverty	14.8 (13.2-16.5)	28.2 (24.7-32.0)	16.4 (14.7-18.2)	19.5 (17.9-21.3)	21.0 (19.3-22.9)
Unknown	9.3 (8.3-10.4)	9.8 (8.0-12.1)	9.4 (8.4-10.6)	9.5 (8.5-10.5)	5.8 (5.1-6.7)
OWN OR RENT DWELLING					
Own	76.1 (74.1-77.9)	49.0 (45.1-52.9)	75.0 (73.0-76.9)	66.5 (64.5-68.4)	62.9 (60.8-64.9)
Rent	21.8 (20.0-23.7)	46.7 (42.8-50.6)	22.8 (21.0-24.8)	30.6 (28.7-32.6)	35.3 (33.3-37.4)
Other	2.1 (1.7-2.8)	4.3 (3.0-6.2)	2.1 (1.6-2.8)	2.9 (2.3-3.7)	1.8 (1.3-2.3)
HEALTH INSURANCE STATUS					
Insured – Medicaid or SCHIP	24.9 (22.9-26.9)	37.1 (33.1-41.2)	26.9 (24.9-29.1)	29.2 (27.3-31.2)	34.7 (32.8-36.7)
Insured - other	69.7 (67.5-71.8)	50.2 (46.1-54.4)	67.2 (65.0-69.4)	62.8 (60.7-64.9)	56.8 (54.7-58.9)
No Insurance	5.4 (4.4-6.6)	12.7 (9.7-16.5)	5.9 (4.9-7.1)	8.0 (6.7-9.5)	8.5 (7.5-9.4)
CHRONIC MEDICAL CONDITION					
No	87.0 (85.6-88.3)	88.6 (86.0-90.8)	86.9 (85.5-88.2)	87.6 (86.3-88.7)	88.9 (87.8-90.0)
Yes	13.0 (11.7-14.4)	11.4 (9.2-14.0)	13.1 (11.8-14.5)	12.4 (11.3-13.7)	11.1 (10.0-12.2)
FAMILY TELEPHONE STATUS					
Dual, Cell Mostly	NA	NA	NA	NA	22.3 (20.8-23.9)
Dual, Other	NA	NA	NA	NA	41.4 (39.6-43.2)
Landline Only	NA	NA	NA	NA	6.0 (5.2-6.9)
Cell Only	NA	NA	NA	NA	29.0 (27.3-30.8)
Phoneless	0.0	0.0	0.0	0.0	1.3 (1.0-1.8)

***** Weighted percent by levels of each characteristic are shown with 95% confidence intervals. The landline weighted estimates are based on the subsample of landline respondents weighted back to the target population controls.

† The association of characteristic and sample source (landline, cell only/mainly) was statistically significant ($p<0.05$) by Chi-square test for each characteristic except sex and chronic medial condition.

§ In the geographic classification of the U.S. population, states are grouped into the following four regions used by the U.S. Census Bureau. Northeast includes Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania. Midwest includes Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, and Nebraska. South includes Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Oklahoma, Arkansas, and Texas. West includes Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii.

Table 4-3 Comparisons of unadjusted and adjusted* prevalence (%) of influenza-related outcomes between landline and cell only/mainly adult respondents, National 2009 H1N1 Flu Survey (standalone component)

Outcome	Prevalence Estimate		Difference, Cell Only/Mainly – Landline	
	Landline (n=29,714)	Cell Only/Mainly (n=7,243)	Unadjusted	Adjusted
Received H1N1 vaccination	25.1	18.8	†-6.3	†-2.9
Very concerned about H1N1 flu	15.3	15.8	0.4	†-2.2
H1N1 flu vaccination very or somewhat effective in preventing H1N1 flu	74.2	73.6	-0.7	-2.3
Very or somewhat high chances of H1N1 flu sickness if not vaccinated	24.9	28.5	†3.6	0.7
Very or somewhat worried about getting sick from H1N1 flu vaccine	29.9	34.3	†4.3	-1.2
Received seasonal flu vaccination	47.9	30.7	†-17.1	†-4.4
Seasonal flu vaccination very or somewhat effective in preventing seasonal flu	81.9	78.3	†-3.5	-2.1
Very or somewhat high chances of seasonal flu sickness if not vaccinated	38.4	38.6	0.2	0.6
Very or somewhat worried about getting sick from seasonal flu vaccine	26.2	29.8	†3.6	-1.2

* Adjusted prevalence determined from predictive marginal of logistic regression model with outcome as dependent variable and main effects for sample source (landline vs. cell only/mainly), age group, race/ethnicity, sex, child in household, region of residence, metropolitan statistical area status, education level, poverty status, housing tenure and employment status. This analysis included 32,352 (H1N1 vaccination), 32,911 (seasonal vaccination) and 33,016 (other outcomes) of 36,957 respondents with non-missing data on all covariates.
† Statistically significant difference in prevalence by sample source ($p < 0.05$).

Table 4-4 Comparisons of unadjusted and adjusted* prevalence (%) of influenza-related outcomes for children between landline and cell only/mainly respondents, National 2009 H1N1 Flu Survey (standalone component)

Outcome	Prevalence Estimate		Difference, Cell Only/Mainly – Landline	
	Landline (n=7,131)	Cell Only/Mainly (n=1,964)	Unadjusted	Adjusted
Received H1N1 vaccination	40.8	37.3	-3.5	-1.0
Received seasonal flu vaccination	46.7	43.6	-3.1	-1.9

* Adjusted prevalence determined from predictive marginal of logistic regression model with outcome as dependent variable and main effects for sample source (landline vs. cell only/mainly), age group, race/ethnicity, sex, region of residence, metropolitan statistical area status, education level, poverty status, housing tenure and health insurance status. This analysis included 7,144 (H1N1) and 7,286 (seasonal) of 9,095 respondents with non-missing data on all covariates.
† Statistically significant difference in prevalence by sample source ($p < 0.05$).

Table 4-5 Influenza vaccination coverage – pH1N1 – among adults through May 2010, by selected respondent characteristics, January-June 2010 interviews from the National 2009 H1N1 Flu Survey (standalone component) and National Health Interview Survey

pH1N1	NHFS Estimates						NHIS Estimates	Difference, NHFS Total - NHIS
	Cell Only/Mainly (COM)	Landline (L)	Difference, COM-L	Landline Weighted (LLWT)	NHFS Total	Difference		
Characteristic	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**LLWT-Total**	**%, 95% CI**	**%, 95% CI**
All Adults	22.1 ± 2.0	28.3 ± 1.0	-6.2 ± 2.3	27.2 ± 1.2	26.1 ± 1.0	1.1	19.8 ± 0.9	**6.2 ± 1.3**
Age (years)								
18-24	17.4 ± 3.4	25.1 ± 4.4	-7.7 ± 5.5	24.6 ± 4.4	20.9 ± 2.7	3.7	15.3 ± 2.6	**5.7 ± 3.8**
25-29	22.6 ± 4.6	21.6 ± 4.6	1.0 ± 6.5	22.0 ± 5.9	22.2 ± 3.4	-0.3	13.1 ± 2.3	**9.1 ± 4.1**
30-34	21.4 ± 4.6	30.0 ± 5.7	-8.5 ± 7.3	28.6 ± 5.2	25.7 ± 3.8	2.9	17.1 ± 2.9	**8.6 ± 4.8**
35-44	19.6 ± 4.0	25.9 ± 2.3	-6.2 ± 4.7	25.4 ± 2.4	23.5 ± 2.1	1.9	18.9 ± 2.1	**4.7 ± 3.0**
45-49	27.2 ± 9.9	26.1 ± 3.3	1.1 ± 10.4	25.7 ± 3.4	26.5 ± 4.2	-0.8	15.9 ± 2.5	**10.6 ± 4.9**
50-54	22.2 ± 6.7	24.7 ± 2.6	-2.6 ± 7.2	24.4 ± 2.8	23.9 ± 2.6	0.5	18.8 ± 2.9	**5.1 ± 3.9**
55-64	27.2 ± 5.9	31.9 ± 2.0	-4.7 ± 6.3	31.9 ± 2.2	30.9 ± 2.0	1.0	26.4 ± 2.4	**4.5 ± 3.1**
≥65	31.9 ± 15.9	31.9 ± 1.8	0.0 ± 16.0	31.7 ± 1.9	31.9 ± 2.1	-0.2	26.6 ± 2.2	**5.3 ± 3.0**
Race/Ethnicity								
Hispanic	18.2 ± 5.8	27.1 ± 5.0	-8.9 ± 7.7	26.6 ± 5.2	22.2 ± 3.9	4.4	16.8 ± 2.3	**5.4 ± 4.5**
Non-Hispanic black only	16.7 ± 4.8	20.9 ± 3.0	-4.1 ± 5.7	21.4 ± 3.7	19.2 ± 2.7	2.3	15.2 ± 2.0	**4.0 ± 3.3**
Non-Hispanic white only	24.6 ± 2.3	29.4 ± 1.1	-4.8 ± 2.6	28.3 ± 1.1	28.0 ± 1.0	0.3	20.9 ± 1.1	**7.1 ± 1.5**
Other / Multiple Race	23.9 ± 6.4	29.2 ± 4.7	-5.3 ± 7.9	27.9 ± 4.3	26.8 ± 3.9	1.1	24.0 ± 3.2	2.9 ± 5.1
Interview Language								
English	23.2 ± 2.2	27.9 ± 1.0	-4.7 ± 2.4	26.8 ± 1.1	26.4 ± 1.0	0.4	20.0 ± 0.9	**6.4 ± 1.3**
Spanish	14.9 ± 6.4	33.5 ± 9.6	-18.6 ± 11.5	34.0 ± 11.9	22.4 ± 5.7	11.5	16.8 ± 4.3	5.6 ± 7.1
Other	11.7 ± 8.8	34.3 ± 11.2	-22.6 ± 14.2	28.9 ± 9.6	24.6 ± 8.2	4.3	21.5 ± 11.3	3.1 ± 13.9
Sex								
Male	20.2 ± 2.8	28.9 ± 1.7	-8.7 ± 3.3	27.5 ± 2.1	25.4 ± 1.5	2.1	17.5 ± 1.3	**7.9 ± 2.0**
Female	24.0 ± 3.4	28.4 ± 1.3	-4.4 ± 3.6	27.8 ± 1.4	27.1 ± 1.3	0.6	22.0 ± 1.2	**5.1 ± 1.8**
Child in Household								
Child in Family	24.1 ± 3.8	28.8 ± 2.0	-4.7 ± 4.3	28.2 ± 2.2	27.1 ± 1.8	1.1	19.5 ± 1.6	**7.6 ± 2.4**
No Child in Family	21.0 ± 2.5	28.0 ± 1.1	-7.0 ± 2.7	26.6 ± 1.3	25.7 ± 1.1	0.9	20.1 ± 1.1	**5.6 ± 1.6**
Region of Residence								
Northeast	21.5 ± 4.1	28.0 ± 2.1	-6.5 ± 4.7	27.0 ± 2.4	26.1 ± 1.9	0.9	19.7 ± 2.4	**6.4 ± 3.1**
Midwest	20.2 ± 2.9	28.6 ± 1.8	-8.5 ± 3.4	29.0 ± 2.8	26.0 ± 1.5	2.9	20.5 ± 1.9	**5.5 ± 2.4**
South	22.1 ± 3.3	26.4 ± 1.5	-4.3 ± 3.6	25.1 ± 1.6	24.7 ± 1.6	0.4	18.5 ± 1.6	**6.2 ± 2.2**
West	24.1 ± 5.3	30.8 ± 2.8	-6.7 ± 6.0	29.3 ± 3.1	28.4 ± 2.6	0.8	21.4 ± 1.8	**7.1 ± 3.1**
Education Level								
<12 years	24.2 ± 9.0	24.0 ± 3.3	0.1 ± 9.6	24.3 ± 4.0	24.1 ± 4.2	0.1	15.8 ± 2.6	**8.3 ± 5.0**
12 years	19.1 ± 3.8	26.4 ± 2.5	-7.3 ± 4.6	25.1 ± 3.3	23.9 ± 2.1	1.2	16.2 ± 1.5	**7.7 ± 2.6**
Some College	19.9 ± 3.2	25.2 ± 1.8	-5.3 ± 3.7	24.8 ± 2.2	23.3 ± 1.7	1.5	17.6 ± 2.0	**5.7 ± 2.6**
College Graduate	25.1 ± 3.2	33.3 ± 1.6	-8.3 ± 3.5	32.2 ± 1.7	30.8 ± 1.5	1.4	25.1 ± 1.5	**5.7 ± 2.1**
Household Poverty Status								
Below Poverty	19.1 ± 4.9	27.2 ± 4.5	-8.1 ± 6.7	27.3 ± 5.8	23.1 ± 3.4	4.2	17.3 ± 2.7	**5.8 ± 4.4**
Above, Income <$75k	21.6 ± 3.3	27.3 ± 1.4	-5.8 ± 3.6	25.9 ± 1.5	25.3 ± 1.5	0.6	17.9 ± 1.3	**7.4 ± 1.9**
Above, Income ≥$75k	27.0 ± 4.1	32.7 ± 1.9	-5.7 ± 4.5	32.0 ± 2.1	31.2 ± 1.8	0.9	23.8 ± 1.8	**7.3 ± 2.6**
Unknown	20.5 ± 4.1	23.8 ± 2.2	-3.3 ± 4.6	22.5 ± 2.4	22.6 ± 2.0	-0.1	19.7 ± 2.9	3.0 ± 3.5
Own or Rent Dwelling								
Own	23.4 ± 2.9	29.2 ± 1.2	-5.7 ± 3.2	28.4 ± 1.3	27.8 ± 1.1	0.5	21.8 ± 1.1	**6.0 ± 1.6**
Rent	21.4 ± 3.5	26.8 ± 2.8	-5.4 ± 4.5	25.8 ± 3.5	23.7 ± 2.3	2.1	15.7 ± 1.4	**8.1 ± 2.7**
Other Arrangement	13.6 ± 5.1	26.7 ± 6.0	-13.1 ± 7.8	24.8 ± 6.2	20.9 ± 4.2	3.9	17.0 ± 4.6	3.9 ± 6.2
Employment Status								
Employed	22.0 ± 2.6	28.5 ± 1.5	-6.4 ± 3.0	27.4 ± 1.8	25.9 ± 1.4	1.5	18.7 ± 1.1	**7.3 ± 1.8**
Out of Work	17.0 ± 6.7	18.8 ± 3.1	-1.8 ± 7.4	17.7 ± 3.5	18.0 ± 3.5	-0.4	12.6 ± 2.6	**5.5 ± 4.3**
Homemaker	24.4 ± 10.2	29.1 ± 3.7	-4.7 ± 10.8	29.8 ± 4.2	28.0 ± 3.7	1.9	21.5 ± 3.5	**6.5 ± 5.1**
Student	18.4 ± 4.9	26.4 ± 5.8	-8.0 ± 7.6	27.4 ± 6.0	22.4 ± 3.8	5.0	21.8 ± 5.5	0.6 ± 6.7
Retired	37.9 ± 15.2	31.6 ± 1.9	6.3 ± 15.3	31.5 ± 2.0	32.2 ± 2.4	-0.7	25.7 ± 2.4	**6.5 ± 3.3**
Unable to Work	25.3 ± 9.7	30.6 ± 4.1	-5.3 ± 10.5	29.4 ± 4.5	28.8 ± 4.2	0.5	24.1 ± 3.7	4.7 ± 5.6
Health Insurance Status								
Insured	26.4 ± 2.7	30.2 ± 1.1	-3.8 ± 2.9	29.4 ± 1.3	29.0 ± 1.1	0.4	22.2 ± 1.0	**6.9 ± 1.5**
No health insurance	10.3 ± 3.1	16.3 ± 3.1	-6.0 ± 4.4	16.4 ± 4.3	12.9 ± 2.2	3.6	9.5 ± 1.7	**3.4 ± 2.8**
Chronic Medical Condition								
None Identified	20.0 ± 2.0	25.9 ± 1.2	-5.9 ± 2.4	25.2 ± 1.5	23.7 ± 1.1	1.5	16.7 ± 1.0	**7.0 ± 1.5**
Have high-risk condition	32.0 ± 6.3	35.2 ± 1.9	-3.2 ± 6.6	34.1 ± 2.1	34.4 ± 2.3	-0.3	27.6 ± 1.8	**6.8 ± 2.9**
Works in Healthcare Setting								
No	18.9 ± 2.0	26.4 ± 1.1	-7.5 ± 2.3	25.4 ± 1.3	23.9 ± 1.0	1.6	17.9 ± 0.9	**5.9 ± 1.4**
Yes	44.5 ± 8.1	46.7 ± 3.2	-2.2 ± 8.7	46.0 ± 3.6	45.8 ± 3.7	0.2	42.2 ± 3.7	3.6 ± 5.2
Family Telephone Status								
Dual Users, Cell Mostly							18.9 ± 2.3	
Dual Users, Other							23.0 ± 1.4	
Landline Only							19.9 ± 2.5	
Cell Only							15.5 ± 1.5	
Phoneless							18.4 ± 6.7	

Table 4-6 Influenza vaccination coverage – Seasonal – among adults through May 2010, by selected respondent characteristics, January-June 2010 interviews from the National 2009 H1N1 Flu Survey (standalone component) and National Health Interview Survey

Seasonal	NHFS Estimates						NHIS Estimates	Difference, NHFS Total - NHIS
	Cell Only/Mainly (COM)	Landline (L)	Difference, COM-L	Landline Weighted (LLWT)	NHFS Total	Difference		
Characteristic	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**LLWT-Total**	**%, 95% CI**	**%, 95% CI**
All Adults	31.8 ± 1.9	48.9 ± 1.1	-17.1 ± 2.2	44.6 ± 1.2	42.9 ± 1.0	1.7	35.6 ± 1.0	**7.3 ± 1.4**
Age (years)								
18-24	22.8 ± 3.9	29.6 ± 4.2	-6.8 ± 5.7	29.7 ± 4.3	25.9 ± 2.9	3.8	20.2 ± 2.8	**5.6 ± 4.0**
25-29	28.3 ± 4.7	29.8 ± 4.6	-1.6 ± 6.6	28.5 ± 4.5	28.9 ± 3.4	-0.4	20.6 ± 2.6	**8.3 ± 4.3**
30-34	31.9 ± 5.4	36.6 ± 4.3	-4.7 ± 6.9	33.9 ± 4.1	34.3 ± 3.5	-0.4	24.6 ± 2.9	**9.7 ± 4.5**
35-44	27.8 ± 4.1	37.4 ± 2.5	-9.6 ± 4.7	37.3 ± 2.6	33.8 ± 2.2	3.5	26.5 ± 2.1	**7.3 ± 3.1**
45-49	31.5 ± 6.4	38.5 ± 3.0	-7.0 ± 7.1	37.7 ± 3.0	35.9 ± 3.0	1.8	28.4 ± 3.1	**7.5 ± 4.3**
50-54	38.2 ± 8.1	45.9 ± 3.2	-7.7 ± 8.7	45.5 ± 3.6	43.6 ± 3.3	1.9	35.6 ± 3.4	**8.0 ± 4.8**
55-64	49.9 ± 6.4	55.6 ± 2.0	-5.7 ± 6.7	55.3 ± 2.2	54.4 ± 2.1	0.9	46.9 ± 2.5	**7.5 ± 3.3**
≥65	57.3 ± 10.1	72.5 ± 1.8	-15.2 ± 10.2	71.8 ± 1.9	71.3 ± 1.9	0.5	64.9 ± 2.3	**6.4 ± 3.0**
Race/Ethnicity								
Hispanic	23.4 ± 4.6	37.7 ± 4.5	-14.3 ± 6.5	36.1 ± 4.4	29.9 ± 3.3	6.2	25.6 ± 2.2	**4.3 ± 4.0**
Non-Hispanic black only	25.2 ± 5.1	42.6 ± 3.9	-17.4 ± 6.4	39.2 ± 3.8	35.4 ± 3.2	3.8	27.8 ± 2.3	**7.6 ± 4.0**
Non-Hispanic white only	36.0 ± 2.4	51.5 ± 1.1	-15.6 ± 2.7	47.7 ± 1.2	47.1 ± 1.1	0.6	38.8 ± 1.3	**8.3 ± 1.7**
Other / Multiple Race	37.5 ± 6.7	44.1 ± 4.6	-6.6 ± 8.2	40.2 ± 4.5	41.1 ± 4.0	-1.0	38.7 ± 3.8	2.4 ± 5.5
Interview Language								
English	33.9 ± 2.1	49.7 ± 1.1	-15.8 ± 2.3	45.7 ± 1.2	44.5 ± 1.0	1.1	36.5 ± 1.1	**8.0 ± 1.5**
Spanish	17.9 ± 5.8	32.2 ± 7.1	-14.2 ± 9.2	29.6 ± 6.6	23.6 ± 4.5	5.9	21.1 ± 3.6	2.5 ± 5.8
Other	18.2 ± 11.9	38.9 ± 9.6	-20.8 ± 15.3	35.8 ± 9.8	30.3 ± 7.9	5.5	24.5 ± 11.2	5.8 ± 13.7
Sex								
Male	29.1 ± 2.7	46.9 ± 1.7	-17.8 ± 3.2	42.0 ± 1.9	39.9 ± 1.5	2.2	30.6 ± 1.5	**9.3 ± 2.1**
Female	35.3 ± 3.0	51.2 ± 1.4	-15.9 ± 3.3	47.9 ± 1.6	46.6 ± 1.3	1.3	40.3 ± 1.3	**6.3 ± 1.9**
Child in Household								
Child in Family	31.3 ± 3.3	39.8 ± 1.9	-8.5 ± 3.8	37.7 ± 1.9	36.8 ± 1.7	0.9	27.9 ± 1.6	**8.9 ± 2.4**
No Child in Family	32.4 ± 2.5	54.0 ± 1.2	-21.7 ± 2.8	49.5 ± 1.5	46.9 ± 1.2	2.6	40.1 ± 1.4	**6.8 ± 1.8**
Region of Residence								
Northeast	31.4 ± 4.4	50.6 ± 2.6	-19.2 ± 5.1	46.4 ± 2.8	44.9 ± 2.3	1.5	37.5 ± 2.7	**7.4 ± 3.6**
Midwest	31.9 ± 3.5	49.3 ± 1.8	-17.4 ± 4.0	45.1 ± 2.1	44.0 ± 1.7	1.2	39.1 ± 2.2	**4.8 ± 2.8**
South	32.5 ± 3.1	49.6 ± 1.6	-17.1 ± 3.5	45.4 ± 1.9	42.7 ± 1.6	2.7	35.2 ± 1.6	**7.5 ± 2.2**
West	30.9 ± 4.7	46.1 ± 2.7	-15.2 ± 5.4	41.4 ± 2.9	40.8 ± 2.4	0.6	31.3 ± 2.1	**9.5 ± 3.2**
Education Level								
<12 years	24.4 ± 6.0	42.6 ± 3.7	-18.2 ± 7.0	38.3 ± 4.2	35.3 ± 3.4	3.0	31.1 ± 2.6	**4.2** ± 4.2
12 years	27.3 ± 4.0	46.7 ± 2.2	-19.4 ± 4.6	41.4 ± 2.6	40.0 ± 2.1	1.5	32.5 ± 1.7	**7.5 ± 2.7**
Some College	31.6 ± 3.5	46.6 ± 2.2	-15.0 ± 4.1	42.3 ± 2.3	41.2 ± 1.9	1.1	30.8 ± 2.2	**10.4 ± 2.9**
College Graduate	38.7 ± 3.3	54.1 ± 1.6	-15.5 ± 3.7	51.0 ± 1.8	49.4 ± 1.5	1.6	42.1 ± 1.7	**7.3 ± 2.3**
Household Poverty Status								
Below Poverty	24.5 ± 4.5	37.0 ± 3.6	-12.4 ± 5.8	32.0 ± 3.7	30.7 ± 2.9	1.3	23.6 ± 2.4	**7.1 ± 3.8**
Above, Income <$75k	31.1 ± 2.7	50.6 ± 1.6	-19.5 ± 3.2	46.2 ± 1.8	43.9 ± 1.4	2.3	34.8 ± 1.4	**9.1 ± 2.0**
Above, Income ≥$75k	41.8 ± 4.3	51.4 ± 1.9	-9.7 ± 4.7	48.7 ± 2.1	48.8 ± 1.8	-0.1	40.9 ± 1.8	**7.8 ± 2.6**
Unknown	29.4 ± 4.9	47.0 ± 2.5	-17.5 ± 5.5	42.4 ± 2.7	40.9 ± 2.4	1.5	37.9 ± 3.2	2.9 ± 4.0
Own or Rent Dwelling								
Own	37.0 ± 2.9	51.9 ± 1.2	-14.9 ± 3.2	48.2 ± 1.4	48.3 ± 1.2	-0.1	40.0 ± 1.3	**8.3 ± 1.8**
Rent	26.8 ± 2.9	38.6 ± 2.6	-11.7 ± 4.0	34.7 ± 2.9	31.8 ± 2.0	2.8	25.8 ± 1.6	**6.1 ± 2.6**
Other Arrangement	27.1 ± 8.0	43.2 ± 6.9	-16.1 ± 10.5	37.4 ± 7.2	36.0 ± 5.4	1.5	34.1 ± 6.1	1.9 ± 8.2
Employment Status								
Employed	32.0 ± 2.4	44.2 ± 1.4	-12.2 ± 2.8	41.6 ± 1.6	39.4 ± 1.3	2.1	31.6 ± 1.4	**7.9 ± 1.9**
Out of Work	23.9 ± 6.4	29.3 ± 3.7	-5.4 ± 7.4	25.4 ± 3.8	26.9 ± 3.6	-1.5	18.5 ± 3.1	**8.3 ± 4.7**
Homemaker	28.0 ± 9.3	49.4 ± 3.9	-21.5 ± 10.1	45.1 ± 4.4	44.3 ± 3.9	0.8	30.4 ± 4.2	**13.9 ± 5.7**
Student	25.1 ± 5.7	31.3 ± 5.9	-6.2 ± 8.2	33.4 ± 6.3	28.2 ± 4.1	5.2	25.6 ± 5.9	2.6 ± 7.2
Retired	64.6 ± 10.4	69.6 ± 1.9	-5.0 ± 10.6	68.7 ± 2.0	69.1 ± 2.0	-0.4	63.0 ± 2.6	**6.1 ± 3.3**
Unable to Work	37.8 ± 9.0	54.9 ± 4.8	-17.1 ± 10.2	50.8 ± 5.5	49.3 ± 4.5	1.5	41.9 ± 3.9	**7.4 ± 5.9**
Health Insurance Status								
Insured	38.4 ± 2.5	52.7 ± 1.2	-14.3 ± 2.7	49.3 ± 1.4	48.5 ± 1.1	0.8	40.6 ± 1.2	**7.8 ± 1.6**
No health insurance	15.0 ± 3.4	19.9 ± 2.7	-4.9 ± 4.3	18.2 ± 2.8	17.1 ± 2.2	1.1	13.2 ± 1.7	**3.9 ± 2.8**
Chronic Medical Condition								
None Identified	29.5 ± 2.2	44.1 ± 1.3	-14.6 ± 2.6	40.2 ± 1.4	38.7 ± 1.2	1.6	29.5 ± 1.2	**9.2 ± 1.7**
Have high-risk condition	43.0 ± 4.7	61.5 ± 1.9	-18.6 ± 5.1	57.6 ± 2.3	56.5 ± 2.0	1.1	50.5 ± 2.0	**6.0 ± 2.8**
Works in Healthcare Setting								
No	29.0 ± 2.1	47.2 ± 1.1	-18.2 ± 2.4	42.9 ± 1.3	41.0 ± 1.1	1.9	33.7 ± 1.1	**7.3 ± 1.5**
Yes	53.0 ± 5.9	64.4 ± 3.1	-11.4 ± 6.7	61.1 ± 3.6	59.9 ± 3.1	1.2	58.6 ± 3.7	1.2 ± 4.8
Family Telephone Status								
Dual Users, Cell Mostly							31.1 ± 2.3	
Dual Users, Other							43.4 ± 1.6	
Landline Only							41.3 ± 3.0	
Cell Only							23.9 ± 1.7	
Phoneless							30.6 ± 8.9	

Table 4-7 Influenza vaccination coverage – pH1N1 – among children through May 2010, by selected respondent characteristics, January-June 2010 interviews from the National 2009 H1N1 Flu Survey (standalone component) and National Health Interview Survey

pH1N1	NHFS Estimates						NHIS Estimates	Difference, NHFS Total - NHIS
	Cell Only/Mainly (COM)	Landline (L)	Difference, COM-L	Landline Weighted (LLWT)	NHFS Total	Difference		
Characteristic	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**LLWT-Total**	**%, 95% CI**	**%, 95% CI**
All Children	42.0 ± 4.1	44.2 ± 2.1	-2.2 ± 4.6	44.3 ± 2.2	43.4 ± 2.0	0.9	34.7 ± 1.9	**8.7 ± 2.8**
Age in November 2009								
6-23 months	51.3 ± 9.7	44.0 ± 6.3	7.3 ± 11.5	44.6 ± 6.5	47.2 ± 5.5	-2.6	39.0 ± 7.3	8.2 ± 9.2
2-4 years	47.2 ± 8.0	48.5 ± 4.9	-1.4 ± 9.4	48.5 ± 4.9	48.0 ± 4.3	0.5	38.9 ± 3.9	**9.1 ± 5.8**
5-12 years	41.9 ± 6.6	46.8 ± 3.4	-4.8 ± 7.4	46.8 ± 3.4	45.2 ± 3.1	1.6	36.4 ± 2.9	**8.8 ± 4.3**
13-17 years	30.6 ± 9.0	35.7 ± 3.8	-5.1 ± 9.7	35.3 ± 3.7	33.9 ± 3.9	1.4	26.7 ± 3.1	**7.2 ± 5.0**
Race/Ethnicity								
Hispanic	56.3 ± 8.9	51.0 ± 6.3	5.3 ± 10.9	51.1 ± 6.0	53.7 ± 5.5	-2.6	33.0 ± 3.1	**20.7 ± 6.3**
Non-Hispanic black only	28.5 ± 10.5	34.0 ± 7.2	-5.5 ± 12.8	33.6 ± 6.5	31.7 ± 6.0	1.8	29.1 ± 4.0	2.6 ± 7.2
Non-Hispanic white only	38.2 ± 5.0	44.1 ± 2.5	-5.9 ± 5.6	43.6 ± 2.5	42.4 ± 2.3	1.2	34.4 ± 2.8	**8.0 ± 3.6**
Other / Multiple Race	38.2 ± 11.8	47.4 ± 7.0	-9.2 ± 13.7	48.2 ± 6.9	44.0 ± 6.3	4.2	50.3 ± 8.3	-6.3 ± 10.4
Interview Language								
English	40.0 ± 4.4	43.3 ± 2.2	-3.3 ± 4.9	43.2 ± 2.2	42.2 ± 2.1	1.0	34.4 ± 2.0	**7.7 ± 2.9**
Spanish	59.0 ± 12.5	54.8 ± 11.0	4.2 ± 16.7	54.3 ± 10.6	56.8 ± 8.3	-2.6	37.3 ± 6.0	**19.5 ± 10.2**
Other	36.3 ± 28.7	56.3 ± 17.2	-20.0 ± 33.4	58.5 ± 16.6	49.5 ± 16.0	9.1	37.6 ± 16.6	11.8 ± 23.0
Sex								
Male	40.0 ± 5.3	41.9 ± 2.9	-1.9 ± 6.1	42.1 ± 2.9	41.3 ± 2.7	0.8	33.4 ± 2.7	**7.9 ± 3.8**
Female	44.0 ± 6.4	46.6 ± 3.1	-2.6 ± 7.1	46.7 ± 3.2	45.6 ± 3.0	1.1	36.1 ± 2.6	**9.6 ± 4.0**
Region of Residence								
Northeast	44.5 ± 10.1	55.7 ± 5.3	-11.3 ± 11.4	54.0 ± 5.2	53.1 ± 4.8	0.9	38.9 ± 4.7	**14.2 ± 6.8**
Midwest	40.5 ± 7.8	43.5 ± 3.6	-3.0 ± 8.6	43.6 ± 3.7	42.4 ± 3.6	1.2	35.7 ± 3.9	**6.8 ± 5.3**
South	40.7 ± 6.5	38.9 ± 3.2	1.8 ± 7.3	39.3 ± 3.4	39.5 ± 3.2	-0.3	31.8 ± 2.9	**7.7 ± 4.3**
West	45.3 ± 9.7	42.5 ± 5.0	2.7 ± 10.9	45.1 ± 5.2	43.4 ± 4.7	1.8	35.4 ± 4.5	**8.0 ± 6.5**
Household Poverty Status								
Below Poverty	48.2 ± 9.2	46.1 ± 7.3	2.2 ± 11.7	45.8 ± 6.7	46.9 ± 5.9	-1.0	37.9 ± 3.3	**9.0 ± 6.7**
Above, Income <$75k	38.6 ± 6.3	40.4 ± 3.3	-1.9 ± 7.1	40.9 ± 3.6	39.7 ± 3.1	1.1	30.7 ± 2.7	**9.1 ± 4.1**
Above, Income ≥$75k	41.0 ± 7.7	47.5 ± 3.2	-6.6 ± 8.3	47.5 ± 3.2	45.9 ± 3.1	1.6	39.5 ± 5.2	**6.5 ± 6.1**
Unknown	40.9 ± 11.1	41.4 ± 6.4	-0.4 ± 12.8	41.8 ± 6.6	41.2 ± 5.7	0.6	26.9 ± 6.8	**14.3 ± 8.9**
Own or Rent Dwelling								
Own	42.9 ± 5.8	44.4 ± 2.3	-1.5 ± 6.2	44.5 ± 2.4	44.0 ± 2.3	0.5	35.8 ± 2.5	**8.2 ± 3.4**
Rent	41.9 ± 6.6	43.0 ± 5.8	-1.2 ± 8.8	43.8 ± 5.6	42.4 ± 4.5	1.4	33.0 ± 2.9	**9.5 ± 5.3**
Other Arrangement	40.5 ± 19.7	44.1 ± 13.3	-3.5 ± 23.8	41.6 ± 12.6	42.4 ± 12.3	-0.8	28.2 ± 13.6	14.1 ± 18.3
Health Insurance Status								
No Insurance	28.2 ± 13.6	31.1 ± 9.1	-2.9 ± 16.4	31.9 ± 9.0	29.5 ± 8.6	2.4	26.5 ± 9.2	3.0 ± 12.6
Medicaid / SCHIP	48.5 ± 7.6	43.9 ± 5.3	4.6 ± 9.3	45.2 ± 5.3	46.0 ± 4.5	-0.7	37.2 ± 3.1	**8.7** ± 5.5
Private / Other Insurance	40.0 ± 5.3	44.7 ± 2.6	-4.7 ± 5.9	44.5 ± 2.6	43.4 ± 2.4	1.1	34.4 ± 2.4	**9.0 ± 3.4**
Chronic Medical Condition								
None Identified	41.6 ± 4.4	43.8 ± 2.3	-2.2 ± 5.0	43.8 ± 2.4	43.0 ± 2.2	0.9	33.8 ± 2.1	**9.2 ± 3.0**
Have high-risk condition	49.4 ± 14.1	45.6 ± 5.7	3.7 ± 15.2	46.1 ± 5.8	46.5 ± 5.7	-0.4	41.9 ± 5.1	4.5 ± 7.6
Family Telephone Status								
Dual Users, Cell Mostly							31.3 ± 3.7	
Dual Users, Other							40.6 ± 3.3	
Landline Only							41.1 ± 7.1	
Cell Only							28.1 ± 2.9	
Phoneless							28.1 ± 14.9	

Table 4-8 Influenza vaccination coverage – Seasonal – among children through May 2010, by selected respondent characteristics, January-June 2010 interviews from the National 2009 H1N1 Flu Survey (standalone component) and National Health Interview Survey

Seasonal	NHFS Estimates						NHIS Estimates	Difference, NHFS Total - NHIS
	Cell Only/Mainly (COM)	Landline (L)	Difference, COM-L	Landline Weighted (LLWT)	NHFS Total	Difference		
Characteristic	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**%, 95% CI**	**LLWT-Total**	**%, 95% CI**	**%, 95% CI**
All Children	45.3 ± 4.2	48.0 ± 2.2	-2.7 ± 4.7	48.0 ± 2.2	47.1 ± 2.0	1.0	40.6 ± 2.0	**6.5 ± 2.8**
Age in November 2009								
6-23 months	56.4 ± 9.2	59.0 ± 6.0	-2.6 ± 11.0	59.0 ± 6.1	57.9 ± 5.2	1.0	52.8 ± 6.7	5.1 ± 8.5
2-4 years	61.6 ± 8.2	63.1 ± 4.3	-1.5 ± 9.3	61.9 ± 4.5	62.5 ± 4.2	-0.6	53.6 ± 5.0	**8.8 ± 6.5**
5-12 years	37.5 ± 5.9	46.0 ± 3.5	-8.5 ± 6.9	46.1 ± 3.6	43.2 ± 3.1	2.9	37.9 ± 2.6	**5.3 ± 4.0**
13-17 years	37.2 ± 10.3	35.2 ± 3.6	2.0 ± 10.9	34.6 ± 3.5	35.9 ± 4.3	-1.4	29.6 ± 3.1	**6.3 ± 5.3**
Race/Ethnicity								
Hispanic	54.6 ± 10.0	48.7 ± 6.9	5.9 ± 12.1	48.0 ± 6.4	51.6 ± 6.0	-3.6	41.9 ± 3.4	**9.7 ± 6.9**
Non-Hispanic black only	33.9 ± 11.8	45.0 ± 7.8	-11.1 ± 14.2	43.8 ± 7.0	40.7 ± 6.7	3.0	38.8 ± 4.6	1.9 ± 8.1
Non-Hispanic white only	41.9 ± 4.7	47.9 ± 2.3	-6.0 ± 5.3	48.1 ± 2.3	46.1 ± 2.1	2.0	39.1 ± 2.8	**7.1 ± 3.5**
Other / Multiple Race	53.0 ± 12.7	53.0 ± 7.3	0.0 ± 14.6	54.3 ± 7.1	52.8 ± 6.5	1.5	49.4 ± 8.4	3.4 ± 10.6
Interview Language								
English	43.9 ± 4.4	47.9 ± 2.1	-4.0 ± 4.9	48.1 ± 2.1	46.5 ± 2.0	1.6	40.1 ± 2.1	**6.4 ± 2.9**
Spanish	58.8 ± 14.4	47.2 ± 13.0	11.6 ± 19.4	44.3 ± 12.2	52.6 ± 9.6	-8.3	45.0 ± 6.4	7.6 ± 11.6
Other	43.1 ± 31.9	54.8 ± 19.8	-11.7 ± 37.5	60.8 ± 18.4	50.2 ± 17.3	10.6	42.4 ± 26.4	7.7 ± 31.6
Sex								
Male	49.4 ± 5.9	45.8 ± 3.0	3.6 ± 6.6	46.4 ± 2.9	47.1 ± 2.8	-0.6	39.1 ± 2.8	**8.0 ± 4.0**
Female	41.0 ± 5.8	50.6 ± 3.1	-9.6 ± 6.6	50.0 ± 3.3	47.2 ± 2.9	2.8	42.2 ± 2.7	**5.0 ± 4.0**
Region of Residence								
Northeast	51.2 ± 11.3	56.5 ± 4.9	-5.3 ± 12.3	55.6 ± 4.9	55.2 ± 4.7	0.4	45.9 ± 4.6	**9.3 ± 6.6**
Midwest	42.7 ± 7.9	43.5 ± 3.5	-0.8 ± 8.7	43.8 ± 3.6	43.3 ± 3.7	0.5	39.3 ± 3.4	4.0 ± 5.0
South	44.8 ± 6.1	46.2 ± 3.3	-1.4 ± 6.9	46.2 ± 3.4	45.6 ± 3.1	0.6	39.8 ± 3.3	**5.9 ± 4.6**
West	46.0 ± 10.5	47.7 ± 5.4	-1.8 ± 11.8	49.0 ± 5.6	47.1 ± 5.0	1.9	39.7 ± 4.6	**7.5 ± 6.8**
Household Poverty Status								
Below Poverty	47.1 ± 9.8	49.6 ± 7.1	-2.5 ± 12.1	48.7 ± 6.6	48.4 ± 6.2	0.3	46.0 ± 3.3	2.4 ± 7.0
Above, Income <$75k	43.5 ± 5.8	43.2 ± 3.4	0.2 ± 6.7	43.0 ± 3.7	43.3 ± 3.1	-0.4	36.0 ± 2.8	**7.3 ± 4.1**
Above, Income ≥$75k	46.2 ± 7.8	52.3 ± 3.2	-6.1 ± 8.4	53.2 ± 3.2	50.8 ± 3.1	2.4	42.6 ± 5.2	**8.2 ± 6.0**
Unknown	43.0 ± 10.9	45.7 ± 6.3	-2.7 ± 12.6	45.6 ± 6.3	44.8 ± 5.7	0.8	36.4 ± 6.9	8.5 ± 8.9
Own or Rent Dwelling								
Own	45.3 ± 6.0	47.4 ± 2.2	-2.1 ± 6.4	47.4 ± 2.3	46.8 ± 2.2	0.5	41.6 ± 2.4	**5.2 ± 3.3**
Rent	46.8 ± 6.8	49.9 ± 6.1	-3.1 ± 9.1	49.5 ± 6.1	48.3 ± 4.7	1.1	38.7 ± 3.3	**9.6 ± 5.7**
Other Arrangement	35.3 ± 18.1	37.2 ± 12.4	-2.0 ± 22.0	35.9 ± 12.1	36.3 ± 11.0	-0.4	42.6 ± 14.8	-6.3 ± 18.5
Health Insurance Status								
No Insurance	36.7 ± 16.5	27.6 ± 8.8	9.2 ± 18.7	28.3 ± 8.7	32.6 ± 9.9	-4.2	26.3 ± 8.9	6.3 ± 13.3
Medicaid / SCHIP	45.3 ± 7.4	49.8 ± 5.5	-4.5 ± 9.2	48.7 ± 5.6	47.7 ± 4.5	0.9	43.0 ± 3.6	4.7 ± 5.8
Private / Other Insurance	47.3 ± 5.6	49.2 ± 2.5	-1.9 ± 6.1	49.7 ± 2.5	48.7 ± 2.4	1.0	41.3 ± 2.5	**7.4 ± 3.4**
Chronic Medical Condition								
None Identified	44.2 ± 4.5	45.9 ± 2.3	-1.8 ± 5.1	45.9 ± 2.4	45.3 ± 2.2	0.6	39.3 ± 2.1	**6.0 ± 3.0**
Have high-risk condition	57.5 ± 12.1	61.1 ± 6.0	-3.6 ± 13.6	60.5 ± 6.0	60.0 ± 5.7	0.5	51.4 ± 5.4	**8.6 ± 7.8**
Family Telephone Status								
Dual Users, Cell Mostly							36.6 ± 3.8	
Dual Users, Other							44.8 ± 3.1	
Landline Only							46.4 ± 7.9	
Cell Only							38.1 ± 3.7	
Phoneless							20.6 ± 9.7	

APPENDIX 4.1

Undercoverage Bias

In a target population split into two subpopulations (e.g., persons living in households with landline telephone service and those living in houses with only telephone service), the prevalence of an outcome Y (e.g. proportion of persons vaccinated during an influenza season) can be expressed as a weighted average of the prevalence in the two subgroups: $Y = w*Y_1 + (1-w)*Y_2$, where w=proportion of population in subgroup 1. If the 1st subgroup is intended to represent the entire population with prevalence Y_1, then the bias of this estimate is $Y_1 – Y = (1-w)*(Y_1 – Y_2)$. This is a common expression used to represent undercoverage bias of a landline telephone survey. In the target population, this indicates that undercoverage bias will tend to increase as the prevalence of the excluded population increases, or as the difference in outcome prevalence between included and excluded population subgroups increases. In practice, surveys have been conducted using landline and cell phone samples, and undercoverage bias estimated based on outcome prevalence estimated from the achieved sample respondents. However, these samples are subject to nonresponse bias that may remain after weighting adjustments, and nonresponse bias may be different between landline and cell samples. Thus, sample estimates of undercoverage bias may be biased estimates of undercoverage bias in the target population. If we assume the expected values of the sample outcome prevalences for landline (y_1) and cell respondents (y_2) are $Y_1 + B_1$ and $Y_2 + B_2$, respectively, then the expected value of the difference in outcome prevalence $(y_1 – y_2) = (Y_1 – Y_2) – (B_1 – B_2)$, and B_1 must equal B_2 for the sample difference to be an unbiased estimate of difference in the target population.

Chapter 5 VALIDITY OF PARENTAL REPORT OF 2009-10 INFLUENZA VACCINATION IN YOUNG CHILDREN IN A POPULATION-BASED NATIONAL SURVEY

ABSTRACT

Accurate determination of influenza vaccination status is needed for public health surveillance, evaluation of seasonal and pandemic vaccination programs, research on influenza vaccination safety and effectiveness, and in clinical settings to avoid extra-vaccination and missed opportunities for vaccination. To monitor the 2009-10 vaccination campaign in response to the influenza A(H1N1)pdm09 (pH1N1) pandemic, the Centers for Disease Control and Prevention (CDC) used surveys that relied on parental report of children's influenza vaccination status. This study assesses the validity of household report of children's pH1N1 and seasonal influenza vaccination during October 2009 through June 2010, using data from the National Immunization Survey (NIS).

The NIS is a national, state-stratified survey of vaccinations received by children aged 19-35 months, consisting of a random-digit-dialed telephone survey of parents or guardians. Mailed questionnaires are used to collect vaccination histories from medical records of providers identified by parents. Household reported influenza vaccination status was compared to provider reported status (≥1 or ≥2 doses in the prior 12 months for seasonal and since October 2009 for pH1N1) as the gold standard to estimate sensitivity, specificity, and net bias (household reported minus provider reported vaccination prevalence). Results were stratified by whether household respondents had a vaccination record (shot card) available to supplement the caregiver's memory (shot card group, n=3,813), or not (recall only group, n=9,086).

Percentage point differences for prevalence of household minus provider reported receipt of at least one influenza vaccination during the reference period (net bias) were -0.6 for the seasonal shot card group, 5.3 for the seasonal shot card group, 7.1 for the pH1N1 shot card group,

and 11.5 for the pH1N1 recall only groups. Estimates of sensitivity and specificity for these groups were 81.5% and 80.1% (seasonal shot card), 80.2% and 70.1% (seasonal recall only), 85.0% and 86.2% (pH1N1 shot card), and 93.2% and 82.8% (pH1N1 recall only). Household reported vaccination with ≥2 doses had lower sensitivity and higher specificity compared to reported receipt of at least one dose. Estimated sensitivity decreased as time from month of vaccination to interview increased.

Parental report of children's influenza vaccination status during the 2009-10 season when both seasonal and pandemic vaccines were recommended was fairly accurate, but tended to overestimate vaccination prevalence as measured by provider report. Continued evaluation for possible changes in validity of parental report of children's vaccinations over time or differential validity among key population subgroups is needed to interpret estimates from ongoing surveys that rely on parental report.

INTRODUCTION

Influenza vaccination has been recommended by the Advisory Committee on Immunization Practices (ACIP) in the United States since 2004 for all children age 6-23 months (101), since 2006 for all children age 6-59 months (102), and since 2008 for all children 6 months-18 years (103). During the 2009-10 influenza season, a monovalent influenza vaccine to protect against the influenza A(H1N1)pdm09 (pH1N1) virus was developed and recommended (4), along with the usual trivalent seasonal influenza vaccine (5). For children under ten years of age, two doses of pH1N1 vaccine were recommended. To monitor and evaluate the 2009-10 influenza vaccination campaign, the Centers for Disease Control and Prevention (CDC) utilized surveys of that relied on parental report of their child's influenza vaccination status (98).

Accurate determination of influenza vaccination status is needed for public health surveillance, evaluation of seasonal and pandemic vaccination programs, research on influenza vaccination safety and effectiveness, and in clinical settings to avoid extra-vaccination and

missed opportunities for vaccination. One previous study has evaluated the validity of parental report of both 2009-10 seasonal and pH1N1 influenza vaccination of children, finding sensitivity of 92% for seasonal and 88% for pH1N1 vaccination, and specificity of 86% for seasonal and 92% for pH1N1 vaccination (100). This study was based on 297 children whose parents were prospectively recruited when they brought their children with fever or respiratory symptoms to emergency departments or a regional pediatric hospital in one county, and is not directly applicable to evaluating misclassification bias of parental-reported influenza vaccination status collected via national and state-specific surveys of the general population.

Other validity studies of parental-reported influenza vaccination of children have been reported for prior seasons (2002-03 through 2007-08), with sensitivity ranging from 85-92% and specificity ranging from 66-92% (61-63, 65, 104); these studies all used clinic-based recruitment. One previous study used the National Immunization Survey (NIS), which includes a telephone survey of parents followed by a mailed provider survey to collect the child's vaccination history, reporting sensitivity of 86% and specificity of 81% for the 2003-04 influenza season for children 6-23 months (64). A previous study compared parental and provider report of 2008-09 season influenza vaccination among adolescents age 13-17 years using the NIS-Teen data, reporting sensitivity of 87-91% and specificity of 86-93%, depending on assumptions made about the completeness of provider reporting of influenza vaccination status (105).

Further data on validity of parental report of influenza vaccination in children are needed, particularly for the 2009-10 season when a pandemic vaccination was recommended in addition to the usual seasonal influenza vaccination. Using data from the NIS, we assessed the validity of household report of children's pH1N1 and seasonal influenza vaccination during October 2009 through June 2010. We also compared the joint distribution of pH1N1 and seasonal vaccination status, month of vaccination, and type of influenza vaccination (injected inactivated and nasally-administered live-attenuated) between household and provider report, and evaluated associations of validity with sociodemographic factors.

METHODS

DATA SOURCE –THE NATIONAL IMMUNIZATION SURVEY (NIS)

The NIS is a list-assisted random digit dialed (RDD) telephone survey of households with children aged 19-35 months followed by a mail survey of providers identified during the household interview to obtain vaccination histories (68). The target population for the NIS is children aged 19-35 months living in households in the United States at the time of the interview. The data used for this study was conducted when the NIS sample frame was restricted to landline telephones. Interviews about age-eligible children in the household are conducted with the adult who is most knowledgeable about the child's vaccinations. A survey to collect the child's vaccination histories is mailed to the child's health care providers who are identified during the interview, if the parent or guardian gives consent for this follow-up.

Because pH1N1 vaccination was not available until October 2009, this study used interview data collected for the three calendar quarters from October 2009 through June 2010, with interviews conducted October 1, 2009 through August 18, 2010 and adequate provider obtained for 12,899 children. Thirty-eight children without provider data were excluded because parents stated their child had not received any vaccinations and did not report any medical providers. Of the 12,899 children included in the analysis, the distribution by provider response category was: 8,292 had a single provider identified by the parent or guardian and that provider returned valid vaccination data; 3,913 had multiple providers identified and all returned valid vaccination data; and 694 had multiple providers identified and some but not all returned valid vaccination data. All 694 of these children were determined to have adequate provider data as determined by being up-to-date with DTaP, MMR, Hib and Hepatitis B vaccinations based on the information from the providers that did report, or the vaccination data from providers that did report matched the parent's shot card data or the numbers of vaccinations reported by memory.

The age of children as of November 1, 2009 included in the analysis ranged from 10-37 months. November 1, 2009 is used as the reference date for calculation of age because this date represents approximately the middle of the usual influenza vaccination period.

Data analyses were conducted using SAS version 9.2 for data management, and SAS-callable SUDAAN release 10.0.1 for statistical analyses (Crosstab and Multilog procedures) to account for survey weighting and complex survey design (70). Weights were constructed for the quarter 4 2009 through quarter 2 2010 sample, with adjustments for probability of selection, non-response and post-stratification adjustments made separately for the household and provider phases. Additional details about the NIS are included in Chapter 2.

DETERMINATION OF HOUSEHOLD REPORTED INFLUENZA VACCINATION STATUS

NIS telephone interviews are conducted with a computer-assisted telephone interview (CATI) questionnaire in English or Spanish, and Language Line Services are used for real-time translation into many other languages. The interview consists of a screener to identify eligible children age 19-35 months in the household and choose as the respondent the adult most knowledgeable about the child's vaccination history. Of the 12,899 children included in this study, 77.7% of respondents were the child's mother, 15.0% the father, and the remaining 7.3% were grandparents or other adults. The respondent was asked if they have a written record of the child's vaccination history (shot card), and if available, were asked to report information directly from it in Section A of the interview. For influenza, this included the date of vaccination, whether it was administered as a "shot" (inactivated influenza vaccine, or TIV) or "spray" (live-attenuated, intranasally administered influenza vaccine, or LAIV), and whether it was seasonal or the "novel 2009 H1N1, swine, or pandemic" flu vaccine. Section A respondents were also asked if the child had received any influenza vaccinations in the past 12 months not recorded on the shot card, and if so, the respondent was asked, "Since this past September, how many times did <child> receive an H1N1 or swine flu vaccine that is NOT listed on the shot record?" and "Has

<child> received a seasonal flu vaccine in the past twelve months that is NOT listed on the shot record?" For each such vaccination recalled by the respondent, additional questions asked for the month and year the child received the vaccination and type (shot or spray).

Respondents who did not have or access a shot card for the interview were skipped to Section B of the interview and asked to recall their child's vaccinations. For influenza, respondents were asked, "Since this past September, has <child> had an H1N1 flu vaccination, shot or spray? ", and if yes, how many, for each one, the month and year received and type (shot or spray). Respondents were then asked about seasonal influenza vaccination: "During the past 12 months has <child> had a seasonal flu shot?" and "During the past 12 months, has <child> had a seasonal flu vaccine sprayed in <his/her> nose by a doctor or other health professional?" For each vaccination reported the respondent was asked for the month and year the child received it. For this study, 3,813 children had shot cards available during the interview (shot card group) and 9,086 did not (recall only group). The remaining sections of the interview asked for sociodemographic information about the household, the child's mother and the child, a section asking for information and consent to contact the child's vaccination providers, and questions about the child's health insurance status.

The vaccination periods for this study were defined as October 2009 through the earlier of June 2010 or date of interview for pH1N1 and during the 12 months prior to the interview for seasonal influenza vaccination. Vaccinations reported from shot cards with reported dates falling in these vaccination periods were considered valid. For vaccinations reported by recall, influenza vaccination status was set as vaccinated if there was an affirmative response to questions about receiving at least one influenza vaccination in the past 12 months for seasonal and since September 2009 for pH1N1. Persons with "missing", "don't know" or "refused" responses to these questions were considered not vaccinated: 3.9% (n=511) for seasonal and 1.7% (n=216) for pH1N1. Status of receiving two or more pH1N1 and two or more seasonal influenza vaccinations during the vaccination period was also determined. For the shot card group, receipt of a valid

influenza vaccination was determined separately from the shot card and from recall of influenza vaccinations not included on the shot card, and then a combined overall status from both shot card and recall was determined (e.g., a child was considered vaccinated if indicated by either the shot card or from recall of a vaccination not on the shot card). Among the shot card group, 2,125 children were determined by respondent report to be vaccinated for seasonal influenza, of whom 1,353 had at least one valid seasonal influenza vaccination reported from a shot card. Also in the shot card group, 1,317 children were determined by respondent report as vaccinated for pH1N1, of which 535 had at least one valid pH1N1 influenza vaccination reported from the shot card.

DETERMINATION OF PROVIDER REPORTED VACCINATION STATUS

During the provider section of the interview, the respondent was asked for the names, addresses and telephone numbers of any health care providers who may have vaccinated their children, and for the full name of their child. When oral consent was obtained for the respondent and sufficient identifying information obtained, an immunization history questionnaire was mailed to the providers. This questionnaire included a "shot grid" to record the dates and types of each influenza vaccination the provider had record of. If multiple providers reported for a child, the influenza vaccinations were consolidated into one synthesized vaccination record. Reported influenza vaccinations with dates of administration falling in the vaccination periods defined in the previous section were considered valid for this analysis.

DEFINITION OF VALIDITY PARAMETERS

The primary measures of validity used in this study were sensitivity and specificity of parental reported influenza vaccination status as compared to provider reported status (see Appendix 5.1). The values of 1-sensitivity and 1-specificity can be viewed as the conditional rate of parental underreporting (false negative) given provider report of vaccination and conditional rate of parental overreporting (false positive) given provider report of non-vaccination,

respectively. Positive (PPV) and negative (NPV) predictive values were also estimated. To gauge the impact of parental misclassification of child's vaccination status on estimates of influenza vaccination coverage, the difference between the proportion of children with household reported influenza vaccination and proportion with provider reported influenza vaccination was calculated (net bias). Appendix 5.1 shows how net bias, positive predictive value and negative predictive value can be expressed as functions of actual prevalence of vaccination (measured in this study by provider reports), sensitivity and specificity.

Many studies of validity of self or parental reported vaccination status also report the Kappa statistic (106) as an overall measure of agreement with medical records. However, Kappa statistics are not reported for this study as they do not provide meaningful interpretation in terms of implications of the two types of misclassification of parental reported influenza vaccination status for surveillance, research or clinical practice.

PRIMARY VALIDITY ANALYSIS

The characteristics of the study population were described overall and stratified by shot card status (shot card or recall only). Characteristics compared included: month of interview, relationship of the household interview respondent to the child, language the interview was conducted in, Census region, metropolitan statistical area (MSA) status, household poverty status, housing tenure (rent or own), number of children aged <18 years in the household, mother's age, mother's race/ethnicity, mother's level of education, mother's marital status, mobility (current residence different from residence when child was born), child's sex, child's age as of November 1, 2009, child's health insurance status, provider response category, and provider facility type.

Validity parameters were estimated for receipt of one or more and two or more pH1N1 and seasonal influenza vaccinations, stratified by shot card status (shot card group, recall only group) and month of interview. To identify potential factors independently associated with sensitivity and specificity, four separate logistic regression models were constructed for receipt of

one or more pH1N1 and one or more seasonal influenza vaccinations, by shot card status. These analyses were restricted to children with a parent as the respondent. To model sensitivity and specificity, parental-reported influenza vaccination status was the outcome variable, and provider reported influenza vaccination status as an independent variable. With this model, the predicted probabilities of household reported vaccination when provider report indicates that the child had been vaccinated estimates sensitivity, while the predicted probability when provider report does not provide evidence of vaccination estimates 1-specificity.

Potential factors were chosen for inclusion in the model based on plausibility that a factor may be causally related to validity of parental report, a factor for which vaccination coverage estimates is typically stratified by, or a factor identified as associated with validity of parental reported influenzas vaccination from prior published studies. These included interview month, relationship of the household interview respondent to the child (mother or father), household poverty status, number of children aged <18 years in the household, mother's age, mother's race/ethnicity, mother's level of education, mother's marital status, mobility, child's sex, child's age as of November 1, 2009, and child's health insurance status. To allow estimates of sensitivity and specificity to vary by these factors, interaction terms for each of these factors with provider reported vaccination status were included in the model.

The PREDMARG statement in SUDAAN procedure MULTILOG was used to generate predictive marginal estimates of sensitivity and specificity, and prevalence ratios of these validity parameters comparing levels of each factor to a reference level. Further three-way interactions of provider reported vaccination status with two other factors were not considered. No attempt was made to reduce the initial model via backwards elimination, as the goal was not to fit a parsimonious, predictive model but to evaluate the independent associations of plausible factors related to accuracy of household reported vaccination status.

ACCURACY OF JOINT DISTRIBUTION OF HOUSEHOLD REPORTED pH1N1 AND SEASONAL INFLUENZA VACCINATION STATUS

To assess the extent that respondents may have confused pH1N1 and seasonal influenza vaccinations, the joint distribution of pH1N1 and seasonal influenza vaccination status was compared between household and provider report. Analysis was conducted overall and stratified by shot card group.

ACCURACY OF HOUSEHOLD REPORTED MONTH OF VACCINATION

To determine accuracy of household reported month of vaccination, two analyses were conducted. For both analyses, each month from October 2009 through June 2010 was considered a separate vaccination period, and determination made of whether a reported household or provider influenza vaccination was reported as administered in the vaccination month. In the first analysis, each monthly vaccination status indicator for household report was cross-tabulated with each monthly vaccination status indicator for provider report. Results were stratified for pH1N1 and seasonal vaccination. In this analysis, each valid month and year of vaccination from both household and provider reports were considered, so multiple vaccinations for the same child were included in multiple monthly vaccination status indicators if month and year of vaccination differed.

The second analysis was intended to examine if sensitivity and specificity of household reported of child's influenza vaccination status decreased as the number of months from the vaccination period to month of interview increased. For each monthly vaccination period, sensitivity and specificity were estimated from the cross-tabulation of the household and provider monthly vaccination status indicators, stratified by interview month and restricted to interview months that were the same month or later than the monthly vaccination period. Results were stratified by pH1N1 and seasonal influenza vaccination, and by shot card status.

ACCURACY OF HOUSEHOLD REPORTED TYPE OF pH1N1 AND SEASONAL INFLUENZA VACCINATION

To assess accuracy of household reported type of influenza vaccination, valid household and provider vaccinations during the vaccination period were summarized and status over one or more vaccinations classified as having both shot (TIV) and spray (LAIV) vaccinations, shot(s) only, spray vaccine(s) only, or unknown type(s). Analysis was restricted to 5,734 children with both household and provider reported vaccination, and was conducted overall and stratified by shot card group and child's age. Children age two years and older are licensed to receive LAIV. Receipt of LAIV in children under age 2 years by providers could represent receipt of vaccination after November 1 for children turning two years of age by time of vaccination, a reporting error by providers, or off-label use.

COMPLETENESS OF PROVIDER REPORTED INFLUENZA VACCINATIONS

Vaccinations reported on shot cards likely are highly accurate and afford an opportunity to evaluate the completeness of provider reported vaccination status. Among children in the shot card group, those with valid influenza vaccinations reported from the shot card were selected, and the distribution of provider reported influenza vaccination status determined, overall and by provider response category.

To evaluate the effect of incompleteness of the "gold standard" provider reported vaccination ascertainment on estimation of validity parameters, a misclassification model was constructed (Appendix 5.2). This model assumed that the provider record check process ascertained a proportion of actual vaccinations that could be less than one. It further assumed that provider ascertainment of actual vaccinations was independent of household reported influenza vaccination status. Putative true values of validity parameters were calculated for selected values of the provider ascertainment proportion and compared to the estimates when the provider ascertainment proportion was 1.0. Scenarios were constructed assuming that there was a

tendency for parents forgetting an influenza vaccination of their child to also forget to report that vaccination provider, so the provider ascertainment proportion when household report was not vaccinated was assumed higher than the provider ascertainment proportion when household report was vaccinated.

SCENARIOS TO ILLUSTRATE POTENTIAL IMPLICATIONS OF IMPERFECT RECALL

The implications of parental misclassification of child's influenza vaccination status for monitoring trends in influenza vaccination coverage from survey data relying on parental report were evaluated using the formulas in Appendix 5.1 expressing prevalence of vaccination based on parental report as a function of true prevalence, sensitivity and specificity. Scenarios are constructed assuming sensitivity and specificity remain fixed over time as true prevalence increases, or if sensitivity and specificity change over time. Sensitivity and specificity could change over time in the population if factors that affect accuracy of recall change over time, such as salience of influenza vaccination or social desirability to report vaccination. For example, since influenza vaccination is recommended annually, it may be more salient and memorable the first few time received, but less likely recalled when it is perceived as routine (so sensitivity of recall would decrease over time). For some persons, sensitivity of recall might increase over time as it becomes routine practice (e.g. more likely to recall not getting vaccinated if annual vaccination has become the norm). Another scenario compares actual and measured trends in influenza vaccination for two subgroups with different sensitivity and specificity of parental report. Since the positive and negative predictive values are relevant for clinical practice, the single group scenarios included calculation of "actual" PPV and NPV to illustrate how these parameters will differ by level of prevalence for fixed levels of sensitivity and specificity. Appendix 5.3 outlines how results from validity studies can be used to correct estimates of vaccination coverage based on parental report (or self-report for adults). A simple deterministic approach is presented as well as a simulation approach which imputes the true vaccination status

of each sample case and creates as distribution of true vaccination coverage over multiple imputations.

RESULTS

CHARACTERISTICS OF STUDY POPULATION

Overall, distribution by month of interview was uniform, except for less interviews conducted at the start (October) and end (July/August) of the data collection period (Table 5-1). Mothers were more likely the respondents in the shot card group (87%) compared to the recall only group (74%). More interviews were conducted in Spanish for the shot card group (21%) than the recall only group (12%). Among sociodemographic characteristics of the household or the mother, compared to the shot card group, the recall only group was more likely to live in the south and less likely to live in the west, less likely to live below the poverty level, more likely to own their home, and less likely to have the child's mother Hispanic. Characteristics of the child also varied by shot card status, with children in the recall only group more likely covered by private health insurance and age 24-37 months. Overall, 58% of children had one provider identified and that provider responded, 32% had two or more providers identified and all responded, and 9% had multiple providers identified but not all responded (all were considered to have adequate provider data). Children in the recall only group were more likely to have one provider and less likely to have multiple providers identified, all of whom responded. Children in the recall group were more likely to have received all of their vaccinations from private facilities.

PRIMARY VALIDITY RESULTS

For receipt of one or more doses of seasonal influenza vaccination in the 12 months preceding the interview, provider reported prevalence was 53.4% for the shot card group and 49.6% in the recall only group (Table 5-2). Prevalence based on household report was similar to

provider report for the shot card group and higher than provider report for the recall only group (net bias 5.3 percentage points). Provider reported prevalence was similar across months of interview, reflecting the 12-month recall period which could include later vaccinations from the prior season for persons interviewed October-February and vaccinations from just the most recent season for those with interviews April-June.

Sensitivity and NPV were similar for the shot card group (Se 81.5%, NPV 79.1%) and recall only groups (Se 80.2%, NPV 78.3%), while specificity and PPV were higher for the shot card group (Sp 80.1% and PPV 82.4% vs. Sp 70.1% and PPV 72.6%) (Table 5-2). For the recall only group, sensitivity was lower for households interviewed October-November and June-August.

For receipt of one or more doses of pH1N1 influenza vaccination since October 2009, provider reported prevalence was 32.8% for the shot card group and 23.7% for the recall only group (Table 5-3). Since children interviewed early in the vaccination period did not have full opportunity for pH1N1 vaccination for the season (household and provider vaccination status only included vaccinations received up until and including the date of interview), these underestimate prevalence for the season. Provider reported prevalence of pH1N1 vaccination increased by month of interview during the first few months, reflecting the increase in cumulative percent vaccinated over time until incidence of vaccination ceased. Overall, pH1N1 vaccination prevalence based on household report was higher than provider report (net bias of 6.1 percentage points for the shot card group and 11.5 percentage points for the recall only group).

Household report of one or more doses of pH1N1 vaccination had higher sensitivity in the recall only compared to shot card group (93.2% vs. 85.0%) while specificity was similar (82.8% vs. 86.2%) (Table 5-3). For the recall only group, sensitivity was somewhat lower for June-August interviews, and specificity was highest for October-November interviews (92-98%) and lowest for February-August interviews (74-82%).

Provider reported prevalence of two or more doses of influenza vaccination during the vaccination period was higher in the shot card group compared to the recall only group for both seasonal and pH1N1 vaccination (16.6 vs. 12.2% for seasonal and 12.2% vs. 9.8% for pH1N1) (Tables 5-4 through 5-5). For pH1N1, cumulative prevalence of provider reported vaccination by month of interview increased until about February, with estimates during February-August ranging from 14-20% for the shot card group and 14-17% for the recall only group. Net bias of household reported prevalence of receipt of two or more vaccinations was negative (-6.1 percentage points) for seasonal vaccination in the shot card group and positive (6.6 percentage points) for pH1N1 vaccination in the recall only group.

Sensitivity for household reported receipt of two or more influenza vaccinations was lower than for receipt of one or more vaccinations for seasonal shot card (45.3% vs. 81.5%) and recall only (38.8% vs. 80.2%) groups, and for pH1N1 shot card (60.1% vs. 85.0%) and recall only (86.5% vs. 93.2%) groups (Tables 6-2 through 6-5). Specificity was high in all groups (range 90-96%) and higher in each group compared to receipt of one or more vaccinations. A large difference was observed for sensitivity for two or doses of pHN1 between the shot card (60.1%) and recall only (86.5%) groups. Sensitivity for two or more vaccinations was substantially higher for pH1N1 than seasonal influenza vaccination (60.1% vs. 45.3% for shot card group and 86.5% vs. 38.8% for recall only group), while specificity did not differ by vaccine within shot card status groups.

CHARACTERISTICS ASSOCIATED WITH SENSITIVITY AND SPECIFICITY

Four logistic regression models were fit to estimate adjusted sensitivity and specificity among parent respondents by vaccine (one or more doses) and shot card status. Characteristics significantly associated with sensitivity and specificity varied by vaccine and shot card status (Tables 5-6 through 5-9). Across all models, month of interview was significantly associated with both sensitivity and specificity. In the recall only group, adjusted specificity tended to be

higher in the first four interview months for both seasonal and pH1N1 vaccination. Also in the recall only group, sensitivity for seasonal vaccination was lower in the earliest and latest interview months, while for pH1N1, adjusted sensitivity tended to decrease during November-August interview months (prevalence of pH1N1 vaccination was low in October and the crude estimate of sensitivity for October had a wide confidence interval).

In the recall only group, validity of parental report was higher for mothers than fathers, with adjusted sensitivity ratios of 1.10 for seasonal and 1.06 for pH1N1 vaccination, and adjusted specificity ratio of 1.09 for pH1N1. Statistically significant associations were observed by mother's race/ethnicity for six of the eight groups and parameters examined. Hispanics had lower adjusted specificity than at least one other racial/ethnic group for all four models – the adjusted specificity ratios among the shot card group for blacks vs. Hispanics were 1.17 for seasonal and 1.15 for pH1N1; for the recall only group, the adjusted specificity ratio was 1.17 for whites vs. Hispanics for seasonal and 1.09-1.11 for whites, blacks and others vs. Hispanics for pH1N1. Specificity was lower for mothers with advanced degrees compared to some other groups with less education in all but shot card group for pH1N1. In the recall only groups, statistically significant adjusted specificity ratios ranged from 1.20-1.23 for those with some college or less compared to those with advanced degrees for seasonal vaccination, and from 1.09-1.12 for those with high school to associate degrees compared to those with advanced degrees.

In the recall only group for seasonal vaccination, households with one child had higher sensitivity than for households with four or more children (adjusted sensitivity ratio 1.11), while specificity was lower for households with 2-3 children compared to those with four or more (adjusted specificity ratio 0.90). This latter association with specificity was also observed in the shot card group for pH1N1. Older mothers (age ≥40 years) had higher specificity than some other groups for seasonal and pH1N1 vaccination in the recall only group. In the shot card group, sensitivity was also higher for seasonal vaccination for the older mothers compared to mothers

30-39 years, while for pH1N1, sensitivity was higher for mothers 18-20 years compared to 40 years and older.

JOINT DISTRIBUTION OF HOUSEHOLD REPORTED pH1N1 AND SEASONAL INFLUENZA VACCINATION STATUS

Among the shot card group based on provider report, 21.5% of child received both seasonal and pH1N1 vaccinations during their respective vaccination periods, 31.9% received seasonal vaccination only, 5.2% received pH1N1 vaccination only, and 41.5% received neither (Table 5-10). Children in the recall only group were slightly less likely be vaccinated, with similar proportions among the vaccinated subgroups. Compared to provider report, distribution of household reported vaccination status for the shot card group was higher for pH1N1 only (10.4% vs. 5.2%) and lower for neither vaccination (36.8% vs. 41.5%). For the recall only group, household reported status was higher for receiving both vaccinations (26.9% vs. 19.8%) and pH1N1 only (8.3% vs. 3.9%). Conditional on provider reporting receipt of both seasonal and pH1N1 vaccinations, household reported status was also both vaccines for 71-80%, with higher error reporting pH1N1 only (13-16%) compared to seasonal only (2-8%), while only 4-5% reported neither vaccination (Table 5-10). Among those with provider reported receipt of seasonal vaccination only, 62-70% were reported by households as receiving seasonal only, while 13-16% reported both, 12-17% reported neither, and 4% reported pH1N1 only. Among those with provider reported receipt of pH1N1 vaccination only, 44% of households in the recall only group reported pH1N1 only, and 49% reported both pH1N1 and seasonal vaccination; in the shot card group, 53% reported pH1N1 only, 23% reported both, and 16% reported neither.

ACCURACY OF HOUSEHOLD REPORTED MONTH OF VACCINATION

The first analysis to assess accuracy of household reported month of vaccination stratified the overall study population by provider reported month of vaccination; for each month of vaccination, the denominator was children with provider reported influenza vaccination in that

month. For each month of provider reported vaccination, the proportion of children with household reported vaccination per month is displayed in tables 5-11 (seasonal) and 5-12 (pH1N1). Children receiving more than one vaccination during the vaccination period could be included in more than one column (provider report) or row (household report). Half of children with provider reported October seasonal vaccination also had household reported October vaccination; for subsequent months of provider vaccination, concurrence by household report decreased over time (Table 5-11). A similar pattern was seen for pH1N1 vaccination, although concurrence was higher for pH1N1 (e.g., households reported October vaccination for 59% of children with October provider reported vaccination) (Table 5-12).

The previous analysis does not take into account the timing between vaccination period and recall period. Tables 5-13 through 5-16 present estimates of sensitivity and specificity by shot card status and vaccine, stratified by monthly vaccination period and subsequent month of interview. In these tables, estimated provider reported vaccination during each month was independently estimated for each subsequent interview month, thus these estimates are expected to be similar across months of interview. For the recall only group, provider reported seasonal vaccination in October ranged from 16-27% across samples by interview months from November through August, from 8-13% for November interviews across interview months December-August, 4-10% for December vaccinations, and 2-4% for January vaccinations (Table 5-14). Confidence intervals for estimated sensitivity and specificity were wide for the shot card group and no patterns were apparent (Tables 5-13 and 5-15). For the recall only group, estimated sensitivity tended to be lower and specificity higher for monthly vaccination periods compared to the full vaccination periods (Tables 5-14 and 5-16). Sensitivity tended to decrease with increasing subsequent month of interview, while specificity was more stable over interview months, and tended to increase as the vaccination period increased. By interview month, prevalence of monthly vaccination was similar between provider and household report, although confidence intervals were fairly wide.

ACCURACY OF HOUSEHOLD REPORTED TYPE OF pH1N1 AND SEASONAL INFLUENZA VACCINATION

Among children with both provider and household reported influenza vaccination, the distributions of provider and household reported type of pH1N1 and seasonal influenza vaccinations ("shot" vs. "spray") were compared, stratified by shot card status and age group (Table 5-17). Children reported with more than one influenza vaccination during the vaccination period could report either "shot" or "spray" vaccinations, either only, or not report type (don't know, refused or missing). For children 10-23 months as of November 2009, most of whom were not eligible for LAIV ("spray") vaccination, 91-97% of provider reported vaccinations were by shot only; household reports were varied across shot card status and pH1n1 and seasonal vaccination from 77-96% and were lower due to higher prevalence of now knowing or reporting the vaccine type or reporting "spray" vaccination. Fifteen percent of the shot card group had undetermined type of pH1N1 vaccination.

Among children 24-37 months, by provider report, about 80% of seasonal vaccinations were by "shot only", while 65% (recall only group) to 77% (shot card group) of pH1N1 vaccinations were by "shot only". In this older age group, distribution by type of seasonal vaccination was very similar between provider and household report among the shot card group, although this does not preclude individual-level misclassification. In the recall only group, about 80% of seasonal vaccinations were by "shot only", with a higher proportion of both "shot" and "spray" vaccinations and lower proportion of "spray only" vaccinations reported by households. Distributions by type of pH1N1 vaccination for provider and household report had overlapping confidence intervals. Agreement of household and provider report on the types of influenza vaccinations received by 24-37 month old children, by shot card status, were 75.0% (pH1N1 shot card), 80.9% (pH1N1 recall only), 85.1% (seasonal shot card) and 82.1% (seasonal recall only). For seasonal vaccination in the recall only group, 9.2% reported both shot and spray vaccinations

when provider reports indicated one or the other, and another 3.5% reported a shot while the provider(s) reported LAIV.

EFFECT OF UNDER-ASCERTAINMENT OF PROVIDER REPORTED VACCINATIONS ON VALIDITY PARAMETER ESTIMATES

Among shot card group respondents, there were 1,353 children with a seasonal influenza vaccination in the past 12 months and 515 with a pH1N1 vaccination reported from the shot card. Of these, weighted prevalence of provider also reporting was 87.6% for seasonal and 73.2% for pH1N1 (Table 5-18). These provider ascertainment proportions (assuming the household reports from the shot card and the shot card were accurate) did not vary by provider reporting status, though sample sizes were small for children with multiple providers identified and some but not all reported valid immunization history questionnaires.

Table 5-19 presents what actual sensitivity, specificity, PPV, NPV, and vaccination prevalence would be assuming varying degrees of provider under-ascertainment of actual influenza vaccinations, and assuming non-differential under-ascertainment by household reported vaccination status. Four scenarios were examined corresponding to the observed values from the primary validity analysis by shot card status and seasonal/pH1N1 vaccination, which presumed 100% provider ascertainment (first data column in Table 5-19). With 90% provider ascertainment, provider vaccination prevalence underestimated actual prevalence by -2.7 to -5.9 percentage points, specificity was underestimated by -2.7 to -9.0 percentage points, PPV was underestimated by -7.0 to -9.2 percentage points, NPV was overestimated by 0.3 to 2.4 percentage points, and as expected there was no impact on sensitivity. Net bias of household report based on "actual" vaccination prevalence looked worse for the seasonal shot card scenario (-6.5 percentage points compared to -0.6 based on provider vaccination prevalence) while for other scenarios with positive net bias based on provider report, net bias based on "actual" prevalence was closer to zero.

For the seasonal shot card group scenario, the minimum plausible provider ascertainment rate without yielding negative expected table cell values was 83%. With that value of provider ascertainment, specificity, PPV and vaccination prevalence based on provider report were substantially lower than "actual" (-18.9, -16.9, and -10.9 percentage points, respectively). Minimum plausible values of provider ascertainment for other scenarios were 73% for seasonal recall only, 70% for pH1N1 shot card, and 63% for pH1N1 recall only. For each of these scenarios, as the provider ascertainment proportion decreased, estimates of specificity, PPV and "actual" vaccination prevalence based on provider report as the gold standard became increasingly too low. Estimates of NPV became increasingly too high but were relatively less affected in magnitude.

Because parents forgetting a vaccination may also be more likely to forget to report a vaccination provider, the provider ascertainment proportion may be lower for children with a household reporting the child as not vaccinated. This is explored in Table 5-20 using the observed values from the four scenarios. Assuming provider ascertainment of 100% given household report of vaccination and 90% given household report is not vaccinated, there was minimal difference between estimated validity parameters based on provider vs. "actual" report (less than 3 percentage points). Two additional combinations of differential provider ascertainment were examined, assuming 80% and 50% provider ascertainment given household report of not vaccinated; in each combination, it was assumed that the provider ascertainment proportion given household report of vaccination was 88% for seasonal and 73% for pH1N1 vaccination. Across the four scenarios, as provider ascertainment given household report of not vaccinated dropped from 80% to 50%, provider reported vaccination prevalence became increasingly too low, estimated sensitivity based on provider report was substantially biased only for the more extreme combination, estimated specificity based on provider report was biased but did not change as much as other validity parameters, estimated NPV based on provider report became increasingly too large, and estimated PPV based on provider report was substantially

negatively biased but not affected by decreasing provider ascertainment given household report of not vaccinated.

SCENARIOS TO ILLUSTRATE POTENTIAL IMPLICATIONS OF IMPERFECT RECALL

To evaluate in one population group the potential change in net bias, PPV and NPV over time as a function of changes in actual vaccination prevalence, sensitivity and specificity, three scenarios were created and evaluated for each of four combinations of the observed validity estimates by shot card status and seasonal/pH1N1 vaccination. In the first scenario, sensitivity and specificity were held constant while actual vaccination prevalence increased over time linearly. As seen in the top graph in Figures 5.1 through 5.4, over time, PPV approached one and NPV decreased, while net bias varied across combinations, becoming increasingly negative, reversing from positive to negative, and decreasing toward zero. In the second single group scenario, sensitivity and specificity also increased linearly along with actual vaccination prevalence. In the middle graphs of Figures 5.1 through 5.4, net bias approached zero, PPV approached 1, and NPV decreased slightly for the seasonal combinations and approached one in the pH1N1 scenarios (which had higher sensitivity and specificity and lower vaccination prevalence). For the final single group scenario, sensitivity and actual prevalence increased over time while specificity decreased. In the bottom graph of Figures 5.1 through 5.4, PPV generally increased, NPV decreased for the seasonal combinations and increased for the pH1N1 combinations, and net bias approached zero for the seasonal combinations and increased or stayed the same for the pH1N1 combinations.

Reducing disparities in influenza vaccination by racial/ethnic groups is a public health priority, and results from this study indicate differential estimates of sensitivity and specificity (e.g. lower for Hispanics). For example, for seasonal influenza vaccination of children in the shot card group, provider reported vaccination prevalence was 50.8% in whites and 51.3% in Hispanics, while household reported vaccination prevalence was 57.2% in whites and 48.4% in

Hispanics. Sensitivity was higher in whites than Hispanics (84.8% vs. 71.4%) and specificity was somewhat lower in whites than Hispanics (71.2% vs. 75.8%). The actual disparity (Hispanic minus white) based on provider report was 0.5 percentage points, while the apparent disparity based on household report was -8.8 percentage points. Thus we may conclude based on household report that Hispanics have lower vaccination prevalence than whites when there is little difference based on provider reported vaccination prevalence.

Scenarios were created to evaluate the apparent (based on household report) and actual disparities between two groups A and B assuming sensitivity and specificity of Group B were 0.8 times the values for Group A and did not change over time. For each scenario, the combinations of validity estimates by shot card status and seasonal/pH1N1 vaccinations were evaluated.

For the first two group scenario, it was assumed there was no difference in vaccination prevalence between Groups A and B, and vaccination prevalence increased over time (actual disparity is zero over time). As seen in the top graphs of Figures 5.5 through 5.8, the apparent disparity increased over time; for the pH1N1 combinations, the disparity reversed direction from initially negative to positive. In the second scenario, it was assumed that vaccination prevalence was 10 percentage points higher in Group A than Group B, and this actual disparity remained constant over time. As seen in the middle graphs of Figures 5.5 through 5.8, the apparent disparity initially underestimated and then overestimated the actual disparity, and for the pH1N1 combinations, the apparent disparity was initially negative then switched to positive. In the final two group scenario, it was assumed that vaccination prevalence increased over time in Group A but remained constant in Group B, so that the actual disparity increased from 10 to 55 percentage points. From the bottom graphs of Figures 5.5 through 5.8, apparent disparities consistently underestimated actual disparities, and for the pH1N1 combinations, the apparent disparity switched from initially negative to positive.

DISCUSSION

This study is unique among validity studies of parental report of influenza vaccination of their young children, with a nationally representative sample of nearly 13,000 children aged 10-37 months at the start of the 2009-10 influenza season and evaluation of both seasonal and pH1N1 vaccination. Influenza vaccination prevalence reported by parents or other adult in the household knowledgeable about the child's vaccinations was higher than vaccination prevalence based on provider report by five to 12 percentage points when recall was not aided by having the child's vaccination record available during the interview.

Sensitivity and specificity were higher for pH1N1 compared to seasonal vaccination in the prior twelve months, with values for pH1N1 from 85-93% for sensitivity and 83-86% for specificity and for seasonal vaccination from 80-81% for sensitivity and 70-80% for specificity, depending on whether the respondent had a shot card available during the interview. Sensitivity tended to decrease as the length of time from the vaccination period to date of interview increased. Prevalence of receiving two or more doses of influenza vaccination was low, despite the majority of children in the age range studied recommended to receive two doses and all children aged <10 years recommended to receive two doses of pH1N1 at least four weeks apart. Household reported receipt of at least two doses of influenza vaccination had lower sensitivity and higher specificity compared to report of at least one dose. This study also identified characteristics of the child's mother and family associated with sensitivity and specificity, evaluated the impact of an imperfect gold standard on estimates of validity parameters, and demonstrated with examples how misclassification bias in estimates and comparisons among subgroups based on household reported vaccination status can change over time as actual vaccination prevalence increases.

For seasonal influenza vaccination, estimates from this study were lower than the range reported in prior studies of clinic-based populations for sensitivity (85-92%) and within the range

for specificity (66-92%) (61-63, 65, 104). Estimates from this study were slightly lower than found in a validity study of NIS data for the 2003-04 season (sensitivity 86% and specificity 81%) (64). Competing recall of both seasonal and pH1N1 vaccinations during 2009-10 is consistent with lower validity of household report. Respondents in this study who had received both seasonal and pH1N1 vaccinations by provider report were more likely to inaccurately report having only pH1N1 than only seasonal vaccination, and children who received only seasonal or only pH1N1 vaccination often were often reported by respondents as having received both pH1N1 and seasonal vaccination. One previous clinic-based study reported sensitivity (88%) and specificity (92%) of parental reported 2009-10 season pH1N1 vaccination in children aged 6-59 months (100), similar to estimated sensitivity from this study and higher for specificity.

Many factors can affect comparability of studies comparing influenza vaccination status reported by parents compared to medical records. These factors include the population and seasons studied, the characteristics of the survey or setting used to determine parental reported vaccination status, the length of time from vaccination to recall, the vaccination period, and completeness of the ascertainment of actual vaccination status. Prior studies have not assessed the potential bias in validity parameter estimation of incomplete ascertainment of actual vaccination status. This study demonstrated that if ascertainment of influenza vaccinations by the "gold standard" medical record is incomplete, bias in validity parameters can be substantial, particularly for vaccination prevalence, specificity and PPV.

There is some evidence in the NIS sample for under-ascertainment of influenza vaccinations by the provider record check process, which can happen if a parent does not identify a vaccination provider, an identified provider is not reachable or does not respond to the survey, or the provider responds but reports an incomplete vaccination history for the child. During the 2009-10 season, about 30% of children of all ages received influenza vaccination in schools (6), which may not be captured by the NIS provider record check process. It is possible that some children under age three years were vaccinated at school-located clinics that primarily targeted

school-aged children, to the extent that families were invited to bring younger children and for themselves to be vaccinated at these venues. Younger children might also have been vaccinated at public health department sponsored vaccination clinics in malls and other non-medical settings. Evidence for provider under-ascertainment of influenza vaccinations is based on the subset of respondents who reported influenza vaccinations from a shot card during the interview. The accuracy of parent's reporting of influenza vaccinations from shot cards is not known, and vaccinating provider may not have provided enough detail on the record to distinguish pH1N1 from seasonal influenza vaccination or whether it was injected or nasally administered. Applying the findings that providers ascertained 88% of seasonal and 73% of pH1N1 vaccinations reported from shot cards as a worst case scenario, this study could underestimate actual vaccination prevalence, specificity and PPV, particularly for pH1N1 vaccination. NIS data for the 2010-11 season and for early 2011-12 seasons can be evaluated to determine provider ascertainment of influenza vaccinations reported by respondents from shot cards without possible confusion with pH1N1. Starting in 2012, the NIS household questionnaire was shortened and no longer asks parents to report from a shot card. Matching the NIS sample to selected Immunization Information Systems is another approach for evaluating completeness of provider reported influenza vaccination status, although these registries may also be incomplete (107).

Decreasing accuracy of recall of past events as length of the recall period increases is a common problem in surveys (66). This study found decreasing sensitivity of household reported pH1N1 influenza vaccination status as months from vaccination period to interview increased. For seasonal vaccination, sensitivity was lower early and late in the interview period, corresponding to longer length of recall of past vaccinations in the past 12 months (e.g. recalling vaccinations in late 2008 if interviewed in October 2009 and not yet vaccinated for the current season, or interviewed in June 2010 and recalling back to a vaccination in October or November 2009). This has implications for approaches to estimation of influenza vaccination coverage, supporting the use of data collected during the vaccination period to estimate prior vaccinations,

such as can be done with product-limit (Kaplan-Meier) survival analysis, and restricting the interview months to those closer to the end of the season's vaccination period. Simulation or multiple imputation approaches could be applied to such analysis to evaluate and correct for the impact of time-varying sensitivity and specificity of vaccination coverage estimates based on household reported vaccination status (29,108).

Other cognitive processes than can affect parental recall of their child's influenza vaccination include the extent that people encode the event of their child getting an influenza vaccination in their memory (routine vs. memorable event), interpretation of the survey questions, distortion in representation of an event over time, failure to retrieve details (e.g., month of vaccination, number of doses received, or type of vaccination), errors reconstructing memories of past events, telescoping (erroneously reporting events that occurred before the stated recall period), making judgments to answer a survey question when their memory is uncertain, and motivated misreporting (23). Motivated misreporting could include answering survey questions without remembering (e.g. guessing) to avoid reporting not knowing the answer, giving answers perceived as socially desirable (e.g., report their child received influenza vaccination when not sure), or applying minimum cognitive effort to get through the interview as quick as possible (satisficing).

Recall of pH1N1 vaccination may have been more accurate than for seasonal because the recall period was shorter on average, and the media attention to the pandemic may have made the pH1N1 vaccination more memorable, the respondent more likely to assume their child's flu vaccination was pH1N1 if they were not sure, or more likely to choose pH1N1 as a more socially desirable response. Among children eligible to receive LAIV, there was congruence in marginal distributions of household and provider reported type (intranasal vs. injected) of influenza vaccinations received, and overall agreement was 75-85%. This suggests that households are able to accurately report vaccination type, possibly because the intranasal administration of LAIV

is memorable compared to usual vaccinations by injection, particularly for children adverse to needles.

For both seasonal and pH1N1 vaccination, specificity was higher in the shot card group. This may be an effect of having a shot card available during the interview. Among children who had not been vaccinated, some household respondents not sure about their child's vaccination status may have factored in absence of an influenza vaccination recorded on the shot card as additional evidence of lack of vaccination. Alternatively, parents who have shot records may also be more likely to pay closer attention and have better recall of their child's vaccinations.

This study identified several sociodemographic factors independently associated with accuracy of household reported influenza vaccination status. Sensitivity and specificity were higher when the child's mother was the respondent instead of the father. Mothers may be more likely than fathers to be involved in the logistics of their child's health care and aware of their vaccinations. Specificity was lower when the child's mother was Hispanic or had an advanced degree. One study of seasonal influenza vaccination during the 2004-05 through 2006-07 seasons also found lower specificity for Hispanics, and lower sensitivity, although based on child's race/ethnicity compared to mother's race/ethnicity used in this study (104). Brown et al. also found lower sensitivity when the mother had less than high school education compared to college graduates, and although not statistically significant, lower specificity for higher levels of education (104). Brown et al.'s findings are consistent with this NIS study for seasonal vaccination in the recall only group, using more detailed levels of education and adjusting for other variables in a multivariable logistic regression model. A pattern of higher sensitivity and lower specificity is consistent with a cognitive strategy of tending to overreport vaccination. Specificity was higher in the recall only group when the child's mother was aged forty or older. These associations can be further examined in the 2010-11 and onward NIS data, although reasons for the differences in specificity are not known.

As demonstrated in the scenarios illustrating the impact of increasing vaccination prevalence, changes in sensitivity and specificity, and differential values across subgroups, comparisons of vaccination prevalence based on household reported status can be biased. Thus, to support ongoing surveillance and program evaluation based on surveys that rely on parental reported vaccination status, it is important to identify subgroups of interest with differing accuracy of household report. It is also important to continue monitoring validity of parental report as vaccination prevalence increases.

The findings in this study also apply to clinical settings during the vaccination period. Providers may need to make decisions whether to vaccinate a child or not based on parental report. While adult self-reported influenza vaccination status is considered sufficiently sensitive and specific to be accepted as evidence of influenza vaccination in clinical practice, available data on accuracy of parental report of child's influenza vaccination status has been considered lacking (4). If clinical decisions were based on parental report, children reported as vaccinated by the parent would not be considered vaccinated while children reported as not vaccinated by the parent would be considered for vaccination. Using values of PPV and NPV estimated from this study for pH1N1 (PPV ~69%, NPV~94%), this clinical decision rule would result in missing an opportunity for vaccination for 31% (1-PPV) of children with parental report of vaccination, and unnecessary repeat vaccination for 6% (1-NPV) of children with parental report of non-vaccination. The population prevalence of missed opportunities would be the product of the actual vaccination prevalence times 1-PPV, and of unnecessary vaccinations the product of one minus the actual vaccination prevalence and 1-NPV. Thus, as vaccination prevalence increases over seasons, PPV will approach one and missed opportunities would decrease, while NPV would approach zero and unnecessary vaccinations would converge toward the value of sensitivity, based on this clinical decision rule and assuming constant sensitivity and specificity over time.

LIMITATIONS

Results from this study may provide a biased representation of all children aged 10-37 months as of November 2009 to the extent that bias in estimates remains after weighting adjustments to account for probability of selection and adjustments for nonresponse and lack of households without landline telephones in the 2009-10 NIS sample frame. This study evaluated potential bias in estimated validity parameters assuming provider ascertainment of influenza vaccinations is incomplete. However, the actual levels of provider ascertainment, overall and stratified by household reported vaccination status, are unknown.

The generalizability of study findings is potentially limited by the restricted age group of children studied. A similar study for 13-17 year olds using data from the NIS-Teen (105) found higher sensitivity (82-91%) and specificity (86-93%) for seasonal influenza vaccination in 2008-09. The NIS-Teen validity study defined the vaccination period as the current season, while this study used reported vaccinations in the past 12 months. Future analysis of the NIS data can redefine the vaccination period to the current season using reported month and year of vaccination. Another potential threat to generalizability is the use of shot cards to aid household report. The National Health Interview Survey and the collection of parental reported influenza vaccination status of children 6 months-17 years using the NIS sampling frame do not ask parents to retrieve a shot record during the interview (except for adolescents 13-17 years as part of the NIS-Teen). Because the recall only and shot card groups differed by many sociodemographic factors, validity results from the recall only group may not directly apply to other surveys. Parents may take their shot records with them to clinical settings, and many parents may exert more cognitive effort for accurate recall in a clinic setting compared to participating in a survey. An additional caveat is the unique circumstances of having two influenza vaccinations recommended and available during a similar time period (pH1N1 and seasonal). This may have

affected validity parameters and underscores the need to repeat this study using subsequent data from non-pandemic seasons.

Further analyses to evaluate accuracy of parental report is possible using the NIS data. For example, the analysis of characteristics associated with sensitivity and specificity could be expanded to consider three way interactions including two characteristics and provider reported vaccination status. Further modeling could be done to assess sensitivity and specificity by months from vaccination period to interview. Since each child contributes to each vaccination period prior to their interview date, the data could be structured and analyzed as a repeated measures design, and months from vaccination period to interview treated as a continuous covariate.

CONCLUSIONS

The attributes of ongoing surveillance systems should be monitored to ensure they are meeting the needs of intended use and are correctly interpreted. For assessment of influenza vaccination coverage, a threat to validity is misclassification bias from inaccurate self or parental reported vaccination status. This study indicates that inaccurate parental report of their child's influenza vaccination can result in bias of 5 to 12 percentage points.

Differential accuracy of parental recall across subgroups can result in biased estimates of subgroup differences. If biases remain constant over time, trends and differences by subgroups can be used to track progress, even if estimated vaccination levels are too high or too low. However, the scenarios in this study show that even with constant sensitivity and specificity over time, as prevalence increases, net bias can change over time depending on the combination of vaccination prevalence, sensitivity and specificity. Thus, ongoing monitoring of validity of parental report of influenza vaccination is needed, overall and by key population subgroups for which vaccination coverage estimates are produced. In this context, sensitivity and specificity are

behavioral parameters and subject to change over time associated with changes in cognitive factors related to recall. If appropriate estimates of sensitivity and specificity of reported vaccination status are available, estimates of vaccination coverage based on self or parental reported vaccination status can be adjusted for misclassification. Such adjustments are particularly important for accurate assessments of vaccination safety and morbidity and mortality averted by vaccination.

In an emergency situation such as an influenza pandemic or shortage, timely and efficient monitoring of influenza vaccination will be needed. Experience from the 2009-10 pandemic indicates that parents were able to fairly accurately report their child's receipt of the pandemic vaccination, during a period when seasonal influenza vaccination was also recommended and available. There appeared to be some misclassification of parental report, erring toward reporting of pH1N1 vaccination likely associated with the media attention during the pandemic. Overall, parental reported vaccination prevalence was likely overestimated.

Increased use of vaccination records by parents and providers can maximize opportunities for influenza vaccination, minimize unnecessary vaccination, and potentially improve surveillance and evaluation of vaccination programs. This can be facilitated by continued development of Immunization Information Systems (IIS) and provider electronic health records (EHR), integration of IIS and EHR, and patient access to their electronic medical records (109-111). Meanwhile, surveys to collect influenza vaccination data by parental and self report remains an efficient approach for surveillance and evaluation of vaccination programs at the national and state levels.

Table 5-1 Weighted distribution* of study sample by shot card status† and selected characteristics, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	Total (n=12,899)	Shot Card Group (n=3,813)	Recall Only Group (n=9,086)
MONTH OF INTERVIEW			
October 2009	7.6 (6.8 - 8.6)	7.2 (6.0 - 8.6)	7.8 (6.7 – 9.0)
November 2009	10.7 (9.7 – 11.8)	11.4 (9.4 – 13.7)	10.4 (9.2 – 11.7)
December 2009	12.5 (11.5 – 13.7)	11.4 (9.6 – 13.6)	12.9 (11.7 – 14.3)
January 2010	10.9 (10.0 – 12.0)	9.9 (8.4 – 11.7)	11.3 (10.2 – 12.6)
February 2010	10.7 (9.8 – 11.6)	9.0 (7.7 – 10.5)	11.3 (10.2 – 12.5)
March 2010	10.8 (9.9 – 11.8)	10.4 (8.7 – 12.3)	11.0 (9.9 – 12.1)
April 2010	9.5 (8.6 – 10.5)	11.2 (9.1 – 13.7)	8.8 (7.9 – 9.9)
May 2010	11.3 (10.1 – 12.6)	12.0 (10.1 – 14.2)	11.0 (9.5 – 12.6)
June 2010	11.3 (10.3 – 12.4)	12.6 (10.6 – 14.9)	10.8 (9.7 – 12.0)
July/August 2010	4.7 (4.2 – 5.3)	4.9 (3.9 – 6.1)	4.6 (4.0 – 5.4)
ADULT RESPONDENT†			
Mother	77.7 (76.2 – 79.1)	87.2 (85.0 – 89.1)	73.8 (72.0 – 75.6)
Father	15.0 (13.8 – 16.3)	8.7 (7.1 – 10.5)	17.6 (16.1 – 19.2)
Grandparent / Other	7.3 (6.4 – 8.3)	4.2 (3.1 -5.5)	8.6 (7.4 – 9.9)
INTERVIEW LANGUAGE†			
English	83.6 (82.0 – 85.0)	77.4 (74.0 – 80.4)	86.1 (84.3 – 87.7)
Spanish	14.5 (13.1 – 16.1)	20.7 (17.8 – 24.0)	12.0 (10.5 – 13.8)
Other Language	1.9 (1.5 – 2.4)	1.9 (1.0 – 3.5)	1.9 (1.5 – 2.4)
REGION OF RESIDENCE†,¶			
Northeast	16.0 (15.4 – 16.6)	14.7 (13.2 – 16.4)	16.5 (15.6 – 17.4)
Midwest	20.8 (20.2 – 21.5)	20.9 (19.2 – 22.7)	20.8 (19.8 – 21.8)
South	38.0 (37.1 – 38.9)	32.5 (30.1 – 34.9)	40.3 (38.9 – 41.7)
West	25.2 (24.2 – 26.2)	31.9 (29.2 – 34.8)	22.4 (20.8 – 24.2)
METROPOLITAN STATISTICAL AREA (MSA)			
MSA, Central City	43.1 (841.5 – 44.7)	45.7 (42.6 – 48.7)	42.1 (40.2 – 44.1)
MSA, Non-central City	40.5 (39.0 – 42.1)	38.1 (35.3 – 41.1)	41.5 (39.6 – 43.4)
Non-MSA	16.3 (15.4 – 17.3)	16.2 (14.5 – 18.1)	16.4 (15.2 – 17.5)
HOUSEHOLD POVERTY STATUS†			
Above Poverty			
Annual Income >$75,000	27.1 (25.8 – 28.4)	24.0 (21.8 – 26.4)	28.3 (26.8 – 29.9)
Annual Income ≤$75,000	35.7 (34.1 – 37.3)	34.0 (31.4 – 36.7)	36.4 (34.5 – 38.4)
Below Poverty	31.8 (30.2 – 33.4)	35.4 (32.3 – 38.6)	30.3 (28.4 – 32.2)
Unknown	5.5 (4.7 – 6.3)	6.7 (5.0 – 8.8)	5.0 (4.2 – 5.9)
OWN OR RENT DWELLING†			
Own	59.3 (57.6 – 61.0)	55.9 (52.7 – 59.0)	60.7 (58.7 – 62.7)
Rent	37.7 (36.0 – 39.4)	40.8 (37.7 – 44.0)	36.4 (34.4 – 38.5)
Other	3.0 (2.5 – 3.6)	3.3 (2.4 – 4.6)	2.9 (2.3 – 3.5)
CHILDREN <18 IN HOUSEHOLD			
One	22.6 (21.3 – 24.0)	23.1 (20.8 – 25.5)	22.4 (20.8 – 24.1)
Two or three	60.7 (59.1 – 62.4)	61.6 (58.7 – 64.5)	60.4 (58.4 – 62.3)
Four or more	16.7 (15.4 – 18.1)	15.3 (13.1 – 17.8)	17.2 (15.7 – 18.9)
MOTHER'S AGE (YEARS)			
18-20	2.8 (2.3 – 3.4)	2.1 (1.4 – 3.2)	3.1 (2.4 – 3.9)
20-29	37.2 (35.6 – 38.8)	38.2 (35.2 – 41.3)	36.8 (34.9 – 38.7)
30-39	49.8 (48.1 – 51.4)	50.7 (47.7 – 53.8)	49.3 (47.4 – 51.3)
> 39	10.3 (9.2 – 11.4)	8.9 (7.3 – 10.8)	10.8 (9.6 – 12.3)
MOTHER's RACE/ETHNICITY†			
Hispanic (H)	25.5 (23.8 – 27.2)	31.2 (28.1 – 34.5)	23.2 (21.2 – 25.2)
Non-H white only	54.2 (52.6 – 55.9)	52.3 (49.3 – 55.3)	55.0 (53.0 – 57.0)
Non-H black only	13.0 (12.1 – 14.1)	10.4 (8.8 – 12.3)	14.1 (12.9 – 15.4)
Non-H other/multiple race	7.2 (6.4 – 8.1)	6.1 (4.8 – 7.7)	7.7 (6.7 – 8.8)

	Total (n=12,899)	Shot Card Group (n=3,813)	Recall Only Group (n=9,086)
MOTHER's EDUCATION LEVEL			
Less than high school	20.0 (18.5 – 21.6)	23.4 (20.4 – 26.6)	18.6 (16.9 – 20.5)
High school	30.0 (28.4 – 31.7)	28.2 (25.4 – 31.3)	30.8 (28.8 – 32.8)
Some College	11.1 (10.3 – 11.9)	10.3 (8.9 – 11.9)	11.4 (10.4 – 12.4)
Associate degree	7.9 (7.1 – 8.8)	7.9 (6.5 – 9.6)	7.9 (6.9 – 9.0)
Four-year college degree	18.4 (17.3 – 19.5)	18.8 (17.0 – 20.8)	18.2 (16.9 – 19.6)
Advanced degree	12.6 (11.8 – 13.5)	11.4 (9.9 – 13.0)	13.1 (12.2 – 14.1)
MOTHER's MARITAL STATUS			
Married	66.8 (65.1 – 68.4)	67.1 (64.0 – 70.1)	66.6 (64.7 – 68.5)
Never married	25.1 (23.6 – 26.6)	25.9 (23.0 – 29.1)	24.7 (23.1 – 26.5)
Divorced/separated/widowed etc.	8.2 (7.2 – 9.2)	6.9 (5.6 – 8.5)	8.7 (7.5 – 10.0)
GEOGRAPHIC MOBILITY SINCE CHILD'S BIRTH			
Moved from different state	7.0 (6.2 – 8.0)	7.8 (6.4 – 9.4)	6.7 (5.7 – 7.9)
Did not move from different state	93.0 (92.0 – 93.6)	92.2 (90.6 – 93.6)	93.3 (92.1 – 94.3)
CHILD's SEX			
Male	51.2 (49.6 – 52.8)	49.8 (46.9 – 52.8)	51.8 (49.9 – 53.6)
Female	48.8 (47.2 – 50.4)	50.2 (47.2 – 53.1)	48.2 (46.4 – 50.1)
CHILD's HEALTH INSURANCE†			
None (VFC eligible)	4.2 (3.6 – 4.9)	4.6 (3.4 – 6.2)	4.1 (3.4 – 4.9)
Medicaid/other VFC	45.6 (43.9 – 47.2)	50.0 (47.0 – 53.0)	43.8 (41.8 – 45.7)
Other public non VFC	6.8 (5.8 – 8.0)	6.3 (5.1 – 7.7)	7.0 (5.7 – 8.6)
Private/other non VFC	43.4 (41.9 – 44.9)	39.1 (36.4 – 41.8)	45.1 (43.3 – 47.0)
CHILD's AGE AS OF 11/1/2009†			
10-23 months	49.7 (48.1 – 51.4)	52.4 (49.4 – 55.5)	48.6 (46.7 – 50.6)
24-37 months	50.3 (48.6 – 51.9)	47.6 (44.5 – 50.6)	51.4 (49.4 – 53.3)
PROVIDER(s) RESPONSE†			
All identified providers responded			
One provider identified	58.5 (57.0 – 60.0)	49.8 (46.8 – 52.7)	62.1 (60.2 – 64.0)
Two or more providers	32.3 (30.8 – 33.8)	38.9 (35.9 – 41.9)	29.6 (27.9 – 31.4)
Multiple providers, not all resp.	9.2 (8.0 – 10.5)	11.4 (9.1 – 14.2)	8.2 (6.9 – 9.8)
PROVIDER(s) FACILITY TYPE†			
All public facilities	11.8 (10.7 – 13.1)	12.5 (10.4 – 15.1)	11.6 (10.2 – 13.0)
All hospital facilities	11.3 (10.3 – 12.3)	11.7 (9.9 – 13.9)	11.1 (9.9 – 12.3)
All private facilities	55.4 (53.8 – 57.0)	49.6 (46.6 – 52.6)	57.8 (55.8 – 59.7)
All military, other, WIC, or Unk.	6.1 (5.3 – 6.9)	6.4 (5.0 – 8.1)	5.9 (5.1 – 7.0)
Mixed	15.4 (14.3 – 16.7)	19.8 (17.5 – 22.3)	13.6 (12.3 – 15.1)

* Weighted percent by levels of each characteristic are shown with 95% confidence intervals.

† Children in the sample were stratified into two groups. The Shot Card Group consists of children for whom the adult respondent had the child's written vaccination record available during the interview, with household reported vaccinations based on both the shot card and recall. The Recall Only Group consists of children for whom the adult respondent only reported the child's vaccinations by recall without a shot card available.

§ The association of characteristic and shot card status (shot card, recall only) was statistically significant ($p<0.05$) by Wald Chi-square test for each characteristic.

¶ In the geographic classification of the U.S. population, states are grouped into the following four regions used by the U.S. Census Bureau. Northeast includes Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania. Midwest includes Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Kansas, and Nebraska. South includes Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Oklahoma, Arkansas, and Texas. West includes Washington, Oregon, California, Nevada, New Mexico, Arizona, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii.

Table 5-2 Estimated validity* of household as compared to provider reported seasonal influenza vaccination status (one or more doses in past 12 months) by shot card status and month of interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	RESPONDENT HAD SHOT CARD							RECALL ONLY						
	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}
TOTAL	**81.5** 77.9-84.7	**80.1** 76.3-83.3	**82.4** 79.0-85.3	**79.1** 75.1-82.6	**52.8** 49.8-55.8	**53.4** 50.3-56.4	**-0.6**	**80.2** 77.8-82.4	**70.1** 67.6-72.6	**72.6** 70.2-74.8	**78.3** 75.6-80.7	**54.9** 52.9-56.8	**49.6** 47.7-51.6	**5.3**
MONTH OF INTERVIEW														
October 2009	**88.2** 81.1-92.9	**74.9** 61.6-84.7	**84.3** 74.9-90.6	**80.6** 69.5-88.3	**63.3** 54.2-71.5	**60.5** 51.1-69.1	**2.8**	**63.7** 50.7-75.0	**81.5** 74.8-86.8	**81.1** 74.9-86.1	**64.4** 50.9-75.9	**43.5** 36.5-50.8	**55.4** 47.8-62.7	**-11.9**
November 2009	**89.0** 78.9-94.6	**78.5** 63.3-88.6	**84.1** 71.0-92.0	**84.8** 72.4-92.2	**59.4** 49.9-68.2	**56.1** 46.3-65.6	**3.3**	**76.7** 69.8-82.4	**70.8** 60.8-79.1	**72.8** 62.9-80.8	**74.9** 68.0-80.7	**53.2** 47.0-59.3	**50.5** 44.2-56.7	**2.7**
December 2009	**89.2** 81.0-94.2	**69.0** 54.5-80.5	**79.0** 66.3-87.9	**83.0** 72.3-90.1	**64.0** 55.9-71.4	**56.7** 47.7-65.3	**7.3**	**81.3** 75.1-86.3	**75.9** 68.9-81.7	**72.9** 65.8-78.9	**83.6** 77.7-88.2	**49.4** 44.1-54.8	**44.3** 39.3-49.5	**5.1**
January 2010	**85.1** 76.4-91.0	**83.0** 72.9-89.9	**82.1** 72.2-89.0	**85.9** 77.0-91.7	**49.6** 40.9-58.2	**47.8** 39.3-56.5	**1.8**	**83.6** 77.3-88.5	**73.0** 66.0-79.0	**75.3** 69.1-80.6	**81.9** 74.8-87.4	**55.0** 49.2-60.7	**49.6** 43.8-55.3	**5.4**
February 2010	**86.0** 77.6-91.5	**78.4** 67.6-86.3	**84.2** 75.7-90.1	**80.6** 69.9-88.2	**58.5** 50.7-65.8	**57.3** 49.5-64.7	**1.2**	**83.1** 76.2-88.4	**65.8** 58.2-72.6	**68.3** 61.6-74.3	**81.4** 73.7-87.3	**57.2** 51.9-62.5	**47.0** 41.9-52.2	**10.2**
March 2010	**81.6** 70.9-88.9	**82.0** 73.5-88.2	**83.6** 75.7-89.2	**79.9** 68.5-87.8	**51.6** 42.6-60.4	**52.8** 43.9-61.6	**-1.2**	**85.2** 79.0-89.8	**69.1** 61.7-75.6	**70.1** 62.9-76.4	**84.6** 78.2-89.4	**55.9** 50.6-61.1	**46.0** 40.7-51.3	**9.9**
April 2010	**76.9** 54.7-90.2	**76.4** 60.5-87.2	**74.8** 58.6-86.1	**78.4** 56.7-91.0	**49.0** 38.2-59.9	**47.6** 36.8-58.6	**1.4**	**90.2** 85.1-93.7	**62.6** 54.7-69.9	**76.3** 70.1-81.5	**82.7** 74.5-88.7	**67.6** 62.1-72.6	**57.2** 51.3-62.8	**10.4**
May 2010	**64.9** 52.5-75.5	**85.9** 78.0-91.3	**85.1** 76.8-90.8	**66.4** 54.2-76.8	**42.2** 33.7-51.1	**55.3** 46.3-63.9	**-13.1**	**84.0** 77.7-88.7	**72.1** 63.9-79.0	**75.4** 67.7-81.7	**81.5** 74.7-86.9	**56.2** 48.6-63.5	**50.4** 42.9-57.9	**5.8**
June 2010	**80.4** 68.9-88.4	**85.7** 74.9-92.3	**83.8** 71.9-91.3	**82.6** 72.2-89.7	**46.0** 37.0-55.1	**47.9** 38.9-57.0	**-1.9**	**73.5** 64.6-80.9	**63.1** 54.0-71.3	**65.2** 56.7-73.0	**71.6** 61.8-79.8	**54.7** 49.1-60.2	**48.5** 42.8-54.4	**6.2**
July/Aug. 2010	**72.2** 53.8-85.3	**85.5** 74.4-92.3	**86.7** 76.8-92.8	**70.2** 50.6-84.4	**47.2** 36.6-58.0	**56.6** 45.6-67.1	**-9.4**	**75.7** 66.8-82.8	**64.5** 53.9-73.8	**71.9** 63.5-79.1	**68.8** 58.3-77.7	**57.4** 50.1-64.5	**54.6** 47.8-61.3	**2.8**

Weighted percents with 95% confidence intervals are presented for validity parameters (see Appendix 6.1 for definitions of validity parameters; Se=sensitivity, Sp=specificity, PPV=positive predictive value, NPV=negative predictive value, P_{HH}=vaccination prevalence by household report, P_{PR}=vaccination prevalence by provider report).

Table 5-3 Estimated validity* of household as compared to provider reported pH1N1influenza vaccination status (one or more doses since October 2009) by shot card status and month of interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	RESPONDENT HAD SHOT CARD							RECALL ONLY						
	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}
TOTAL	**85.0** 80.5-88.7	**86.2** 83.4-88.5	**69.1** 63.7-74.0	**94.1** 92.1-95.5	**32.8** 29.9-35.9	**26.7** 23.9-29.6	**6.1**	**93.2** 91.3-94.7	**82.8** 81.1-84.3	**62.7** 59.8-65.6	**97.5** 96.8-98.1	**35.2** 33.4-37.1	**23.7** 22.2-25.3	**11.5**
MONTH OF INTERVIEW														
October 2009	**93.3** 60.9-99.2	**98.7** 94.4-99.7	**38.1** 9.1-79.1	**99.9** 99.6-100	**2.0** 0.7-5.5	**0.8** 0.3-2.1	**1.2**	**89.0** 59.7-97.8	**97.8** 95.6-98.9	**46.9** 23.2-72.1	**99.8** 98.9-99.9	**4.1** 2.4-6.9	**2.2** 1.0-4.5	**1.9**
November 2009	**62.5** 29.6-86.8	**91.3** 84.8-95.2	**51.1** 34.7-67.4	**94.4** 81.3-98.5	**15.5** 10.8-21.8	**12.7** 7.5-20.7	**2.8**	**99.7** 98.1-100	**92.3** 89.1-94.7	**58.4** 46.2-69.7	**100.0** 99.8-100	**16.6** 13.0-21.0	**9.7** 7.0-13.4	**6.9**
December 2009	**86.8** 75.3-93.5	**84.0** 75.5-90.0	**63.4** 47.0-77.2	**95.3** 91.2-97.5	**33.1** 24.7-42.7	**24.1** 16.7-33.6	**9.0**	**94.6** 88.9-97.5	**83.4** 77.7-87.8	**63.5** 54.1-72.0	**98.1** 95.9-99.1	**34.9** 30.0-40.1	**23.4** 19.5-27.8	**11.5**
January 2010	**85.8** 70.6-93.8	**79.7** 71.2-86.2	**60.6** 46.0-73.5	**93.9** 86.9-97.3	**37.8** 29.5-46.8	**26.7** 19.1-35.9	**11.1**	**98.0** 93.1-99.4	**85.2** 81.0-88.6	**64.0** 56.1-71.1	**99.4** 97.8-99.8	**32.4** 27.8-37.3	**21.1** 17.4-25.4	**11.3**
February 2010	**88.6** 80.2-93.7	**88.6** 80.9-93.4	**78.6** 65.8-87.5	**94.3** 89.9-96.8	**36.2** 29.0-44.0	**32.1** 25.3-39.7	**4.1**	**97.3** 94.3-98.8	**74.5** 68.6-79.7	**57.1** 49.0-64.8	**98.8** 97.3-99.4	**44.0** 38.9-49.3	**25.8** 21.7-30.5	**18.2**
March 2010	**81.6** 67.5-90.5	**89.3** 84.1-92.9	**83.0** 73.7-89.5	**88.3** 78.2-94.1	**38.5** 30.2-47.5	**39.2** 30.1-49.0	**-0.7**	**95.3** 91.5-97.5	**80.8** 75.3-85.3	**65.6** 57.7-72.7	**97.8** 96.0-98.8	**40.3** 35.3-45.4	**27.7** 23.6-32.2	**12.6**
April 2010	**92.6** 86.1-96.2	**78.3** 61.8-88.9	**66.2** 44.4-82.8	**95.8** 92.8-97.7	**44.0** 33.1-55.6	**31.5** 21.7-43.2	**12.5**	**94.4** 89.5-97.1	**73.6** 67.2-79.1	**65.5** 57.6-72.7	**96.1** 92.7-98.0	**50.0** 44.2-55.7	**34.6** 29.3-40.4	**15.4**
May 2010	**83.2** 72.0-90.4	**82.8** 74.1-89.0	**73.4** 60.3-83.4	**89.6** 82.5-94.0	**41.2** 32.6-50.3	**36.4** 27.9-45.8	**4.8**	**91.2** 84.5-95.2	**81.9** 76.1-86.5	**67.4** 60.0-74.0	**95.8** 92.5-97.7	**39.4** 32.3-47.0	**29.1** 23.3-35.7	**10.3**
June 2010	**89.0** 73.8-95.9	**82.8** 73.3-89.4	**66.2** 50.6-78.9	**95.2** 87.9-98.2	**36.9** 28.4-46.2	**27.4** 19.9-36.6	**9.5**	**86.8** 77.7-92.5	**73.6** 66.2-79.9	**60.9** 51.5-69.6	**92.2** 86.4-95.6	**45.8** 40.0-51.7	**32.1** 26.9-37.8	**13.7**
July/Aug. 2010	**82.9** 69.0-91.4	**87.9** 79.4-93.2	**74.4** 60.5-84.7	**92.4** 84.8-96.3	**33.2** 24.9-42.6	**29.8** 22.0-38.9	**3.4**	**82.8** 69.6-91.0	**76.8** 69.5-82.7	**61.3** 51.9-70.0	**91.0** 82.8-95.5	**41.6** 34.7-48.8	**30.8** 24.6-37.7	**10.8**

Weighted percents with 95% confidence intervals are presented for validity parameters (see Appendix 6.1 for definitions of validity parameters; Se=sensitivity, Sp=specificity, PPV=positive predictive value, NPV=negative predictive value, P_{HH}=vaccination prevalence by household report, P_{PR}=vaccination prevalence by provider report).

Table 5-4 Estimated validity* of household as compared to provider reported seasonal influenza vaccination status (two or more doses in past 12 months) by shot card status and month of interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	RESPONDENT HAD SHOT CARD							RECALL ONLY						
	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}
TOTAL	**45.3** 37.0-53.9	**96.5** 95.1-97.5	**71.9** 62.6-79.6	**89.9** 87.4-91.9	**10.5** 8.6-12.7	**16.6** 14.2-19.3	**-6.1**	**38.8** 34.1-43.8	**90.3** 89.2-91.3	**35.7** 31.1-40.5	**91.4** 90.4-92.3	**13.3** 12.1-14.5	**12.2** 11.1-13.4	**1.1**
MONTH OF INTERVIEW														
October 2009	**59.1** 42.3-74.0	**94.6** 89.5-97.3	**83.8** 69.4-92.2	**83.1** 74.1-89.4	**22.6** 15.6-31.6	**32.0** 23.8-41.4	**-9.4**	**45.2** 32.2-58.9	**94.0** 90.9-96.1	**67.9** 53.5-79.6	**85.9** 80.9-89.7	**14.7** 10.5-20.1	**22.0** 16.9-28.1	**-7.3**
November 2009	**46.5** 23.5-71.0	**92.8** 80.0-97.7	**71.6** 38.4-91.1	**81.7** 68.5-90.2	**18.2** 10.2-30.3	**28.0** 18.3-40.2	**-9.8**	**23.5** 15.2-34.4	**92.9** 89.9-95.1	**39.3** 26.4-54.0	**86.2** 82.3-89.3	**9.7** 7.3-12.9	**16.3** 13.0-20.3	**-6.6**
December 2009	**44.3** 20.4-71.1	**97.6** 92.7-99.2	**85.0** 57.0-96.0	**85.2** 73.7-92.2	**12.2** 5.9-23.5	**23.4** 14.6-35.2	**-11.2**	**45.6** 31.2-60.8	**88.9** 85.4-91.6	**39.6** 26.4-54.4	**91.1** 87.9-93.5	**15.9** 12.3-20.2	**13.8** 10.4-18.0	**2.1**
January 2010	**33.4** 16.9-55.4	**97.8** 94.5-99.2	**57.4** 29.7-81.1	**94.4** 90.0-97.0	**4.7** 2.6-8.1	**8.0** 5.0-12.5	**-3.3**	**41.1** 26.5-57.4	**91.9** 88.7-94.2	**38.4** 25.1-53.7	**92.7** 89.2-95.1	**11.7** 8.8-15.4	**11.0** 8.0-14.8	**0.7**
February 2010	**45.5** 24.3-68.5	**97.7** 94.9-99.0	**67.3** 41.6-85.6	**94.6** 89.9-97.2	**6.3** 3.7-10.5	**9.3** 5.8-14.5	**-3.0**	**43.1** 29.0-58.4	**88.3** 83.4-91.8	**24.2** 14.9-36.7	**94.7** 92.1-96.5	**14.2** 10.6-18.8	**8.0** 5.9-10.7	**6.2**
March 2010	**60.7** 39.5-78.5	**98.6** 96.6-99.4	**81.1** 58.9-92.8	**96.1** 93.3-97.8	**6.9** 3.9-11.8	**9.2** 5.8-14.2	**-2.3**	**45.4** 30.5-61.2	**91.9** 89.1-94.0	**34.4** 22.4-48.8	**94.7** 92.3-96.4	**11.3** 8.7-14.5	**8.6** 6.3-11.6	**2.7**
April 2010	**57.5** 27.6-82.7	**97.2** 93.8-98.8	**74.0** 50.3-88.9	**94.3** 84.6-98.0	**9.4** 5.5-15.7	**12.1** 6.8-20.8	**-2.7**	**32.3** 17.5-51.7	**86.0** 81.5-89.6	**22.3** 12.0-37.7	**91.1** 86.5-94.2	**16.0** 12.3-20.6	**11.1** 7.8-15.5	**4.9**
May 2010	**32.7** 19.3-49.6	**97.6** 94.1-99.0	**74.1** 51.1-88.7	**87.2** 79.2-92.4	**7.7** 5.1-11.6	**17.5** 12.0-24.9	**-9.8**	**30.4** 18.6-45.4	**88.8** 84.7-91.9	**20.6** 12.4-32.3	**93.0** 89.8-95.3	**12.9** 9.7-16.9	**8.7** 6.3-11.9	**4.2**
June 2010	**27.3** 13.9-46.5	**93.7** 87.4-96.9	**40.2** 20.8-63.2	**89.3** 81.6-94.0	**9.1** 5.6-14.6	**13.4** 8.6-20.4	**-4.3**	**42.9** 30.6-56.3	**89.7** 86.6-92.1	**36.8** 24.5-51.2	**91.8** 87.9-94.5	**14.3** 11.2-18.1	**12.3** 8.6-17.3	**2.0**
July/Aug. 2010	**48.6** 27.6-70.1	**96.0** 89.9-98.5	**67.4** 39.1-86.9	**91.7** 85.1-95.5	**10.5** 6.0-17.5	**14.5** 9.3-22.0	**-4.0**	**37.6** 21.9-56.5	**93.3** 89.6-95.7	**48.0** 29.4-67.2	**90.1** 85.6-93.3	**11.1** 7.7-15.7	**14.2** 10.3-19.1	**-3.1**

Weighted percents with 95% confidence intervals are presented for validity parameters (see Appendix 6.1 for definitions of validity parameters; Se=sensitivity, Sp=specificity, PPV=positive predictive value, NPV=negative predictive value, P_{HH}=vaccination prevalence by household report, P_{PR}=vaccination prevalence by provider report).

Table 5-5 Estimated validity* of household as compared to provider reported pH1N1influenza vaccination status (two or more doses in since October 2009) by shot card status and month of interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	RESPONDENT HAD SHOT CARD							RECALL ONLY						
	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}	Se	Sp	PPV	NPV	P_{HH}	P_{PR}	P_{HH} -P_{PR}
TOTAL	**60.1** 51.1-68.5	**95.0** 93.4-96.2	**62.5** 53.8-70.5	**94.5** 92.7-95.9	**11.7** 10.0-13.8	**12.2** 10.3-14.3	**-0.5**	**86.5** 83.0-89.4	**91.2** 90.2-92.1	**51.7** 47.5-55.9	**98.4** 98.0-98.8	**16.4** 15.2-17.8	**9.8** 8.8-10.9	**6.6**
MONTH OF INTERVIEW														
October 2009	-	-	-	-	**0.0**	**0.0**	-	-	-	-	-	**0.0**	**0.0**	-
November 2009	**67.9** 18.2-95.3	**97.8** 89.6-99.6	**30.4** 5.7-76.0	**99.5** 96.8-99.9	**3.1** 0.9-9.6	**1.4** 0.5-3.3	**1.7**	**86.5** 38.8-98.5	**98.8** 96.7-99.6	**26.7** 6.8-64.4	**99.9** 99.5-100	**1.6** 0.7-3.6	**0.5** 0.2-1.5	**1.1**
December 2009	**60.5** 22.4-89.1	**97.1** 92.3-98.9	**52.5** 26.6-77.1	**97.9** 90.2-99.6	**5.9** 3.4-10.0	**5.1** 2.5-10.0	**0.8**	**91.6** 77.5-97.2	**96.7** 94.8-97.6	**56.6** 42.2-69.9	**99.6** 98.8-99.9	**7.3** 5.5-9.7	**4.5** 3.2-6.5	**2.8**
January 2010	**76.2** 55.6-89.1	**95.2** 90.4-97.7	**55.7** 34.9-74.7	**98.1** 95.6-99.2	**10.1** 6.6-14.9	**7.4** 4.8-11.0	**2.7**	**85.4** 69.5-93.8	**93.2** 90.2-95.3	**50.5** 38.8-62.2	**98.7** 96.9-99.5	**12.8** 10.0-16.2	**7.6** 5.6-10.1	**5.2**
February 2010	**78.9** 64.2-88.7	**92.3** 86.8-95.6	**68.4** 50.3-82.3	**95.4** 92.1-97.3	**20.2** 14.2-27.8	**17.5** 12.0-24.9	**2.7**	**92.2** 84.6-96.2	**85.4** 80.5-89.3	**46.7** 35.1-58.7	**98.7** 97.5-99.4	**24.0** 19.5-29.2	**12.2** 8.9-16.4	**11.8**
March 2010	**34.7** 18.0-56.2	**94.2** 90.7-96.4	**60.1** 45.3-73.2	**85.1** 71.5-92.8	**11.7** 8.5-15.8	**20.2** 12.6-30.8	**-8.5**	**95.5** 91.6-97.7	**90.4** 87.1-92.9	**63.4** 54.0-71.9	**99.1** 98.4-99.5	**22.4** 18.7-26.6	**14.9** 11.8-18.5	**7.5**
April 2010	**65.7** 45.4-81.6	**95.8** 92.7-97.6	**71.3** 54.6-83.6	**94.6** 89.5-97.3	**12.6** 8.4-18.4	**13.7** 9.0-20.1	**-1.1**	**82.5** 68.1-91.2	**82.9** 76.9-87.5	**49.7** 39.2-60.3	**95.8** 91.5-98.0	**28.3** 23.4-33.8	**17.1** 13.4-21.5	**11.2**
May 2010	**56.4** 38.3-73.0	**86.6** 74.3-93.5	**50.9** 29.4-72.0	**89.0** 81.6-93.7	**21.9** 14.7-31.4	**19.7** 14.0-27.1	**2.2**	**80.2** 67.8-88.7	**86.3** 82.2-89.6	**49.0** 36.4-61.7	**96.4** 94.1-97.8	**23.1** 18.0-29.1	**14.1** 9.8-19.9	**9.0**
June 2010	**66.2** 44.2-82.9	**96.1** 93.6-97.6	**79.2** 62.3-89.7	**92.7** 87.1-95.9	**15.4** 9.2-24.6	**18.4** 11.7-27.8	**-3.0**	**84.5** 75.4-90.6	**86.6** 83.0-89.6	**52.1** 42.1-62.0	**97.0** 95.2-98.2	**23.8** 19.6-28.6	**14.7** 11.2-19.0	**9.1**
July/Aug. 2010	**55.5** 37.1-72.5	**94.1** 88.4-97.1	**66.5** 45.7-82.3	**91.0** 84.5-94.9	**14.4** 9.5-21.4	**17.3** 11.7-24.7	**-2.9**	**77.9** 64.4-87.4	**86.0** 80.2-90.3	**48.5** 35.4-61.8	**95.8** 92.8-97.6	**23.2** 18.0-29.5	**14.5** 10.5-19.6	**8.7**

Weighted percents with 95% confidence intervals are presented for validity parameters (see Appendix 6.1 for definitions of validity parameters; Se=sensitivity, Sp=specificity, PPV=positive predictive value, NPV=negative predictive value, P_{HH}=vaccination prevalence by household report, P_{PR}=vaccination prevalence by provider report).

Table 5-6 Adjusted* estimates (%) of sensitivity and specificity of parental report of child's seasonal influenza vaccination status (one or more doses in past 12 months) as of date of interview using shot card and recall (shot card group), by selected characteristics, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Characteristic	Adjusted Sensitivity	Adjusted Sensitivity Ratio†	Adjusted Specificity	Adjusted Specificity Ratio
MONTH OF INTERVIEW				
October 2009	88	**1.27 (1.03-1.57)**	74	0.87 (0.72-1.04)
November 2009	88	**1.28 (1.02-1.62)**	75	0.89 (0.73-1.08)
December 2009	92	**1.33 (1.07-1.65)**	68	**0.80 (0.66-0.97)**
January 2010	87	**1.26 (1.01-1.56)**	83	0.98 (0.85-1.14)
February 2010	82	1.20 (0.96-1.49)	81	0.95 (0.82-1.10)
March 2010	83	1.20 (0.97-1.50)	81	0.95 (0.83-1.09)
April 2010	76	1.12 (0.88-1.44)	76	0.90 (0.76-1.06)
May 2010	66	0.95 (0.74-1.21)	85	1.00 (0.87-1.14)
June 2010	78	1.13 (0.90-1.40)	89	1.04 (0.93-1.17)
July/August 2010	69	Referent	85	Referent
ADULT RESPONDENT				
Mother	82	1.11 (0.97-1.27)	79	0.96 (0.89-1.05)
Father	74	Referent	83	Referent
HOUSEHOLD POVERTY STATUS				
Above Poverty				
Annual Income >$75,000	78	1.11 (0.85-1.44)	74	0.87 (0.72-1.06)
Annual Income ≤$75,000	83	1.18 (0.92-1.51)	81	0.95 (0.81-1.11)
Below Poverty	84	1.20 (0.94-1.55)	82	0.97 (0.83-1.14)
Unknown	70	Referent	85	Referent
CHILDREN <18 IN HOUSEHOLD				
One	80	1.09 (0.93-1.28)	84	1.03 (0.91-1.17)
Two or three	84	1.15 (1.00-1.32)	78	0.97 (0.86-1.08)
Four or more	73	Referent	81	Referent
MOTHER'S AGE (YEARS)				
18-20	62	0.69 (0.41-1.16)	88	1.06 (0.82-1.37)
20-29	82	0.91 (0.83-1.00)	76	0.92 (0.79-1.07)
30-39	80	**0.89 (0.81-0.98)**	81	0.98 (0.86-1.11)
> 39	90	Referent	83	Referent
MOTHER's RACE/ETHNICITY				
Hispanic (H)	74	Referent	74	Referent
Non-H white only	85	**1.15 (1.03-1.29)**	81	1.10 (0.99-1.23)
Non-H black only	86	**1.16 (1.02-1.32)**	87	**1.17 (1.03-1.34)**
Non-H other/multiple race	83	1.12 (0.95-1.32)	84	1.14 (0.99-1.32)
MOTHER's EDUCATION LEVEL				
Less than high school	76	0.89 (0.75-1.04)	80	1.12 (0.93-1.33)
High school	82	0.96 (0.86-1.08)	86	**1.20 (1.02-1.39)**
Some College	82	0.96 (0.84-1.11)	80	1.12 (0.95-1.31)
Associate degree	85	0.99 (0.89-1.11)	89	**1.23 (1.05-1.44)**
Four-year college degree	82	0.96 (0.88-1.06)	70	0.98 (0.85-1.12)
Advanced degree	86	Referent	72	Referent
MOTHER's MARITAL STATUS				
Married	84	Referent	78	Referent
Never married	76	0.90 (0.80-1.02)	83	1.06 (0.94-1.19)
Divorced/separated/widowed etc.	69	0.82 (0.67-1.01)	84	1.08 (0.93-1.24)

GEOGRAPHIC MOBILITY SINCE CHILD'S BIRTH				
Moved from different state	79	0.97 (0.86-1.10)	70	0.87 (0.72-1.05)
Did not move from different state	82	Referent	81	Referent
CHILD's SEX				
Male	79	0.94 (0.88-1.01)	77	0.93 (0.87-1.00)
Female	84	Referent	83	Referent
CHILD's HEALTH INSURANCE				
None (VFC eligible)	84	1.08 (0.86-1.35)	75	0.91 (0.76-1.09)
Medicaid/other VFC	82	1.05 (0.93-1.19)	77	0.93 (0.85-1.03)
Other public non VFC	88	1.12 (0.99-1.27)	76	0.92 (0.79-1.07)
Private/other non VFC	78	Referent	83	Referent
CHILD's AGE AS OF 11/1/2009				
10-23 months	83	1.05 (0.96-1.13)	76	**0.91 (0.84-0.98)**
24-37 months	79	Referent	84	Referent

*** Predictive marginal estimates from logistic regression model with parental reported influenza vaccination status as the outcome and independent variables including provider reported vaccination status, characteristics, and interaction terms of provider vaccination status and each characteristic.**

† Adjusted ratios with 95% confidence limits in parentheses, based on ratios of predictive marginal (adjusted prevalence) estimates for sensitivity and specificity.

Table 5-7 Adjusted* estimates (%) of sensitivity and specificity of parental report of child's seasonal influenza vaccination status (one or more doses in past 12 months) as of date of interview using recall only (recall only group), by selected characteristics, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Characteristic	Adjusted Sensitivity	Adjusted Sensitivity Ratio†	Adjusted Specificity	Adjusted Specificity Ratio
MONTH OF INTERVIEW				
October 2009	65	**0.80 (0.66-0.97)**	80	**1.22 (1.03-1.45)**
November 2009	75	0.93 (0.82-1.06)	70	1.07 (0.89-1.29)
December 2009	81	1.00 (0.89-1.11)	73	1.13 (0.95-1.33)
January 2010	83	1.02 (0.92-1.14)	70	1.08 (0.91-1.28)
February 2010	81	1.00 (0.89-1.12)	64	0.99 (0.82-1.18)
March 2010	85	1.05 (0.94-1.17)	66	1.01 (0.85-1.21)
April 2010	89	1.11 (1.00-1.22)	61	0.94 (0.78-1.14)
May 2010	88	1.09 (0.99-1.21)	72	1.10 (0.92-1.32)
June 2010	74	0.91 (0.80-1.05)	63	0.97 (0.81-1.17)
July/August 2010	81	Referent	65	Referent
ADULT RESPONDENT				
Mother	82	**1.10 (1.02-1.20)**	69	1.02 (0.92-1.12)
Father	74	Referent	68	Referent
HOUSEHOLD POVERTY STATUS				
Above Poverty				
Annual Income >$75,000	87	**1.22 (1.04-1.44)**	68	1.04 (0.84-1.28)
Annual Income ≤$75,000	80	1.12 (0.95-1.32)	72	1.09 (0.90-1.33)
Below Poverty	79	1.11 (0.94-1.32)	66	1.00 (0.81-1.25)
Unknown	71	Referent	65	Referent
CHILDREN <18 IN HOUSEHOLD				
One	84	**1.11 (1.02-1.22)**	68	0.91 (0.81-1.02)
Two or three	81	1.08 (1.00-1.18)	67	**0.90 (0.82-0.98)**
Four or more	75	Referent	75	Referent
MOTHER'S AGE (YEARS)				
18-20	87	1.09 (0.92-1.28)	35	**0.48 (0.30-0.78)**
20-29	82	1.03 (0.92-1.15)	64	**0.87 (0.76-0.98)**
30-39	79	0.99 (0.90-1.09)	72	0.97 (0.88-1.08)
> 39	80	Referent	73	Referent
MOTHER's RACE/ETHNICITY				
Hispanic (H)	80	Referent	60	Referent
Non-H white only	83	1.03 (0.96-1.12)	71	**1.17 (1.03-1.34)**
Non-H black only	79	0.98 (0.89-1.08)	71	**1.17 (1.02-1.35)**
Non-H other/multiple race	72	0.90 (0.79-1.02)	75	**1.24 (1.06-1.47)**
MOTHER's EDUCATION LEVEL				
Less than high school	76	0.90 (0.81-1.01)	72	**1.20 (1.01-1.42)**
High school	80	0.95 (0.88-1.03)	71	**1.20 (1.03-1.39)**
Some College	83	0.99 (0.91-1.07)	73	**1.23 (1.06-1.42)**
Associate degree	86	1.02 (0.95-1.11)	69	1.15 (0.98-1.36)
Four-year college degree	82	0.98 (0.92-1.05)	64	1.07 (0.94-1.23)
Advanced degree	84	Referent	60	Referent
MOTHER's MARITAL STATUS				
Married	80	Referent	69	Referent
Never married	82	1.02 (0.94-1.11)	66	0.97 (0.86-1.08)
Divorced/separated/widowed etc.	78	0.98 (0.87-1.09)	74	1.08 (0.96-1.22)

GEOGRAPHIC MOBILITY SINCE CHILD'S BIRTH				
Moved from different state	78	0.97 (0.88-1.07)	64	0.93 (0.79-1.10)
Did not move from different state	81	Referent	69	Referent
CHILD's SEX				
Male	79	0.96 (0.91-1.00)	68	0.99 (0.92-1.06)
Female	83	Referent	69	Referent
CHILD's HEALTH INSURANCE				
None (VFC eligible)	73	0.87 (0.70-1.09)	76	1.13 (0.99-1.30)
Medicaid/other VFC	78	0.94 (0.87-1.01)	72	1.06 (0.96-1.18)
Other public non VFC	80	0.96 (0.82-1.11)	54	0.80 (0.62-1.04)
Private/other non VFC	84	Referent	67	Referent
CHILD's AGE AS OF 11/1/2009				
10-23 months	79	0.96 (0.90-1.02)	69	1.02 (0.95-1.10)
24-37 months	82	Referent	68	Referent

*** Predictive marginal estimates from logistic regression model with parental reported influenza vaccination status as the outcome and independent variables including provider reported vaccination status, characteristics, and interaction terms of provider vaccination status and each characteristic.**

† Adjusted ratios with 95% confidence limits in parentheses, based on ratios of predictive marginal (adjusted prevalence) estimates for sensitivity and specificity.

Table 5-8 Adjusted* estimates (%) of sensitivity and specificity of parental report of child's pH1N1 influenza vaccination status (since October 2009) as of date of interview using shot card and recall (shot card group), by selected characteristics, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Characteristic	Adjusted Sensitivity	Adjusted Sensitivity Ratio†	Adjusted Specificity	Adjusted Specificity Ratio
MONTH OF INTERVIEW				
October 2009	91	1.04 (0.83-1.30)	99	**1.11 (1.02-1;21)**
November 2009	64	0.74 (0.52-1.04)	91	1.02 (0.93-1.13)
December 2009	85	0.98 (0.83-1.15)	83	0.93 (0.83-1.05)
January 2010	85	0.98 (0.83-1.16)	80	0.90 (0.80-1.03)
February 2010	86	0.99 (0.87-1.13)	88	0.99 (0.88-1.10)
March 2010	82	0.94 (0.81-1.08)	88	0.99 (0.90-1.09)
April 2010	91	1.04 (0.92-1.18)	78	0.88 (0.75-1.03)
May 2010	87	1.00 (0.87-1.15)	82	0.93 (0.82-1.04)
June 2010	89	1.02 (0.90-1.16)	82	0.93 (0.82-1.05)
July/August 2010	87	Referent	89	Referent
ADULT RESPONDENT				
Mother	84	1.01 (0.89-1.13)	85	0.94 (0.89-1.00)
Father	84	Referent	90	Referent
HOUSEHOLD POVERTY STATUS				
Above Poverty				
Annual Income >$75,000	89	0.95 (0.84-1.08)	81	1.03 (0.87-1.22)
Annual Income ≤$75,000	86	0.92 (0.83-1.03)	87	1.11 (0.95-1.29)
Below Poverty	78	**0.84 (0.73-0.97)**	87	1.11 (0.95-1.29)
Unknown	93	Referent	79	Referent
CHILDREN <18 IN HOUSEHOLD				
One	87	1.02 (0.89-1.18)	84	0.92 (0.84-1.01)
Two or three	83	0.98 (0.87-1.10)	84	**0.93 (0.87-0.90)**
Four or more	85	Referent	91	Referent
MOTHER'S AGE (YEARS)				
18-20	98	**1.17 (1.02-1.34)**	95	1.09 (0.97-1.21)
20-29	86	1.03 (0.89-1.18)	83	0.95 (0.87-1.04)
30-39	82	0.98 (0.85-1.12)	86	0.98 (0.91-1.06)
> 39	84	Referent	87	Referent
MOTHER's RACE/ETHNICITY				
Hispanic (H)	86	Referent	81	Referent
Non-H white only	86	1.00 (0.90-1.12)	86	1.06 (0.98-1.14)
Non-H black only	73	0.85 (0.67-1.07)	94	**1.15 (1.04-1.27)**
Non-H other/multiple race	77	0.90 (0.74-1.10)	81	1.00 (0.86-1.15)
MOTHER's EDUCATION LEVEL				
Less than high school	80	0.92 (0.76-1.12)	84	1.06 (0.91-1.23)
High school	87	1.00 (0.87-1.14)	89	1.11 (0.99-1.25)
Some College	84	0.97 (0.83-1.12)	89	1.12 (0.99-1.27)
Associate degree	75	0.85 (0.69-1.06)	84	1.06 (0.93-1.20)
Four-year college degree	88	1.00 (0.91-1.11)	83	1.04 (0.95-1.14)
Advanced degree	87		80	Referent
MOTHER's MARITAL STATUS				
Married	85	Referent	86	Referent
Never married	82	0.97 (0.85-1.11)	85	0.99 (0.90-1.08)
Divorced/separated/widowed etc.	90	1.06 (0.91-1.23)	80	0.93 (0.81-1.08)

GEOGRAPHIC MOBILITY SINCE CHILD'S BIRTH				
Moved from different state	90	1.07 (0.96-1.19)	87	1.02 (0.94-1.11)
Did not move from different state	84	Referent	85	Referent
CHILD's SEX				
Male	82	0.95 (0.87-1.03)	87	1.04 (0.99-1.10)
Female	87	Referent	83	Referent
CHILD's HEALTH INSURANCE				
None (VFC eligible)	88	1.05 (0.80-1.37)	89	1.03 (0.92-1.18)
Medicaid/other VFC	85	1.02 (0.90-1.15)	85	0.99 (0.92-1.07)
Other public non VFC	73	0.87 (0.68-1.11)	78	0.91 (0.78-1.06)
Private/other non VFC	84	Referent	86	Referent
CHILD's AGE AS OF 11/1/2009				
10-23 months	84	1.00 (0.91-1.10)	85	1.00 (0.95-1.06)
24-37 months	84	Referent	85	Referent

*** Predictive marginal estimates from logistic regression model with parental reported influenza vaccination status as the outcome and independent variables including provider reported vaccination status, characteristics, and interaction terms of provider vaccination status and each characteristic.**

† Adjusted ratios with 95% confidence limits in parentheses, based on ratios of predictive marginal (adjusted prevalence) estimates for sensitivity and specificity.

Table 5-9 Adjusted* estimates (%) of sensitivity and specificity of parental report of child's pH1N1 influenza vaccination status (since October 2009) as of date of interview using recall only (recall only group), by selected characteristics, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Characteristic	Adjusted Sensitivity	Adjusted Sensitivity Ratio†	Adjusted Specificity	Adjusted Specificity Ratio
MONTH OF INTERVIEW				
October 2009	80	0.92 (0.70-1.22)	97	**1.29 (1.17-1.41)**
November 2009	99	**1.14 (1.04-1.25)**	92	**1.22 (1.10-1.34)**
December 2009	93	1.07 (0.97-1.19)	85	**1.13 (1.02-1.25)**
January 2010	99	**1.14 (1.03-1.25)**	85	**1.13 (1.02-1.25)**
February 2010	95	1.09 (0.98-1.20)	74	0.98 (0.87-1.10)
March 2010	94	1.08 (0.97-1.20)	79	1.05 (0.94-1.18)
April 2010	93	1.07 (0.96-1.18)	73	0.96 (0.85-1.09)
May 2010	90	1.03 (0.93-1.15)	82	1.08 (0.97-1.21)
June 2010	84	0.96 (0.86-1.08)	73	0.97 (0.85-1.10)
July/August 2010	87	Referent	76	Referent
ADULT RESPONDENT				
Mother	93	**1.06 (1.01-1.12)**	83	**1.09 (1.03-1.16)**
Father	87	Referent	76	Referent
HOUSEHOLD POVERTY STATUS				
Above Poverty				
Annual Income >$75,000	94	**1.21 (1.07-1.36)**	83	1.08 (0.96-1.22)
Annual Income ≤$75,000	91	**1.17 (1.03-1.32)**	84	1.08 (0.96-1.22)
Below Poverty	93	**1.20 (1.05-1.36)**	78	1.01 (0.90-1.15)
Unknown	78	Referent	77	Referent
CHILDREN <18 IN HOUSEHOLD				
One	95	1.05 (0.99-1.12)	83	1.03 (0.96-1.10)
Two or three	92	1.02 (0.96-1.07)	82	1.01 (0.95-1.07)
Four or more	90	Referent	81	Referent
MOTHER'S AGE (YEARS)				
18-20	96	1.01 (0.95-1.09)	71	0.82 (0.66-1.01)
20-29	90	0.95 (0.90-1.01)	82	0.94 (0.89-1.00)
30-39	93	0.98 (0.94-1.03)	81	**0.93 (0.88-0.98)**
> 39	94	Referent	87	Referent
MOTHER's RACE/ETHNICITY				
Hispanic (H)	95	Referent	76	Referernt
Non-H white only	94	0.99 (0.96-1.04)	83	**1.10 (1.03-1.17)**
Non-H black only	77	**0.81 (0.71-0.92)**	83	**1.09 (1.01-1.18)**
Non-H other/multiple race	92	0.97 (0.91-1.02)	84	**1.11 (1.01-1.21)**
MOTHER's EDUCATION LEVEL				
Less than high school	86	0.94 (0.85-1.04)	83	1.09 (0.99-1.19)
High school	94	1.03 (0.97-1.09)	83	**1.09 (1.01-1.19)**
Some College	93	1.02 (0.95-1.09)	84	**1.10 (1.02-1.20)**
Associate degree	97	1.06 (1.00-1.13)	85	**1.12 (1.02-1.22)**
Four-year college degree	93	1.02 (0.97-1.07)	80	1.04 (0.97-1.12)
Advanced degree	91	Referent	76	Referent
MOTHER's MARITAL STATUS				
Married	91	Referent	82	Referent
Never married	94	1.03 (0.98-1.09)	81	0.98 (0.93-1.04)
Divorced/separated/widowed etc.	88	0.97 (0.89-1.05)	83	1.02 (0.94-1.11)

GEOGRAPHIC MOBILITY SINCE CHILD'S BIRTH				
Moved from different state	93	1.01 (0.96-1.07)	78	0.96 (0.87-1.05)
Did not move from different state	92	Referent	82	Referent
CHILD's SEX				
Male	92	1.00 (0.97-1.04)	82	1.00 (0.96-1.04)
Female	92	Referent	82	Referent
CHILD's HEALTH INSURANCE				
None (VFC eligible)	81	0.87 (0.72-1.04)	83	1.05 (0.94-1.16)
Medicaid/other VFC	91	0.97 (0.92-1.01)	84	1.06 (0.99-1.13)
Other public non VFC	96	1.02 (0.98-1.07)	85	1.08 (0.98-1.19)
Private/other non VFC	94	Referent	79	Referent
CHILD's AGE AS OF 11/1/2009				
10-23 months	91	0.98 (0.94-1.01)	83	1.02 (0.98-1.07)
24-37 months	93	Referent	81	Referent

*** Predictive marginal estimates from logistic regression model with parental reported influenza vaccination status as the outcome and independent variables including provider reported vaccination status, characteristics, and interaction terms of provider vaccination status and each characteristic.**

† Adjusted ratios with 95% confidence limits in parentheses, based on ratios of predictive marginal (adjusted prevalence) estimates for sensitivity and specificity.

Table 5-10 Joint distribution of seasonal and pH1N1 influenza vaccination status* by provider and household report, by shot card status, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

		Marginal Distribution (%) by Provider Report	Marginal Distribution (%) by Household Report	Distribution (%) by Household Report Given Provider Status			
				Both Seasonal and pH1N1	Seasonal Only	pH1N1 Only	Neither/ missing
Shotcard Group	Both	21.5 (19.0-24.3)	22.5 (20.0-25.1)	71.1 (64.1-77.2)	7.8 (5.4-11.4)	16.2 (8.3-12.9)	4.9 (3.0-7.9)
	Seasonal Only	31.9 (29.1-34.8)	30.4 (27.6-33.3)	12.7 (9.7-16.5)	70.5 (65.7-74.9)	4.2 (2.7-6.6)	12.5 (9.6-16.1)
	pH1N1Only	5.2 (3.3-6.9)	10.4 (8.3-12.9)	22.7 (14.9-33.0)	8.1 (1.8-30.2)	53.0 (38.4-67.1)	16.1 (9.1-27.0)
	Neither/missing	41.5 (38.5-44.4)	36.8 (34.1-39.7)	4.7 (3.2-6.7)	13.9 (10.9-17.6)	6.8 (4.3-10.6)	74.6 (70.1-78.6)
Recall Only	Both	19.8 (18.4-21.3)	26.9 (25.3-28.6)	80.7 (77.1-83.8)	2.5 (1.7-3.6)	12.6 (10.0-15.9)	4.2 (2.8-6.3)
	Seasonal Only	29.9 (28.1-31.7)	28.0 (26.2-29.8)	16.4 (14.2-18.7)	61.9 (58.5-65.3)	4.3 (3.2-5.7)	17.4 (14.6-20.6)
	pH1N1Only	3.9 (3.4-4.5)	8.3 (7.4-9.4)	49.2 (42.1-56.3)	3.0 (1.3-6.7)	43.7 (36.7-50.8)	4.2 (2.1-8.1)
	Neither/missing	46.4 (44.5-48.4)	36.8 (34.9-38.7)	8.9 (7.3-10.7)	19.1 (16.9-21.5)	6.1 (4.9-7.7)	65.9 (63.0-68.6)

***** Percent with 95% confidence intervals

Table 5-11 Percent of children with provider reported seasonal influenza vaccination in a given month with household reported seasonal influenza vaccination in each month, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	Month(s) of Seasonal Influenza Vaccination Reported by Providers					
Month(s) Reported by Household*	Oct. n=2,755	Nov. n=1,467	Dec. n=2,757	Jan. n=323	Feb. n=147	March n=66
October 2009	49.5	22.3	17.8	13.9	9.2	4.4
November 2009	13.7	41.9	18.6	12.0	9.8	9.5
December 2009	7.6	9.0	25.3	13.1	8.2	11.1
January 2010	4.0	3.2	5.1	41.0	10.1	13.6
February 2010	1.0	1.9	4.6	3.8	21.1	3.3
March 2010	<1.0	<1.0	<1.0	<1.0	<1.0	26.6
April 2010	<1.0	<1.0	<1.0	<1.0	<1.0	6.8
May 2010	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0%
June 2010	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0%

* Children receiving more than one vaccination may be included in more than one column (provider report) or more than one row (household report). Percents in any column may sum to less than 100% because not all children with provider reported vaccination report vaccination that month, or may sum to more than 100% if households report multiple vaccinations in different months.

Table 5-12 Percent of children with provider reported pH1N1 influenza vaccination in a given month with household reported pH1N1 influenza vaccination in each month, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	Month(s) of pH1N1 Influenza Vaccination Reported by Providers					
Month(s) Reported by Household	Oct. n=848	Nov. n=2,128	Dec. n=1,732	Jan. n=841	Feb. n=344	March n=149
October 2009	59.4	20.0	19.7	13.6	10.2	6.6
November 2009	31.8	52.2	36.2	20.0	12.4	20.0
December 2009	19.5	23.5	42.9	25.8	18.7	18.6
January 2010	6.8	9.9	14.1	43.4	26.8	15.4
February 2010	3.0	2.9	5.1	14.0	33.8	25.8
March 2010	<1.0	<1.0	2.9	<1.0	<1.0	32.5
April 2010	<1.0	<1.0	<1.0	<1.0	<1.0	5.9
May 2010	<1.0	<1.0	<1.0	<1.0	<1.0	3.6
June 2010	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0

* Children receiving more than one vaccination may be included in more than one column (provider report) or more than one row (household report). Percents in any column may sum to less than 100% because not all children with provider reported vaccination report vaccination that month, or may sum to more than 100% if households report multiple vaccinations in different months.

Table 5-13 Sensitivity and specificity of parental report of child's seasonal influenza vaccination status by date of interview using shot card and recall (shot card group), by monthly vaccination periods October-December 2009 and month of survey interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Monthly Vaccination Period	Month of Interview									
	Oct. 2009	Nov. 2009	Dec. 2009	Jan. 2010	Feb. 2010	March 2010	April 2010	May 2010	June 2010	Jul./Aug. 2010
Oct. 2009										
Sens.	53 (31-73)	92 (82-96)	73 (55-86)	59 (44-73)	68 (53-81)	58 (33-80)	54 (32-74)	45 (27-65)	71 (50-86)	71 (53-84)
Spec.	94 (91-97)	95 (92-97)	91 (84-95)	93 (88-96)	93 (88-96)	93 (89-96)	91 (81-96)	95 (91-97)	90 (81-95)	95 (90-97)
P_{HH}	16 (11-24)	29 (19-41)	23 (16-33)	17 (12-24)	22 (16-30)	17 (13-23)	17 (11-26)	14 (10-19)	22 (14-32)	18 (12-27)
P_{PR}	23 (15-33)	27 (18-40)	23 (15-33)	20 (14-26)	25 (18-33)	20 (13-30)	18 (11-26)	23 (16-23)	19 (12-28)	20 (13-29)
Nov. 2009										
Sens.		29 (12-55)	72 (42-90)	75 (57-87)	53 (28-76)	43 (23-65)	49 (22-77)	39 (22-60)	66 (47-81)	57 (34-78)
Spec.		98 (97-99)	90 (79-95)	95 (92-97)	89 (82-93)	96 (93-98)	97 (93-99)	97 (94-99)	96 (92-98)	95 (90-97)
P_{HH}		4 (2-7)	18 (10-30)	11 (7-15)	15 (10-22)	8 (5-12)	13 (7-22)	9 (6-14)	13 (9-20)	12 (7-19)
P_{PR}		9 (5-17)	12 (6-23)	9 (6-13)	9 (6-15)	11 (7-17)	21 (12-34)	17 (11-25)	15 (10-22)	13 (7-20)
Dec. 2009										
Sens.			NR*	NR	57 (33-78)	NR	NR	42 (17-72)	50 (23-76)	NR
Spec.			99 (98-100)	98 (95-99)	98 (96-99)	94 (80-98)	98 (96-99)	98 (96-99)	98 (96-99)	98 (96-99)
P_{HH}			3 (1-6)	8 (4-18)	7 (4-12)	8 (3-19)	5 (2-10)	5 (2-10)	7 (3-13)	7 (4-13)
P_{PR}			4 (2-8)	8 (4-17)	9 (6-15)	4 (2-7)	4 (2-10)	7 (4-12)	11 (6-19)	11 (6-18)

* Estimate not reliable (sample size <30)

Table 5-14 Sensitivity and specificity of parental report of child's seasonal influenza vaccination status by date of interview using recall only (recall only group) , by monthly vaccination periods October 2009-January 2010 and month of survey interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Monthly Vaccination Period	Month of Interview									
	Oct. 2009	Nov. 2009	Dec. 2009	Jan. 2010	Feb. 2010	March 2010	April 2010	May 2010	June 2010	Jul./Aug. 2010
Oct. 2009										
Sens.	59 (45-72)	61 (44-76)	53 (42-64)	45 (32-58)	43 (33-53)	38 (28-49)	45 (33-59)	27 (16-41)	24 (17-35)	37 (16-31)
Spec.	96 (95-98)	86 (79-91)	88 (84-91)	88 (85-91)	82 (77-87)	90 (87-92)	86 (82-90)	89 (85-92)	83 (76-88)	81 (71-89)
P_{HH}	14 (10-20)	23 (17-30)	19 (16-23)	18 (14-22)	22 (18-27)	15 (12-18)	22 (17-28)	15 (12-20)	19 (14-24)	23 (16-31)
P_{PR}	19 (14-25)	19 (14-26)	16 (13-20)	18 (15-23)	18 (15-22)	17 (13-21)	27 (21-33)	26 (19-34)	21 (16-26)	24 (18-31)
Nov. 2009										
Sens.		39 (27-54)	58 (41-73)	39 (25-55)	46 (28-64)	43 (26-62)	27 (13-48)	29 (19-42)	40 (26-57)	29 (14-52)
Spec.		96 (93-98)	92 (90-94)	91 (88-93)	88 (85-91)	90 (86-93)	89 (84-92)	92 (87-95)	92 (90-94)	89 (84-93)
P_{HH}		7 (4-10)	13 (10-17)	12 (10-16)	15 (12-20)	14 (10-19)	13 (10-18)	10 (7-14)	11 (8-14)	13 (9-18)
P_{PR}		8 (6-11)	11 (8-15)	11 (8-16)	11 (8-15)	11 (8-16)	12 (8-16)	9 (7-13)	10 (8-14)	13 (9-18)
Dec. 2009										
Sens.			40 (20-65)	44 (24-67)	24 (12-41)	27 (13-48)	14 (7-25)	10 (4-21)	11 (4-26)	11 (3-29)
Spec.			99 (97-100)	96 (94-98)	96 (94-97)	94 (91-96)	94 (91-96)	93 (85-97)	94 (91-97)	97 (94-98)
P_{HH}			3 (1-6)	7 (5-10)	5 (4-7)	7 (5-10)	7 (5-10)	7 (3-15)	6 (4-9)	4 (2-7)
P_{PR}			4 (2-8)	9 (6-14)	5 (3-8)	6 (5-9)	9 (6-14)	8 (4-14)	7 (5-10)	10 (6-16)
Jan. 2010										
Sens.				NR*	NR	NR	30 (13-54)	27 (8-61)	33 (10-68)	NR
Spec.				100 (98-100)	97 (94-98)	97 (95-98)	97 (95-99)	97 (95-99)	96 (93-98)	95 (91-97)
P_{HH}				1 (1-3)	4 (2-7)	4 (3-7)	4 (2-6)	4 (2-6)	5 (3-9)	5 (3-9)
P_{PR}				2 (1-4)	3 (2-5)	4 (2-6)	4 (2-6)	3 (2-5)	4 (2-6)	4 (2-8)

* Estimate not reliable (sample size <30)

Table 5-15 Sensitivity and specificity of parental report of child's pH1N1 influenza vaccination status by date of interview using shot card and recall (shot card group), by monthly vaccination periods October 2009 – January 2010 and month of survey interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Monthly Vaccination Period	Month of Interview									
	Oct. 2009	Nov. 2009	Dec. 2009	Jan. 2010	Feb. 2010	March 2010	April 2010	May 2010	June 2010	Jul./Aug. 2010
Oct. 2009										
Sens.	NR*	85 (65-95)	NR	NR	53 (30-75)	NR	NR	NR	58 (30-81)	NR
Spec.	99 (94-100)	95 (89-98)	95 (89-98)	94 (89-97)	96 (91-98)	95 (92-97)	90 (76-97)	89 (77-95)	94 (88-98)	97 (94-99)
P_{HH}	2 (0-5)	8 (5-14)	9 (5-15)	8 (5-13)	7 (4-11)	8 (5-12)	13 (6-25)	13 (7-24)	8 (4-13)	4 (2-7)
P_{PR}	3 (2-6)	4 (3-7)	4 (2-10)	5 (3-8)	5 (3-9)	6 (3-11)	5 (3-9)	4 (2-6)	4 (2-7)	3 (1-5)
Nov. 2009										
Sens.		27 (12-50)	77 (52-91)	60 (25-87)	61 (37-80)	42 (22-65)	76 (52-90)	70 (51-84)	68 (50-81)	72 (48-88)
Spec.		95 (88-98)	93 (87-96)	93 (88-96)	94 (89-96)	96 (94-98)	95 (90-97)	95 (91-97)	97 (94-98)	96 (93-98)
P_{HH}		9 (5-14)	19 (12-29)	15 (10-21)	15 (11-21)	10 (7-14)	19 (10-32)	14 (9-21)	10 (7-15)	13 (8-20)
P_{PR}		17 (10-30)	17 (11-27)	14 (8-24)	16 (11-24)	16 (10-26)	20 (11-33)	14 (9-20)	11 (7-16)	14 (8-21)
Dec. 2009										
Sens.			44 (28-62)	82 (67-91)	65 (46-81)	62 (43-79)	50 (28-72)	53 (35-71)	45 (25-66)	58 (39-75)
Spec.			99 (97-99)	88 (75-95)	92 (86-96)	97 (94-98)	97 (93-99)	94 (87-97)	95 (91-98)	97 (92-99)
P_{HH}			7 (5-11)	19 (12-29)	18 (12-26)	16 (9-25)	7 (4-12)	13 (8-21)	10 (6-15)	NR
P_{PR}			13 (9-19)	10 (7-15)	17 (12-25)	21 (13-32)	8 (5-13)	15 (11-22)	12 (8-19)	16 (11-24)
Jan. 2010										
Sens.				34 (17-56)	79 (60-90)	46 (14-81)	NR	63 (32-86)	75 (47-91)	NR
Spec.				98 (94-99)	93 (84-97)	96 (93-98)	94 (84-98)	96 (92-98)	98 (96-99)	95 (89-98)
P_{HH}				NR	13 (8-21)	9 (4-19)	NR	11 (6-22)	10 (4-21)	NR
P_{PR}				8 (5-13)	9 (5-14)	12 (6-24)	7 (4-13)	13 (7-23)	11 (5-21)	9 (5-15)

* Estimate not reliable (sample size <30)

Table 5-16 Sensitivity and specificity of parental report of child's pH1N1 influenza vaccination status by date of interview using recall only (recall only group) , by monthly vaccination periods October 2009 – January 2010 and month of survey interview, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Monthly Vaccination Period	Month of Interview									
	Oct. 2009	Nov. 2009	Dec. 2009	Jan. 2010	Feb. 2010	March 2010	April 2010	May 2010	June 2010	Jul./Aug. 2010
Oct. 2009										
Sens.	34 (16-60)	87 (69-96)	78 (59-89)	67 (46-83)	49 (32-66)	55 (37-72)	49 (29-68)	62 (39-81)	46 (28-64)	NR
Spec.	99 (97-100)	96 (93-97)	95 (92-96)	94 (92-96)	89 (83-92)	93 (90-95)	88 (84-92)	90 (84-94)	88 (82-92)	91 (86-94)
P_{HH}	3 (1-5)	9 (6-12)	10 (7-13)	9 (6-12)	14 (10-19)	11 (8-14)	14 (10-18)	12 (8-17)	13 (9-19)	9 (6-14)
P_{PR}	6 (3-9)	5 (3-9)	6 (4-9)	5 (3-8)	7 (5-9)	7 (5-10)	6 (4-8)	3 (2-6)	4 (2-5)	4 (2-9)
Nov. 2009										
Sens.		39 (28-51)	87 (79-92)	66 (52-77)	57 (43-70)	51 (40-62)	38 (24-53)	37 (23-54)	48 (35-60)	33 (20-50)
Spec.		96 (94-98)	90 (86-93)	90 (87-93)	87 (83-91)	93 (90-95)	87 (82-91)	93 (90-95)	90 (86-93)	93 (88-96)
P_{HH}		8 (6-10)	22 (18-26)	17 (14-20)	19 (15-23)	13 (10-16)	17 (13-22)	11 (9-15)	14 (11-19)	10 (7-15)
P_{PR}		11 (9-15)	15 (12-19)	12 (9-15)	14 (10-18)	12 (9-15)	16 (12-22)	14 (10-19)	13 (10-16)	12 (8-16)
Dec. 2009										
Sens.			39 (28-52)	67 (54-78)	39 (24-56)	59 (47-71)	43 (30-57)	30 (17-47)	36 (24-50)	21 (9-43)
Spec.			98 (98-99)	94 (91-96)	88 (84-91)	93 (90-95)	91 (86-94)	93 (90-95)	94 (92-96)	95 (91-97)
P_{HH}			6 (4-8)	12 (10-16)	14 (11-18)	14 (11-17)	15 (11-19)	10 (8-13)	10 (8-13)	7 (5-12)
P_{PR}			12 (9-15)	10 (8-13)	9 (6-13)	13 (10-16)	15 (12-20)	13 (8-19)	14 (11-19)	13 (9-19)
Jan. 2010										
Sens.				42 (23-63)	66 (48-80)	60 (43-75)	35 (21-53)	24 (11-43)	32 (18-50)	26 (12-48)
Spec.				98 (96-99)	91 (87-93)	93 (90-95)	92 (88-95)	96 (94-97)	93 (90-95)	95 (92-97)
P_{HH}				4 (2-6)	13 (10-17)	10 (8-14)	10 (7-14)	6 (4-8)	9 (6-12)	6 (4-10)
P_{PR}				4 (2-5)	6 (4-8)	7 (5-10)	9 (6-12)	9 (5-15)	7 (5-10)	6 (4-10)

* Estimate not reliable (sample size <30)

Table 5-17 Distributions of types of seasonal and pH1N1 influenza vaccinations received* by provider and household report among children with influenza vaccination reported by both sources, by shot card status and age as of November 2009, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

Seasonal or pH1N1 influenza vaccination	Shot Card Status	Age of Child as of November 2009	Source of Report	Distribution (%) by type of influenza vaccination received			
				Both Shot and Spray	Shot Only	Spray Only	Don't Know
Seasonal	Shot Card	10-23 months (n=935)	Provider	1.9 (0.6-5.6)	95.5 (91.9-97.6)	1.2 (0.3-4.2)	1.4 (0.7-2.9)
			Household	0.7 (0.3-1.8)	88.7 (84.3-92.0)	5.2 (2.8-9.2)	5.4 (3.5-8.4)
		24-37 months (n=808)	Provider	2.7 (1.5-5.0)	81.1 (75.0-86.0)	14.1 (9.7-20.1)	2.1 (1.1-3.8)
			Household	3.3 (1.4-7.5)	81.1 (75.8-85.4)	13.3 (9.9-17.5)	2.4 (1.2-4.6)
	Recall Only	10-23 months (n=2,004)	Provider	0.3 (0.1-0.8)	97.0 (95.1-98.2)	1.5 (0.6-3.4)	1.2 (0.6-2.3)
			Household	3.3 (2.4-4.6)	96.0 (94.6-97.0)	0.7 (0.4-1.3)	0.0
		24-37 months (n=1,987)	Provider	3.8 (2.2-6.3)	80.8 (77.6-83.6)	12.9 (10.8-15.4)	2.5 (1.6-3.9)
			Household	11.8 (9.4-14.6)	80.2 (76.9-83.2)	8.0 (6.1-10.4)	0.0
pH1N1	Shot Card	10-23 months (n=512)	Provider	0.9 (0.4-2.3)	90.8 (83.8-95.0)	5.1 (2.1-11.7)	3.2 (1.1-8.8)
			Household	1.4 (0.6-3.1)	77.0 (70.0-82.9)	6.3 (3.3-11.9)	15.3 (10.6-21.5)
		24-37 months (n=413)	Provider	4.4 (1.9-10.2)	77.5 (69.1-84.1)	16.1 (10.9-23.2)	2.0 (1.0-3.9)
			Household	1.1 (0.5-2.3)	64.5 (53.5-74.1)	28.2 (19.6-38.9)	6.2 (3.8-10.1)
	Recall Only	10-23 months (n=1,293)	Provider	0.5 (0.2-0.9)	95.0 (92.8-96.5)	3.0 (1.9-4.5)	1.6 (0.7-3.6)
			Household	1.4 (0.9-2.4)	91.0 (88.3-93.1)	7.0 (5.1-9.6)	0.5 (0.2-1.3)
		24-37 months (n=1,146)	Provider	4.3 (2.8-6.5)	64.8 (59.8-69.6)	28.1 (23.6-33.0)	2.8 (1.9-4.3)
			Household	5.7 (3.8-8.3)	57.9 (52.6-63.0)	35.2 (30.4-40.4)	1.3 (0.4-3.5)

* Percent (95% confidence intervals) distributions by type of influenza vaccinations received during the vaccination period; types were shot (injected inactivated) influenza vaccines licensed for use in children ≥6 months and spray (intranasal live, attenuated) influenza vaccines licensed for use in children ≥2 years. Some children age <2 years in November may have received intranasal, live attenuated influenza vaccination after turning two years of age in December or later.

Table 5-18 Provider ascertainment* of influenza vaccinations reported by survey respondents from vaccination records, by provider response category, National Immunization Survey (NIS), Quarter 4 2009 – Quarter 2 2010

	Seasonal Vaccination		pH1N1 Vaccination	
	Unweighted number	% Ascertained by providers (95% CI†)	Unweighted number	% Ascertained by providers (95% CI)
Total	1,353	87.6 (84.0-90.5)	514	73.2 (63.8-80.9)
Single provider identified and returned valid IHQ§	751	87.5 (82.2-91.4)	271	74.9 (63.7-83.5)
Multiple providers identified and all returned valid IHQ§	511	88.1 (83.1-91.8)	203	82.7 (72.3-89.7)
Multiple providers identified and some but not all returned valid IHQ's	91	86.6 (68.8-95.0)	40	51.7 (25.6-76.9)

***** Weighted percent of influenza vaccinations with valid date during the vaccination period reported by adult survey respondent from a vaccination record (shot card) that were also reported during the vaccination period by the provider or providers responding to the NIS.

† CI = confidence interval

§ IHQ = Immunization History Questionnaire mailed to providers identified by respondents as having provided vaccinations for the sample child.

Table 5-19 Effect of incomplete of provider ascertainment of influenza vaccinations status on validity parameters, assuming non-differential under-ascertainment by household reported influenza vaccination status

Source of Observed Values	Validity Parameter (%)*	Percent of actual vaccinations reported by providers						
		100%	90%		80%		Minimum Plausible Value†	
		Observed	"True"	Difference§	"True"	Difference	"True"	Difference
Seasonal influenza vaccination, shot card group	Sensitivity	81.5	81.5	0.0	Implausible value		81.5	0.0
	Specificity	80.1	89.1	-9.0			99.0	-18.9
	PPV	82.4	91.6	-9.2			99.3	-16.9
	NPV	79.1	76.8	2.3			74.8	4.3
	P_{HH}	52.8	52.8	-			52.8	-
	P_{PR}	53.4	53.4	-			53.4	-
	P_{TRUE}	53.4	59.3	-5.9			64.3	-10.9
	$P_{HH} - P_{PR}$	-0.6	-0.6	-			-0.6	-
	$P_{HH} - P_{TRUE}$	-0.6	-6.5	-			-11.5	-
Seasonal influenza vaccination, recall only group	Sensitivity	80.2	80.2	0.0	80.2	0.0	80.2	0.0
	Specificity	70.1	76.3	-6.2	86.4	-16.3	98.7	-28.6
	PPV	72.6	80.5	-8.1	90.6	-18.1	99.3	-26.8
	NPV	78.3	75.9	2.4	72.9	5.4	70.3	8.0
	P_{HH}	54.9	54.9	-	54.9	-	54.9	-
	P_{PR}	49.6	49.6	-	49.6	-	49.6	-
	P_{TRUE}	49.6	55.0	-5.4	61.9	-12.3	67.8	-18.2
	$P_{HH} - P_{PR}$	5.3	5.3	-	5.3	-	5.3	-
	$P_{HH} - P_{TRUE}$	5.3	-0.1	-	-7.0	-	-12.9	-
pH1N1 influenza vaccination, shot card group	Sensitivity	85.0	85.0	0.0	85.0	0.0	85.0	0.0
	Specificity	86.2	89.2	-3.0	93.3	-7.1	99.4	-13.2
	PPV	69.1	76.9	-7.7	86.5	-17.3	98.8	-29.7
	NPV	94.1	93.4	0.7	92.5	1.5	91.5	2.6
	P_{HH}	32.8	32.8	-	32.8	-	32.8	-
	P_{PR}	26.7	26.7	-	26.7	-	26.7	-
	P_{TRUE}	26.7	29.7	-3.0	33.4	-6.7	38.2	-11.5
	$P_{HH} - P_{PR}$	6.1	6.1	-	6.1	-	6.1	-
	$P_{HH} - P_{TRUE}$	6.1	3.1	-	-0.6	-	-5.4	-
pH1N1 vaccination, recall only group	Sensitivity	93.2	93.2	0.0	93.2	0.0	93.2	0.0
	Specificity	82.8	85.5	-2.7	89.2	-6.4	99.8	-17.0
	PPV	62.7	69.7	-7.0	78.4	-15.7	99.6	-36.9
	NPV	97.5	97.2	0.3	96.9	0.6	96.0	1.5
	P_{HH}	35.2	35.2	-	35.2	-	35.2	-
	P_{PR}	23.7	23.7	-	23.7	-	23.7	-
	P_{TRUE}	23.7	26.4	-2.7	29.6	-5.9	37.6	-13.9
	$P_{HH} - P_{PR}$	11.5	11.5	-	11.5	-	11.5	-
	$P_{HH} - P_{TRUE}$	11.5	8.8	-	5.6	-	-2.4	-

* PPV=positive predictive value; NPV=negative predictive value; P_{HH}=prevalence of vaccination based on household report; P_{PR}=prevalence of vaccination based on provider report; P_{TRUE}=expected true value of vaccination prevalence based on assumptions about the proportion of actual vaccinations reported by providers.

† Minimum value of provider ascertainment proportion that yielded valid values for expected true cell counts ≥0 and "true" values of sensitivity, specificity, PPV, NPV and vaccination prevalence within 0 and 1 inclusive; these values were 0.83 and 0.73 for observed values for seasonal vaccination from the shot card and recall only groups, and 0.70 and 0.63 for pH1N1 vaccination for the shot card and recall only groups, respectively.

§ Difference between observed values of validity parameters (e.g., assuming 100% provider ascertainment of vaccinations) and expected values assuming incomplete provider ascertainment.

Table 5-20 Effect of incomplete of provider ascertainment of influenza vaccinations status on validity parameters, assuming higher under-ascertainment when the household reports that the child has not received influenza vaccination

Source of Observed Values	Validity Parameter (%)*	Percent of actual vaccinations reported by providers, by household (HH) reported vaccination status						
		100%	100% | HH vacc. 90% | HH not vacc.		(88% seasonal, 73% pH1N1) | HH vacc. 80% | HH not vacc.		(88% seasonal, 73% pH1N1) | HH vacc. 50% | HH not vacc.	
		Observed	"True"	Difference§	"True"	Difference	"True"	Difference
Seasonal influenza vaccination, shot card group	Sensitivity	81.5	79.9	1.6	80.0	1.5	71.5	10.0
	Specificity	80.1	79.6	0.5	91.3	-11.2	89.1	-9.0
	PPV	82.4	82.4	0.0	93.7	-11.2	93.7	-11.2
	NPV	79.1	76.8	2.3	73.9	5.2	58.2	20.9
	P_{HH}	52.8	52.8	-	52.8	-	52.8	-
	P_{PR}	53.4	53.4	-	53.4	-	53.4	-
	P_{TRUE}	53.4	54.5	-1.1	61.8	-8.4	69.2	-16.4
	$P_{HH} - P_{PR}$	-0.6	-0.6	-	-0.6	-	-0.6	-
	$P_{HH} - P_{TRUE}$	-0.6	-1.7	-	-9.0	-	-16.6	-
Seasonal influenza vaccination, recall only group	Sensitivity	80.2	78.5	1.7	78.6	1.6	69.7	10.5
	Specificity	70.1	69.4	0.7	77.3	-7.2	72.6	-2.5
	PPV	72.6	72.5	0.0	82.3	-9.9	82.3	-9.9
	NPV	78.3	75.9	2.4	72.9	5.4	56.6	21.7
	P_{HH}	54.9	54.9	-	54.9	-	54.9	-
	P_{PR}	49.6	49.6	-	49.6	-	49.6	-
	P_{TRUE}	49.6	50.6	-1.0	57.4	-7.8	64.7	-15.1
	$P_{HH} - P_{PR}$	5.3	5.3	-	5.3	-	5.3	-
	$P_{HH} - P_{TRUE}$	5.3	4.3	-	-2.5	-	-9.8	-
pH1N1 influenza vaccination, shot card group	Sensitivity	85.0	83.6	1.4	86.1	-1.1	79.5	5.5
	Specificity	86.2	86.1	0.1	97.3	-11.1	97.2	-11.0
	PPV	69.1	69.2	0.0	94.8	-25.6	94.8	-25.6
	NPV	94.1	93.4	0.7	92.5	1.5	88.1	6.0
	P_{HH}	32.8	32.8	-	32.8	-	32.8	-
	P_{PR}	26.7	26.7	-	26.7	-	26.7	-
	P_{TRUE}	26.7	27.2	-0.5	36.1	-9.4	39.1	-12.4
	$P_{HH} - P_{PR}$	6.1	6.1	-	6.1	-	6.1	-
	$P_{HH} - P_{TRUE}$	6.1	5.6	-	-3.3	-	-6.3	-
pH1N1 vaccination, recall only group	Sensitivity	93.2	92.5	0.7	93.8	-0.6	90.4	2.8
	Specificity	82.8	82.8	0.0	92.7	-9.9	92.6	-9.8
	PPV	62.7	62.8	0.0	86.0	-23.2	86.0	-23.2
	NPV	97.5	97.2	0.3	96.9	0.6	95.0	2.5
	P_{HH}	35.2	35.2	-	35.2	-	35.2	-
	P_{PR}	23.7	23.7	-	23.7	-	23.7	-
	P_{TRUE}	23.7	23.9	-0.2	32.3	-8.6	33.5	-9.8
	$P_{HH} - P_{PR}$	11.5	11.5	-	11.5	-	11.5	-
	$P_{HH} - P_{TRUE}$	11.5	11.3	-	2.9	-	1.7	-

* PPV=positive predictive value; NPV=negative predictive value; P_{HH}=prevalence of vaccination based on household report; P_{PR}=prevalence of vaccination based on provider report; P_{TRUE}=expected true value of vaccination prevalence based on assumptions about the proportion of actual vaccinations reported by providers.

§ Difference between observed values of validity parameters (e.g., assuming 100% provider ascertainment of vaccinations) and expected values assuming incomplete provider ascertainment.

Figure 5-1 One group scenarios, seasonal vaccination estimates from the shot card group

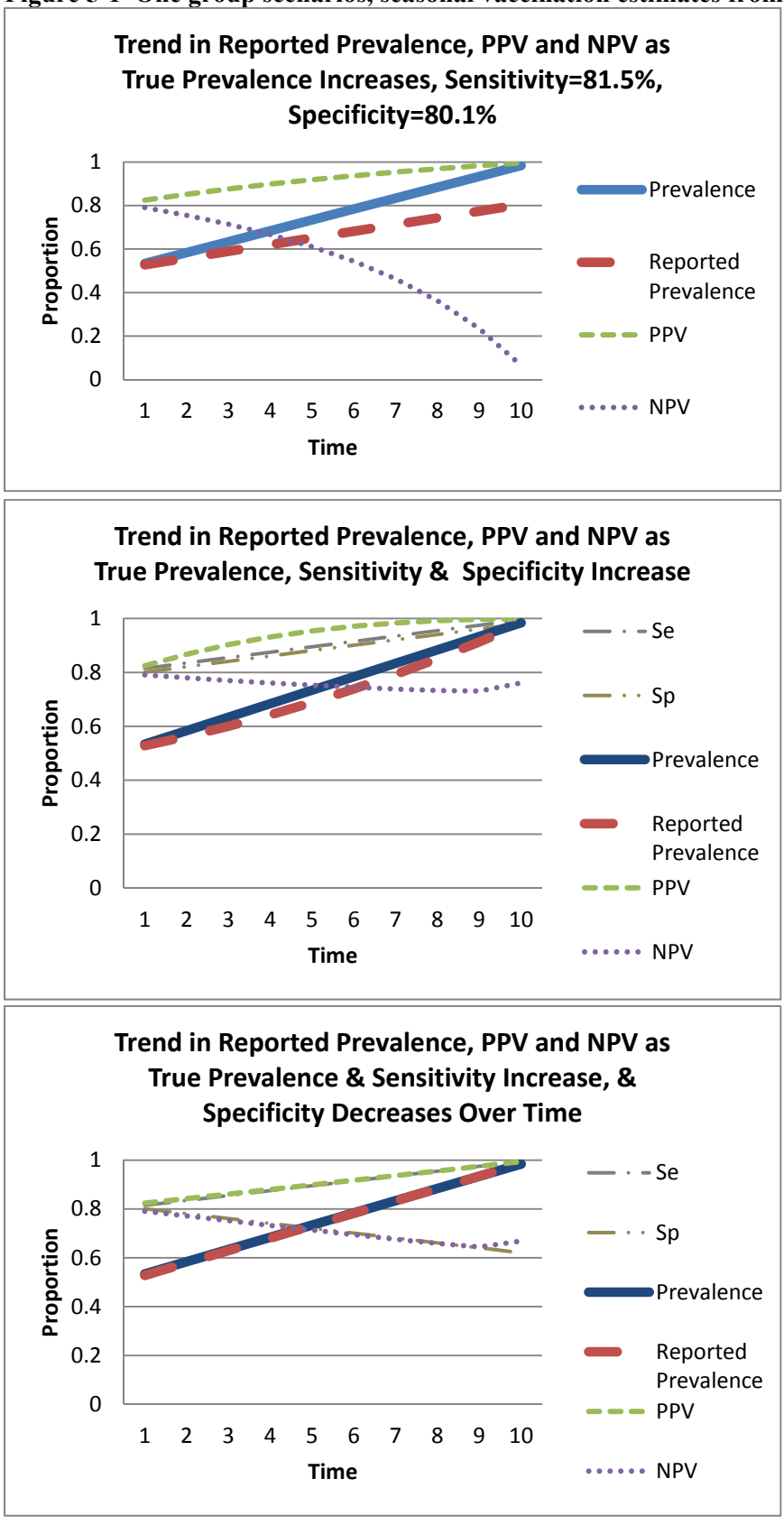


Figure 5-2 One group scenarios, seasonal vaccination estimates from the recall only group

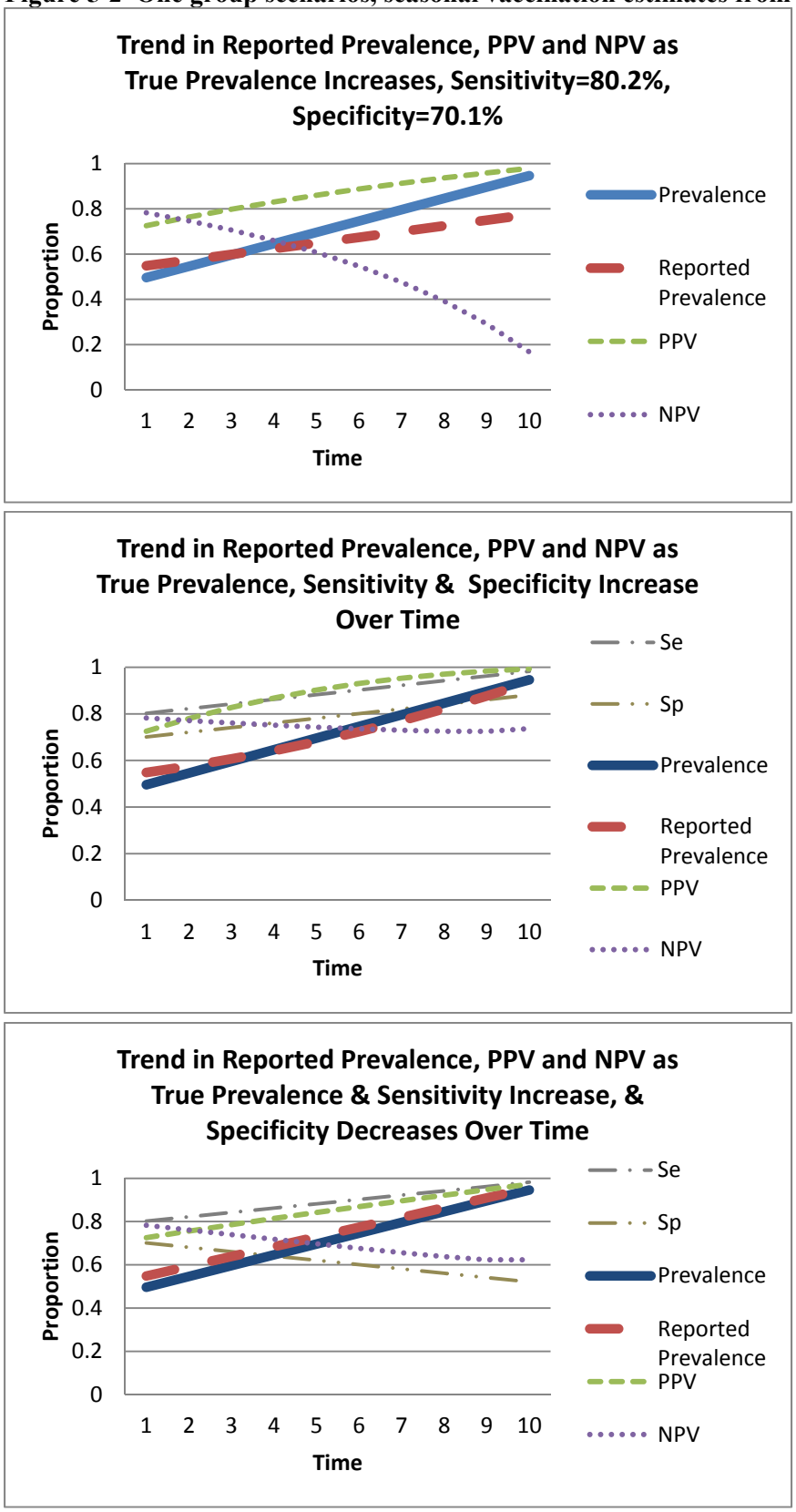


Figure 5-3 One group scenarios, pH1N1 vaccination estimates from the shot card group

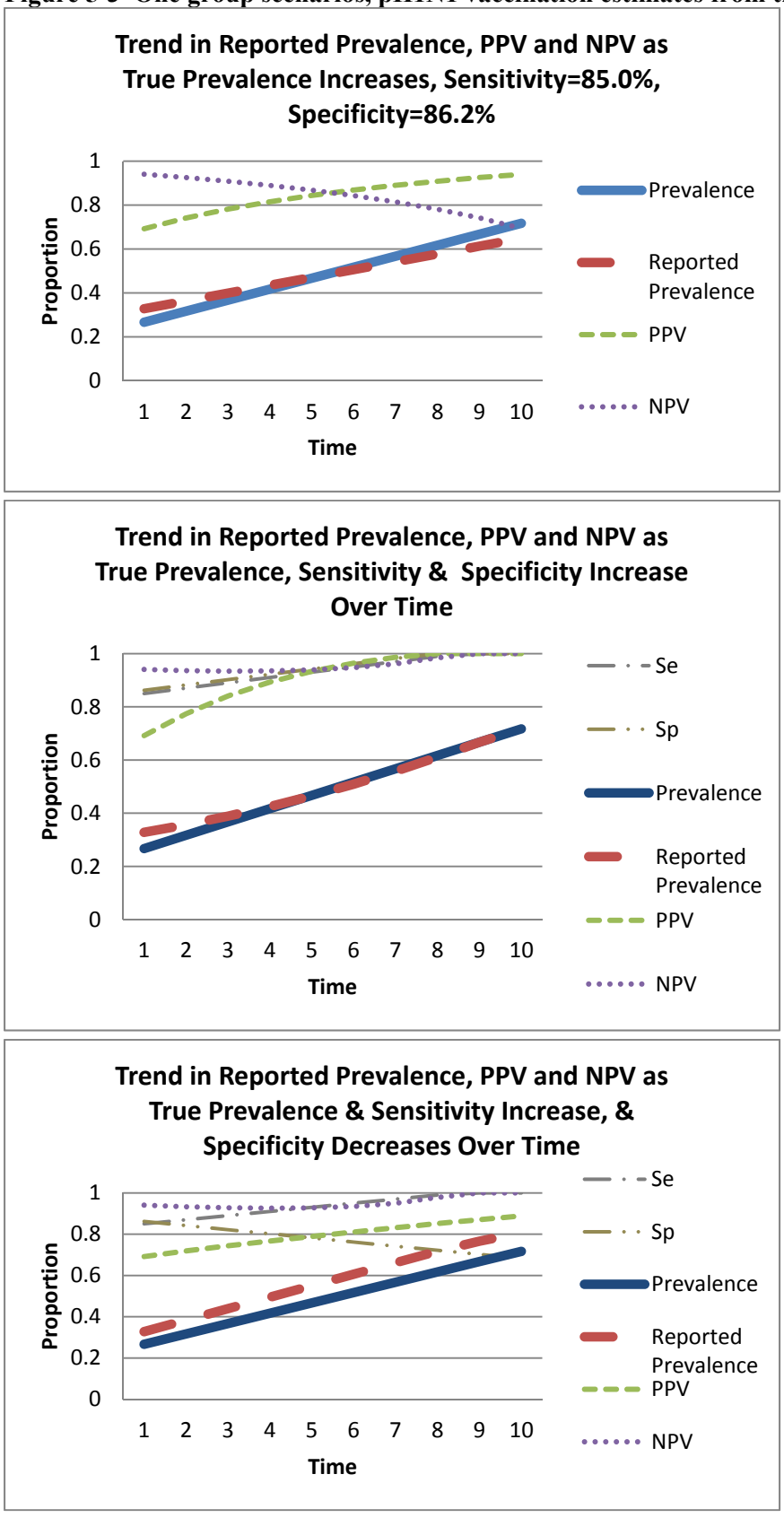


Figure 5-4 One group scenarios, pH1N1 vaccination estimates from the recall only group

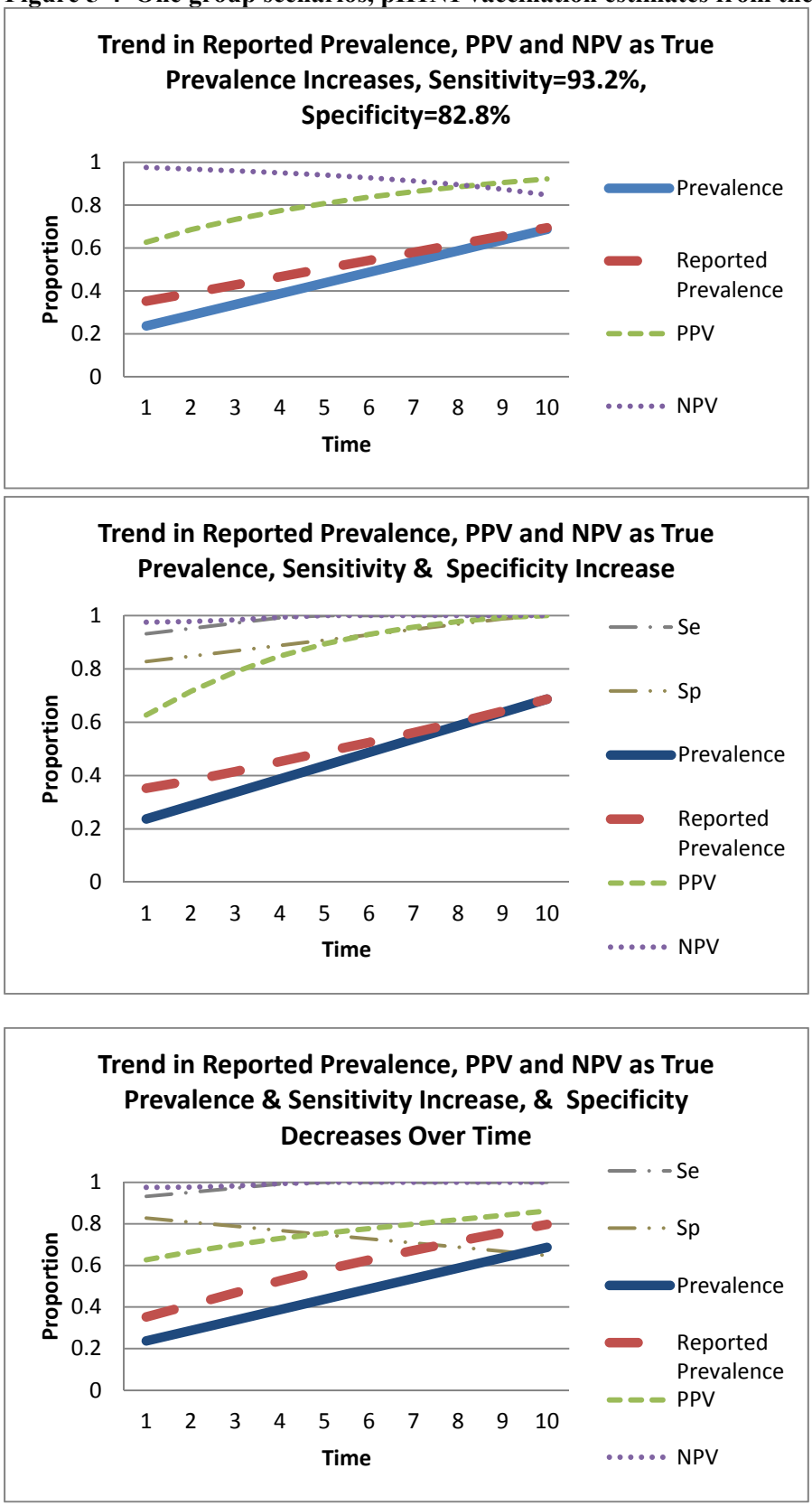


Figure 5-5 Two group scenarios, seasonal vaccination estimates from the shot card group

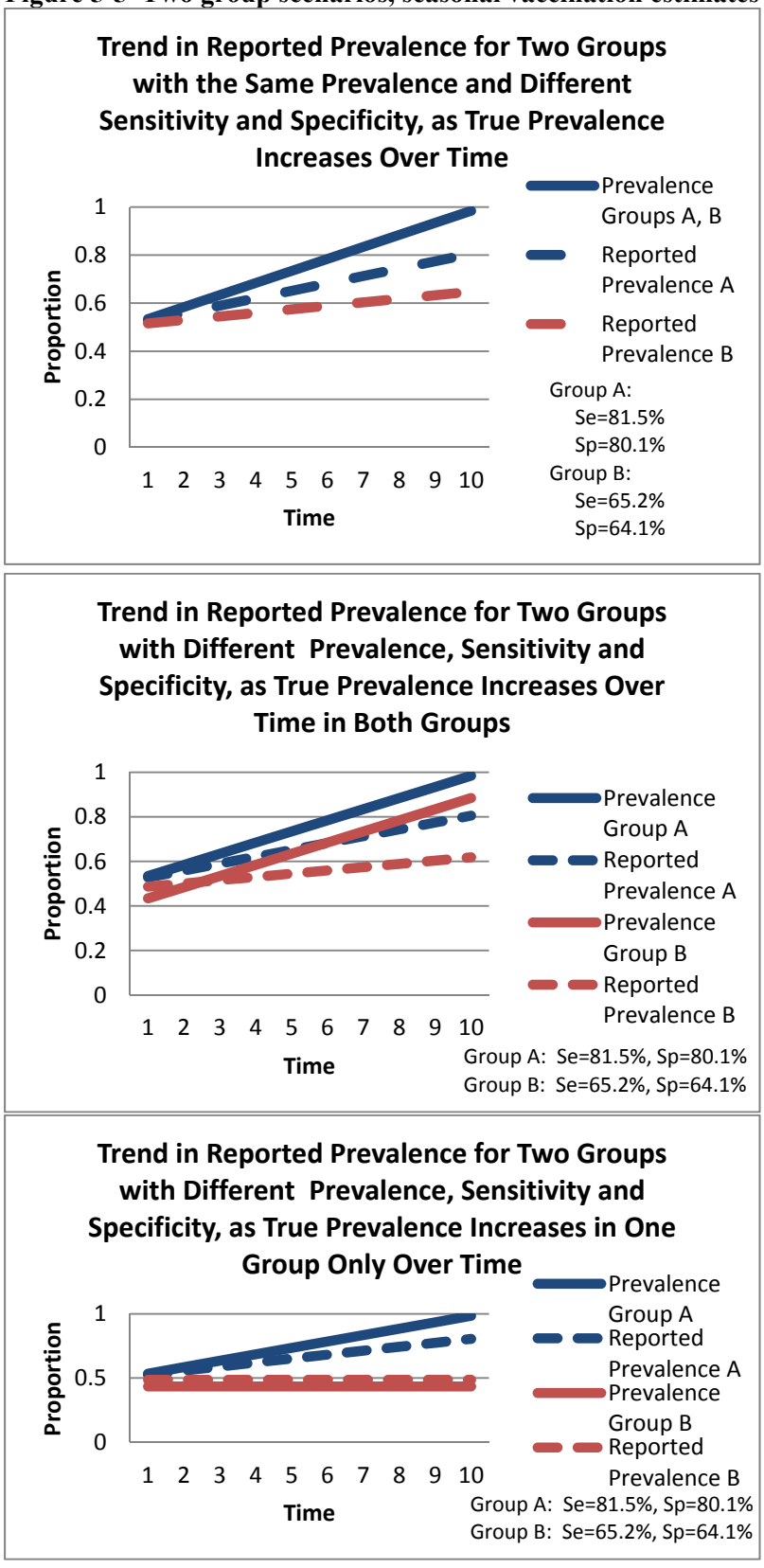


Figure 5-6 Two group scenarios, seasonal vaccination estimates from the recall only group

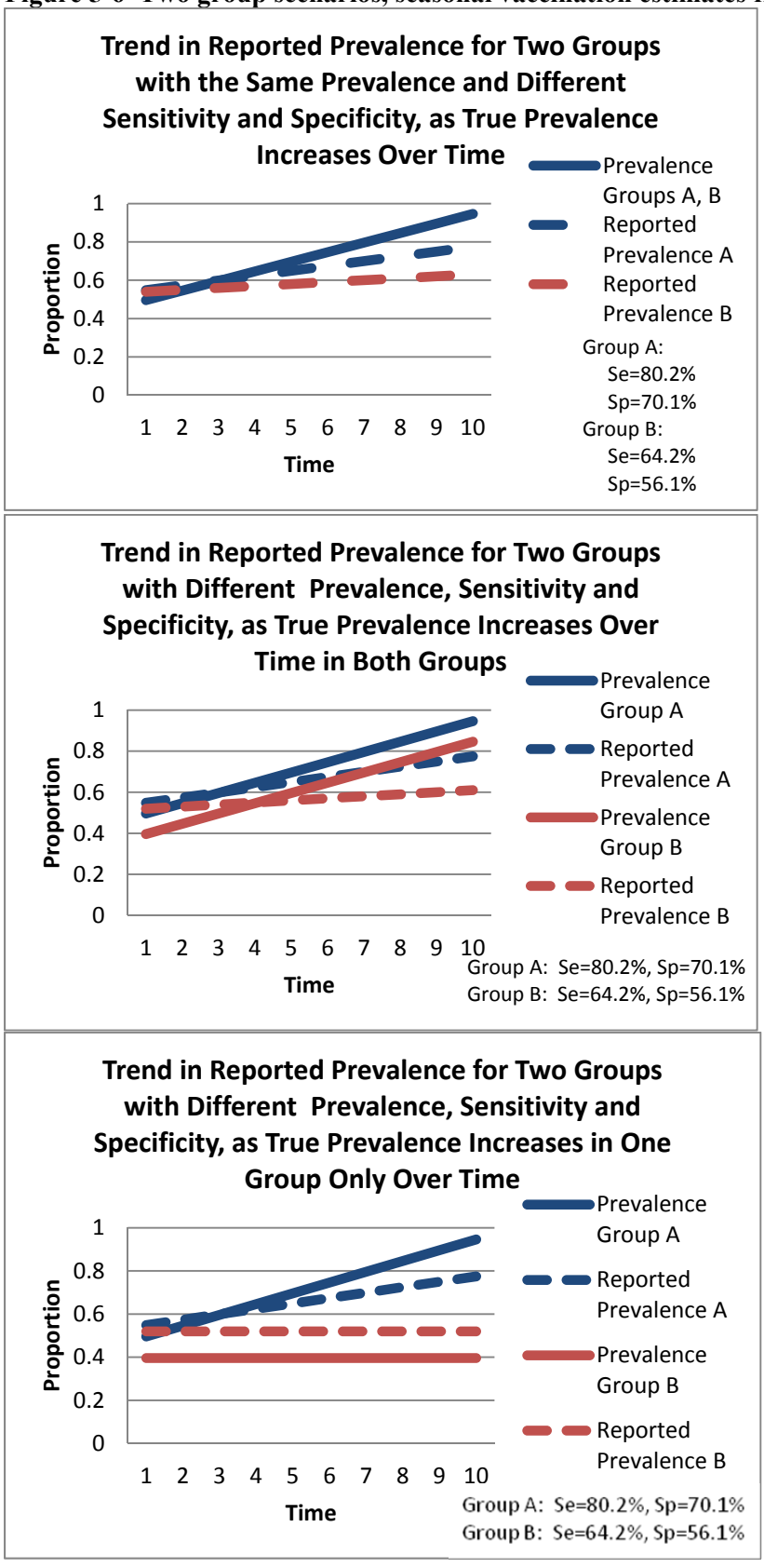
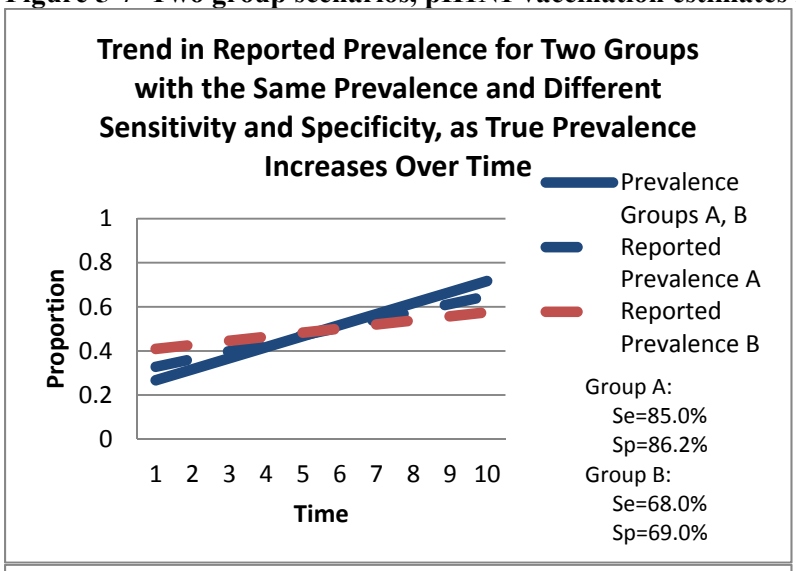
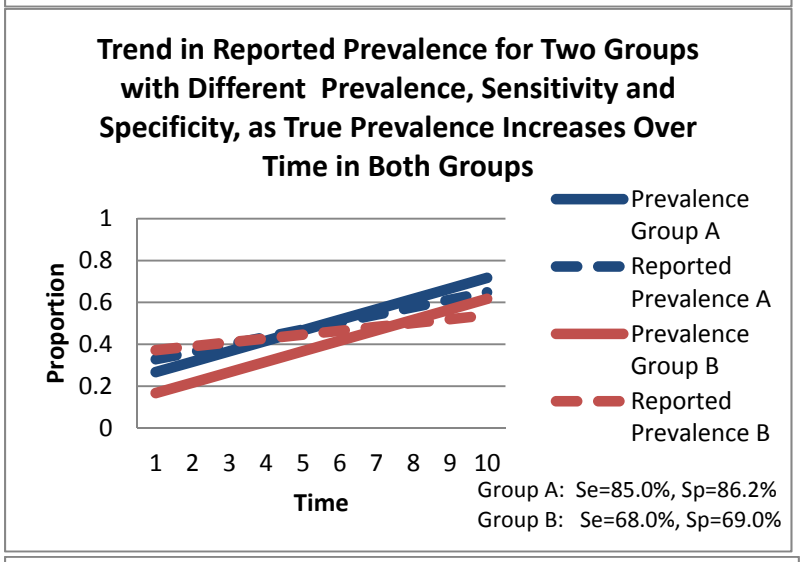


Figure 5-7 Two group scenarios, pH1N1 vaccination estimates from the shot card group





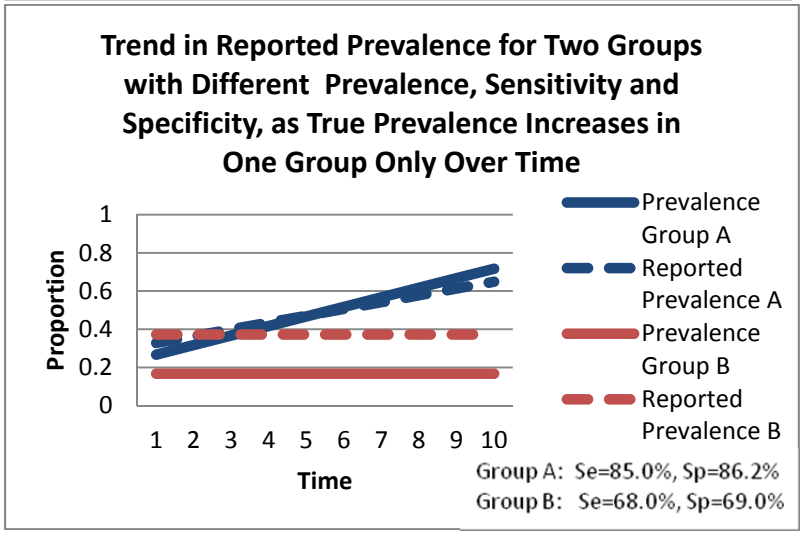
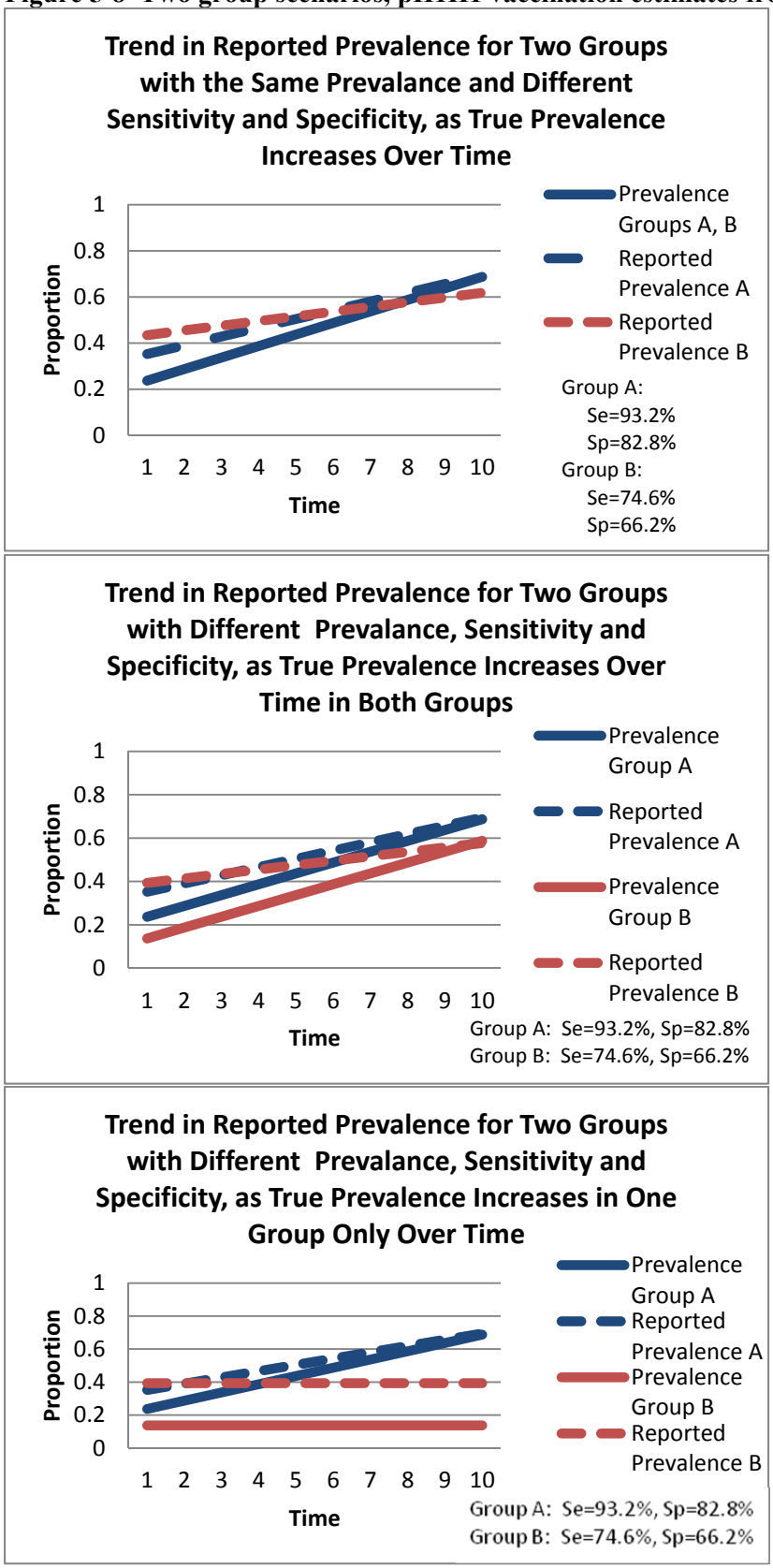


Figure 5-8 Two group scenarios, pH1H1 vaccination estimates from the recall only group



APPENDIX 5.1

Definitions of Validity Parameters

Validity parameters are defined in terms of the elements of the 2x2 table cross-classifying influenza status as reported by the household compared to by the gold standard source (health care provider).

		Provider Report	
		Vaccinated	Not Vaccinated
Household Report	Vaccinated	A	B
	Not Vaccinated	C	D

Sensitivity (Se) = proportion of those with provider report of vaccination that are reported to be vaccinated by household report = A / (A+C)

1-Sensitivity = C / (A+C) = conditional household underreporting or false negative rate given provider report of vaccination

Specificity (Sp) = proportion of those with provider report of not vaccinated that are reported to be not vaccinated by household report = D / (B+D)

1-Specificity = B / (B+D) = conditional household overreporting or false positive rate given provider report of not vaccinated

Positive Predictive Value (PPV) = proportion of those with household report of vaccination that are reported as vaccinated by provider = A / (A+B)

Negative Predictive Value (NPV) = proportion of those with household report of not vaccinated that are reported as not vaccinated by provider = D / (C+D)

Vaccination Prevalence by provider report (P) = (A+C) / (A+B+C+D)

Vaccination Prevalence by household report (P_{HH}) = (A+B) / (A+B+C+D)

Net Bias = Difference in prevalence of vaccination between household and provide report = $P_{HH} - P = (B-C) / (A+B+C+D)$.

Using laws of probability, the following expressions for PPV, NPV, Net Bias and P_{HH} as functions of Se, Sp and P can be derived:

(1) PPV = Se*P / [Se*P + (1-Sp)*(1-P)]

(2) NPV = Sp*(1-P) / [Sp*(1-P) + (1-Se)*P]

(3) Net Bias = (1-Sp)*(1-P) – (1-Se)*P

(4) P_{HH} = Se*P + (1-Sp)*(1-P)

As P increases toward 1, PPV approaches 1, NPV approaches 0, Net Bias approaches Se-1, and P_{HH} approaches Se.

APPENDIX 5.2

Model for Misclassification of Provider Reported Vaccination Status

Provider reports of a child's influenza vaccination status in the NIS may be incomplete because the parent did not identify a provider who vaccinated their child, the parent identified all the child's influenza vaccination providers but not all of those providers returned immunization history questionnaires, or all providers were identified and returned immunization history questionnaires but some influenza vaccinations were not reported. Because some parents may forget a child received an influenza vaccination from a particular provider and also forget to mention that provider during the NIS interview, there may be an association between households failing to report an actual influenza vaccination and that vaccination not being reported as part of the NIS provider record check process.

The following model of misclassification of provider reported influenza vaccination status assumes that influenza vaccinations reported by providers were actual vaccinations, while some children with no provider reported vaccinations were actually vaccinated. The provider ascertainment proportion (P_R) is defined as the proportion of all actual vaccinations that are reported by providers. The general model allows the provider ascertainment proportion to differ by household reported vaccination status, while the simplified model assumes independence between household and provider report.

Since provider reported vaccinations are considered actual, but providers may miss some vaccinations, the observed cell counts in the table below (a, b, c, d) differ from the actual cell counts (A, B, C, D), with the constraints that $a+b = A+B$ and $c+d = C+D$. The assumption that providers may miss some actual vaccinations implies that $a \leq A$, $c \leq C$, $b \geq B$, and $d \geq D$.

		Provider Report		Actual Vaccination Status	
		Vaccinated	Not Vaccinated	Vaccinated	Not Vaccinated
Household Report	Vaccinated	a	b	A	B
	Not Vaccinated	c	d	C	D

Defining the provider ascertainment proportions among those with household report of vaccination as P_{R1} and among those with household report of not vaccinated as P_{R2}, we have $a = P_{R1}*A$ and $c = P_{R2}*C$. We can then define values for (A, B, C, D) in terms of (a, b, c, d, P_{R1}, P_{R2}) using the constraints on the row totals above:

$A = a / P_{R1}$

$B = b – a*[(1- P_{R1})/ P_{R1}]$

$C = c / P_{R2}$

$D = d – c*[(1- P_{R2})/ P_{R2}]$.

Using these expressions, the observed cell counts, and assigning values to the provider ascertainment proportions, the actual validity parameters can be calculated:

$Se = A / (A+C) = (a / P_{R1}) / [(a / P_{R1}) + (c / P_{R2})]$

$Sp = D / (B+D) = \{d – c*[(1- P_{R2})/ P_{R2}]\} / \{b – a*[(1- P_{R1})/ P_{R1}] + d – c*[(1- P_{R2})/ P_{R2}]\}$

$PPV = A / (A+B) = [a/(a+b)]/ P_{R1}$

$NPV = D /(C+D) = \{d – c*[(1- P_{R2})/ P_{R2}]\} / (c+d)$

$P = (A+C) / (A+B+C+D) = [(a / P_{R1}) + (c / P_{R2})]/ (a+b+c+d)$

$P_{HH} = (A+B) / (A+B+C+D) = (a+b)/(a+b+c+d)$

$Net\ Bias = P_{HH} - P = [a + b - (a / P_{R1}) - (c / P_{R2})] / (a+b+c+d)$

Compared to the estimates of validity parameters based on the observed data, some observations about these putative actual values can be made. If provider ascertainment is incomplete:

1) Sensitivity based on observed data (Se^=a/(a+c)) could over or under estimate actual Se depending on values of a, c, P_{R1}, and P_{R2}. If household and provider report are independent ($P_{R1} = P_{R2}$), Se^ = Se.

2) Specificity based on observed data (Sp^=d/(b+d)) could over or under estimate actual Sp.
3) Positive Predictive Value based on observed data (PPV^=a/(a+b)) will underestimate actual PPV to the extent that the provider ascertainment proportion among children with household report of vaccination decreases from one.
4) Negative Predictive Value based on observed data (NPV^=d/(c+d) will overestimate actual NPV to the extent that the provider ascertainment proportion among children with household report of not vaccinated decreases from one, and as the value of c increases relative to the value of d.
5) The prevalence of vaccination based on provider report (P^=(a+c)/ (a+b+c+d)) will underestimate actual prevalence of vaccination (P) to the extent that the provider ascertainment proportions decrease from one. The difference in prevalence based on provider report and true prevalence is $[a*(1-P_{R1})/P_{R1} + c*(1-P_{R2})/P_{R2}]/(a+b+c+d)$, which is ≥ 0 and increases as P_{R1} and P_{R2} decrease.
6) Because prevalence based on provider report will be equal to or less than actual prevalence, observed Net Bias ($P_{HH} - P^$) will be equal to or less than actual Net Bias, and will increasingly less than actual Net Bias as P_{R1} and P_{R2} decrease. Observed Net Bias can be closer or further from zero than actual Net Bias. If actual Net Bias is ≤ 0, observed Net Bias will overestimate the extent of the negative bias. If actual Net Bias is >0, observed Net Bias will underestimate the extent of positive bias.

APPENDIX 5.3

Estimating Actual Vaccination Prevalence Using Validity Study Results

Results from validity studies can be used to estimate actual prevalence of vaccination using estimates of vaccination prevalence from surveys using parental or self report of vaccination for which provider data is not collected, or is collected only for representative sample. From the expression of net bias in terms of actual vaccination prevalence, sensitivity and specificity from Appendix 5.1, equation (3) , Net Bias = $P_{HH} - P = (1\text{-}Sp)*(1\text{-}P) - (1\text{-}Se)*P$, an estimate for the actual vaccination prevalence (P) can be derived:

$P^{\wedge} = [P_{HH} - (1\text{-}Sp)] / (Se + Sp - 1)$.

This equation can be used to obtain a putative actual vaccination prevalence based on observed vaccination prevalence if estimates of sensitivity and specificity applicable to the study population are available. A Monte Carlo simulation approach could be used by applying a distribution to estimated values of Se and Sp (e.g. normal distribution with mean as estimated Se and variance from estimated variance of Se), and making multiple draws to obtain a distribution of actual vaccination prevalence. To account for differential validity of recall by month, the simulation could be stratified by month of vaccination using month-specific estimates of sensitivity and specificity.

If influenza vaccination coverage is estimated from interview data collected during the vaccination period using product-limit survival estimates, an individual-level simulation could be performed (29). With this approach, the putative actual vaccination status of each person would be imputed based on reported characteristics, estimates of vaccination coverage developed, and then the whole process repeated multiple times to obtain a distribution of actual vaccination coverage. This approach would allow use of different estimates of sensitivity and specificity by monthly vaccination period. For each individual, the imputed vaccination status based on household reported status would be based on the estimated values for PPV and 1-NPV,

respectively. PPV and 1-NPV can be expressed as functions of sensitivity, specificity and the actual vaccination prevalence (See Appendix 5.1). However, actual vaccination prevalence is unknown. For the simulation, values of estimated actual prevalence could be obtained from the validity study and observed vaccination prevalence from the survey, stratified by month and available characteristics, using the formula above, $P^{\wedge} = [P_{HH} - (1\text{-}Sp)] / (Se + Sp - 1)$. Once estimates of $P^{\wedge}$ were derived, the values of PPV and NPV would be simulated using distributions for $P^{\wedge}$, sensitivity and specificity, and the resulting value used to impute the actual individual vaccination status (e.g. if PPV >0.5, assign as vaccinated, else assign as not vaccinated). This individual level approach takes into account possible differential validity of recall by month and may provide a more realistic assessment of uncertainty in the final adjusted, "actual" estimates.

Simulation models could be further expanded to account for uncertainty in completeness of the provider reported data in the validity study, and for bias in survey estimates related to selection bias and representativeness. A multiple imputation approach for correcting self-reported measures in survey data using validation study results has also been proposed (108).

Chapter 6 CONCLUSIONS

A central theme of this dissertation is the notion that public health surveillance should be designed to meet the information needs appropriate for use of the data to take public health action. Groves introduces the quality assurance concept of "fitness for use" in survey methodology relating to non-statistical considerations such as credibility, relevance and timeliness (23). A quick Internet search yields many examples of the "project management triangle" notion of balancing attributes of "good, fast and cheap" since it is often difficult to achieve all three. The CDC framework for evaluating public health surveillance systems provides a comprehensive list of surveillance system attributes to consider, and notes that a surveillance system must often make trade-offs between system attributes depending on intended use (112, 113).

This dissertation examines some of the key attributes for surveillance of use of influenza vaccination using population-based telephone surveys, relevant during routine seasonal vaccination campaigns and during public health emergencies such as an influenza pandemic or vaccine shortage. The first study shows that sometimes, a "quicker and cheaper" survey can be conducted without incurring additional selection bias. The second study shows that assessment of selection bias can be relative; comparison of key telephone survey outcomes to a gold standard is important, even if a true gold standard is elusive. The third study evaluates misclassification of self and parental reported influenza vaccination status, an additional threat to validity of telephone and in-persons surveys that do not use medical records to confirm vaccination status. Again this study illustrates the elusiveness of truth, as ascertainment of influenza vaccination status from health care providers may be incomplete.

CONTRIBUTIONS TO PUBLIC HEALTH AND SURVEY METHODOLOGY

The first study in this dissertation compared characteristics of early and later responders to the National 2009 H1N1 Flu Survey (NHFS), which was designed to provide weekly national estimates of pH1N1 and seasonal influenza vaccination during the 2009-10 pandemic season. This provides the first assessment of early and later cell telephone sample respondents, contributing to understanding of response propensity characteristics of cell phone respondents critical for understanding dual landline and cell telephone sample frames. Results of this study also indicated that prevalence of key outcomes did not differ substantially when restricting respondents to those reached by the end of the second week of a five week follow-up period. These results support the conduct of rapid, two-week dual frame telephone surveys conducted by the CDC in November to provide an assessment of mid-season progress of influenza vaccination efforts to support promotional efforts for continued influenza vaccination.

These findings are relevant to future emergency situations, when it may be necessary to trade-off timeliness of information for lower response rates. The "fitness for use" of survey estimates in this situation will depend on how the estimates will be used, how much potential random and systematic error can be tolerated, and the loss function associated with incorrect conclusions resulting from survey error.

The second study in this dissertation provides an important assessment of potential selection bias in the NHFS by comparison to the NHIS, a presumed "gold standard" area-sample-based, in-persons survey. Such evaluations to an external data source are critical for understanding the implications of the movement of telephone surveys to dual landline and cell telephone samples. Few surveys have this type of comparison reported, but this is crucial for assessing the longer-term viability of dual frame telephone surveys. This study found that influenza vaccination coverage estimates from the NHFS were about six to nine percentage points higher than estimates from NHIS, and this potential bias was not different for the unique

monovalent pandemic vaccine compared to the usual seasonal vaccination, both of which were recommended during the 2009-10 influenza season.

Continued use of telephone surveys (BRFSS) is needed to achieve timely national and state-level estimates at lower cost than what is feasible with the NHIS methodology, and this study quantified the potential trade-off in terms of validity of estimates. Important lessons learned for future influenza vaccination surveillance include using existing general health surveys when possible to avoid possible selection bias in influenza-specific surveys related to survey topic, and the need for ongoing comparisons of estimates from more timely surveys (NIS, BRFSS) with less timely estimates from the NHIS. With availability of preliminary NHIS quarterly data via the National Center for Health Statistics Research Data Center, more timely analysis of influenza vaccination from NHIS is possible. Comparing estimates from these data sources over time can help minimize false signals of changes in trends by population subgroups, and should be expanded to compare NHIS estimates with estimates from BRFSS for adults and from NIS for children 6 months-17 years based on parental report. This is particularly important during periods when there are changes in either surveillance system, such as the transition of telephone surveys from landline to dual landline and cell telephone sampling frames.

The third and final study in this dissertation evaluated another critical threat to validity of survey data on influenza vaccination, information bias from misclassification of parental reported influenza vaccination. It provided the only national level assessment of this issue for the youngest children eligible for influenza vaccination, complementing a similar analysis for adolescents using data from the NIS-Teen. This study indicates that inaccurate parental report of their child's influenza vaccination can result in bias of 5 to 12 percentage points. Again this illustrates the trade-off of increased bias in estimates associated with more timely and affordable data that does not include collecting data from health care providers. This study also provides a framework and example for future studies validating self or parental reported health-related outcomes to medical records, particularly to encourage consideration of the effect of incomplete

ascertainment of medical records used as the "gold standard" on estimates of validity parameters. It also provided scenarios to illustrate how apparent and actual vaccination trends may differ over time as actual vaccination rates increase, whether sensitivity or specificity parameters change over time or not.

Lessons learned from this study include the need for cautious interpretation of trends in vaccination coverage and comparisons among population subgroups with potentially different accuracy of vaccination recall or actual vaccination prevalence. It also shows the need for ongoing monitoring of validity of parental report of children's influenza vaccination, and for self report by adults.

LIMITATIONS

While the first study demonstrated that restricting the NHFS sample to early responders would not have affected survey estimates substantively, generalizing these findings to other health events or to future pandemic or inter-pandemic influenza vaccination surveys should be done with caution. The public's propensity to participate in landline and cell telephone surveys may change over time, and unique circumstances surrounding future influenza seasons or related to other health events could alter response propensities. When possible, similar evaluations should be done for other surveys needing to rapidly collect health information.

The most significant limitation of the second study is that the NHIS may not provide a true gold standard for benchmarking telephone surveys. Response rates to the NHIS have been declining as part of the general societal trend toward increased resistance to participation in voluntary surveys, even if conducted by visits to households. While synthesizing data from all available sources for targeting public health action can mitigate against false positive or false negative signals, estimates from NHIS and telephone surveys may share similar selection biases to the extent that survey outcomes are associated with general declines in response propensity, regardless of type of survey.

Aside from possible differential nonresponse bias between NHIS and NHFS, differences in survey estimates may also reflect other differences between the surveys, such as mode of interview (in-person vs. by telephone), experience of interviewers, question wording, and methods of weighting the data. This could also affect accuracy of parental reported influenza vaccination of children, so that some of the differences between NHIS and NHFS may reflect misclassification bias in addition to differential selection bias. Further studies should evaluate this possibility by comparing parental and provider reported influenza vaccination status from NHIS with provider reported status determined by a provider record check being conducted for children 19-35 months and 13-17 years to evaluate potential selection bias in NIS and NIS-Teen. This effort could be expanded to include collection of provider vaccination status for children of other ages. Further study is also needed to assess factors associated with propensity to respond to landline and cell phone surveys.

The final study of validity of parental report of children's influenza vaccination was based on NIS, which is subject to selection bias that may remain after weighting adjustments. It is also subject to misclassification error in provider reported vaccination status. Although there was some evidence of provider under-ascertainment of influenza vaccinations, and the potential effects of this on validity parameters was assessed, the actual levels of ascertainment remain unknown. Study findings may not generalize to other age groups or to clinical settings when health care providers may need to consider parental reports of children's vaccination status in their decisions to vaccinate or not.

The second and third studies in this dissertation indicated potential selection bias of the NHFS of 6-9 percentage points, and misclassification bias of parental report in NIS of 5-12 percentage points. Do these findings indicate that estimates from NHFS or similar telephone surveys relying on parental report of influenza vaccination may be overestimating influenza vaccination coverage by 11 to 21 percentage points (i.e., are these biases additive)? This is certainly possible, but difficult to determine. The survey context can affect both selection bias

and possibly accuracy of parental recall of their children's influenza vaccination status. For example, if accuracy of parental recall for NHIS is higher than for NIS, total bias would be less than additive.

CONCLUSIONS

This dissertation illustrates the importance of ongoing evaluation of surveillance systems. In the context of designing a system to monitor pandemic influenza vaccination, the concepts of "fitness for use" and surveillance system evaluation are helpful. The information needs of the system must be carefully specified, and from that specification follows the trade-offs allowable among the surveillance system attributes deemed most important. Design of the actual system follows. In emergency situations, the system must be flexible and adaptable to emerging information needs. It is also important for designers of such systems to work with users of the information to sort out what levels of information they "want" vs. "need" to know for public health action, since this can shift the balance of trade offs of system attributes.

Findings from this dissertation can be used to develop a total survey error model to simulate the distribution of true vaccination coverage as a function of estimated distributions for non-response bias stratified by landline and cell-only/mostly sampling strata, and age-specific misclassification of vaccination status. This total survey error model could be used to provide more valid estimates of vaccination coverage for use in models to estimate influenza-associated morbidity and mortality averted by vaccination each season, and for assessment of vaccination safety using estimated vaccination coverage as the denominator for rates of reported vaccine-associated adverse events. The total survey error model could also be a first step toward a more comprehensive model aimed at providing valid estimates of vaccination coverage during the influenza vaccination period using rapid surveys and administrative data on influenza vaccinations. This model would be calibrated to less timely "gold standard" surveys such as the National Health Interview Survey, and include adjustments for misclassification of reported

vaccination status. Such a model would reduce potential confusion arising from reporting of "interim" and "final" estimates from different data sources at different times during and after the annual influenza vaccination campaign.

While use of existing surveillance systems for influenza vaccination is reasonable for monitoring influenza vaccination campaigns and assessing the impact of vaccination on health outcomes, the actual proportion of the United States population that receives influenza vaccination each season remains elusive. Vaccine manufacturers track the quantities of vaccine they distribute, but influenza vaccination is primarily a private sector enterprise and administration of influenza vaccination is not a reportable condition for health care providers. Efforts to track administration of pH1N1 vaccinations during 2009-10 demonstrated that while efficient systems existed to capture this information, states did not have the resources to fully implement this system to capture private provider pH1N1 vaccinations (16). Such systems may be more feasible in smaller scale emergencies where smaller quantities of vaccine (e.g. anthrax vaccination) are administered in selected geographic areas by public health staff.

The existence of Immunization Information Systems (IIS) in most states, increased use of electronic health records by providers, and efforts toward interoperability of IIS and electronic health records have the potential to provide comprehensive, real-time influenza vaccination data in emergency and routine influenza seasons (109-111, 114, 115). While more mature IIS may provide accurate assessments of influenza vaccination (115), further progress is needed in most IIS to improve participation of children and providers (107, 114). Application of the concepts of "fitness for use", "total survey error" and the CDC framework for evaluating surveillance systems to these administrative data bases is critical to help promote and improve their use for local assessment of influenza and other vaccinations (116).

Innovative ways of promoting access to and use of personal health records, such as "apps" on smart phones or tablets to keep track of vaccinations or other health records (117) might also improve completeness of information in electronic health records and IIS, and improve

accuracy of household reported vaccination status for surveys. Development of these systems operate in a complex environment with interplay of issues such as confidentiality and security of personal information. Telephone surveys remain a viable, cost-efficient approach for assessing use of influenza vaccination and other health related information, but response rates may keep declining. This underscores the importance of carefully assessing survey system attributes over time and exploring opportunities for synergism with administrative records.

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