Statistical Improvements in Weekly-Updated Cumulative Estimates of Flu Vaccination Coverage for Children in the United States

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Abstract[1]
The NIS-Flu is a national random-digit dialing cellular telephone survey of households, sponsored by the CDC, from which weekly estimates of cumulative influenza (flu) vaccination coverage for children 6 months through 17 years of age are generated by NORC at the University of Chicago. The survey has been conducted during each flu season (October-June) since the 2010-11 season.

The current NIS-Flu estimator uses a composite estimation technique, combining direct estimates from all prior weeks to generate weekly "enhanced" estimates with smaller variance than the direct estimate from a survey week. However, the current estimator is subject to weaknesses such as larger variance for initial estimates of vaccination coverage for the immediate prior month and instability of estimates for weeks within a month. Thus, research has been conducted on methods intended to improve accuracy and stability of the weekly cumulative estimates.

We will present descriptions of alternative estimators using conditional probabilities, Kaplan-Meier estimation, and smoothing with prior seasons' data; performance evaluation results; and determination of the NIS-Flu estimator to be used for the 2021-22 season.

Key Words: Cumulative vaccination coverage; Composite estimation; Variance reduction; Estimate revisions; Surveys and questionnaires

1. Introduction

The Advisory Committee on Immunization Practices (ACIP) recommends that all persons aged ≥6 months receive annual influenza vaccination (CDC, 2020). The ability to monitor influenza vaccination coverage enables the Centers for Disease Control and Prevention (CDC) to evaluate the effectiveness of the influenza vaccination program. The availability of estimates within the influenza season allows for the direction of efforts toward priority and under-vaccinated groups while the availability of estimates soon after the end of the influenza season allows for the guiding of improvements for subsequent seasons. The availability of weekly estimates within the influenza season has also been used to gain a better understanding of vaccine demand fluctuations within a season and is particularly important during emergency situations such as an influenza pandemic or influenza vaccination shortage.

[1] The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

The National Immunization Survey-Flu (NIS-Flu) is a national random-digit-dialed cellular telephone survey of households conducted October through June of each year. The survey is conducted by NORC at the University of Chicago for the National Center for Immunization and Respiratory Diseases (NCIRD) at the Centers for Disease Control and Prevention (CDC) to estimate weekly and monthly influenza vaccination coverage for children age 6 months through 17 years (Ganesh, et al, 2010). Estimates are produced on a weekly, monthly, and full season basis for the nation, each state, and select local areas and territories. At the national level, estimates are produced by age group, gender, race/ethnicity, household poverty status, and mother's education, and other socio-demographic variables.

This article describes the current estimation methodology and limitations of the current weekly enhanced estimates. Section 2 describes the data collection methodology, while Section 3 describes the current weekly estimation methodology. Section 4 discusses limitations associated with accuracy and stability of the weekly estimator, reviews two estimation refinements implemented for the 2020-21 season, presents four estimation refinements for consideration along with summary assessments of the refinements. Section 5 presents summary discussion.

2. Data Collection Methodology

The NIS-Flu consists of three components to enable the production of estimates for all children 6 months to 17 years old. While the NIS-Child collects parent report of childhood influenza vaccination for children 19-35 months at the time of interview and the NIS-Teen for children 13-17 years, there was a gap in parent reported influenza vaccination coverage data for children 6-18 months and children 3-12 years old; these data were needed to provide influenza vaccination coverage estimates for all children aged 6 months through 17 years in the United States. Thus, the NIS-Child Influenza Module (NIS-CIM) was conducted beginning in the 2010-11 influenza season for households with children 6-18 months and children 3-12 years old that are identified during the screening for the NIS and NIS-Teen. Combining the data from these three sources is what is referred to as the NIS-Flu and allows for the production of influenza estimates for all children 6 months-17 years.

Respondents ≥18 years most knowledgeable about the child's vaccinations (hereafter referred to as "parent" in this report) are asked if their child has received a flu vaccination since July 1 and, if so, in which month; this information is parent-reported and not verified by medical records. Beginning with the 2020-2021 season, if the reported month of vaccination is the current month in which the interview is taking place, the parent was asked whether the child was vaccinated in the current week or earlier in the month.

For respondents who indicated their child had been vaccinated but had a missing month of vaccination (15.1% for the 2020-2021 flu season), month was imputed from other survey respondents with non-missing month of vaccination, matched for week of interview, age group, state of residence, and race/ethnicity. Respondents who indicated the child received a flu vaccination were also asked the kind of place at which the child was vaccinated. The range of the Council of American Survey and Research Organizations (CASRO) response rates for the NIS-Flu for the 2020–21 season was 21.8%-23.9%. The estimates for children are based on n=157,893 NIS-Flu completed interviews (NORC, 2021).

3. Current Weekly Estimator

Weekly estimates are generated within the four to six days following the end of each survey week (defined as Sunday-Saturday), with monthly estimates generated within the 11-13 days following the end of each survey month (defined as the set of survey weeks with end dates within the month). Weekly estimates are produced two ways: using a direct estimate (i.e. the weighted proportion vaccinated using the interviews conducted during that week), and using a composite, or at times also called an enhanced estimate which uses all interviews conducted up to and including the present week. End of influenza season estimates are calculated using Kaplan-Meier survival analyses with month of influenza vaccination (≥1 dose) as the unit of KM analysis, using all data collected October through June (Copeland, et al, 2013).

3.1 Direct Estimator

Direct estimates are based upon the NIS-Flu completed interviews from any given survey week, and are derived using the survey weights calculated for the completed interviews from that week.

n_W = number of NIS-Flu completed interviews obtained in survey week W

$\hat{\theta}^D_{W|W}$ = direct estimate of cumulative proportion of children that have received influenza vaccination as of week W, based upon NIS-Flu completes from survey week W

$\hat{\theta}^D_{m|W}$ = direct estimate of cumulative proportion of children that have received influenza vaccination as of the end of month $m < M$, based upon NIS-Flu completes from survey week $W \in M$

$\hat{\theta}^D_{\langle m\rangle|W}$ = direct estimate of proportion of children that received influenza vaccination within month $m < M$, based upon NIS-Flu completes from survey week $W \in M$

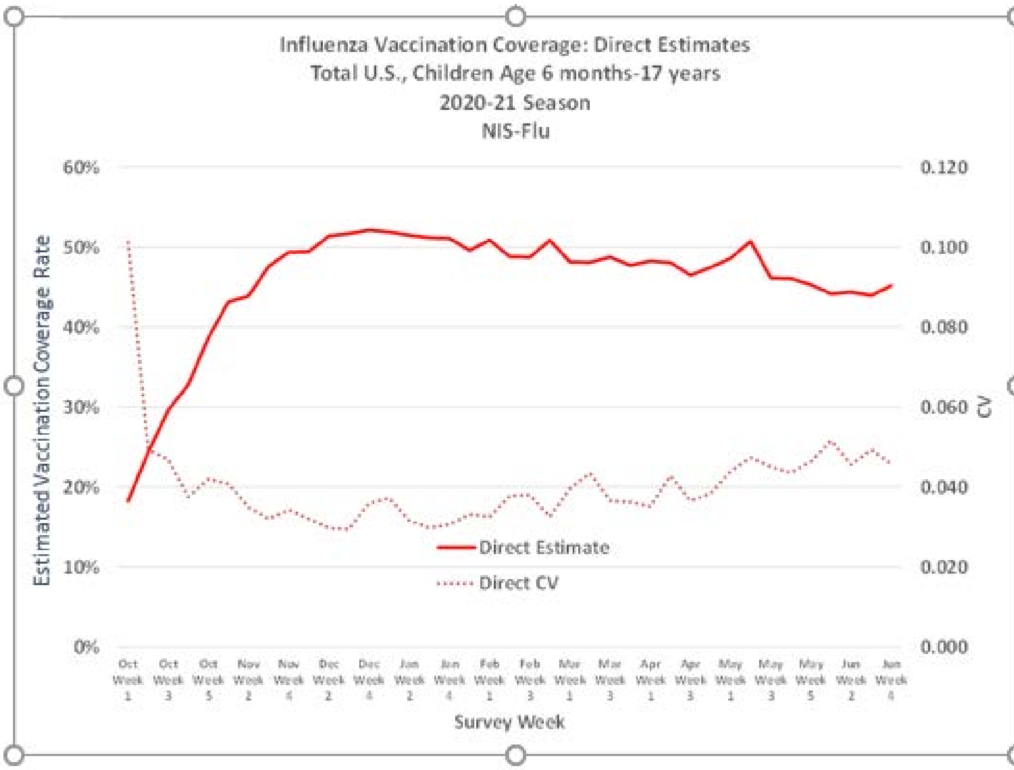
$\hat{\theta}^D_{\langle M\rangle W|W}$ = direct estimate of proportion of children that received influenza vaccination within month M as of week $W \in M$, based upon NIS-Flu completes from survey week W

NOTE: $\hat{\theta}^D_{W|W} = \hat{\theta}^D_{M-1|W} + \hat{\theta}^D_{\langle M\rangle W|W} = \sum_{m<M} \hat{\theta}^D_{\langle m\rangle|W} + \hat{\theta}^D_{\langle M\rangle W|W}$

Direct estimates are subject to large variability, especially at the population subgroup level, as weekly samples are independent and relatively small in size. Additionally, direct estimates are not constrained to be non-decreasing across time, which, with very rare exceptions, is true for the underlying true population values. Graph 3.1 presents weekly direct estimates for the total population of children age 6 months – 17 years for the U.S. during the 2020-21 season. As can also be seen in Graph 3.1, for the 2020-21 season, there appears to be a decrease in the reported vaccination rate later in the season.

The coefficient of variation (CV) of the direct weekly estimate of the vaccination coverage rate for total children at the national level ranged from 0.030 to 0.052, with the exception of the initial survey week for the season. CVs for estimates of population demographic subgroups ranged from 0.036 to 0.320, and from 0.084 to 0.875 for states/local areas.

Graph 3.1:



*CV is the coefficient of variation.

3.2 Composite Estimator

To reduce variability in the direct estimators, a composite, or enhanced, estimation approach was developed which uses data from completed interviews from the current week but also from all prior weeks. Enhanced estimates are derived using the direct estimates for all survey weeks up to and including the current survey week as described in more detail below.

Each week, beginning with Oct week 2, enhanced estimates are derived through use of a composite estimator for each calendar month prior to the month containing the current week (current month), and the direct estimator for the current month, as follows:

$\hat{\theta}^E_{\langle m\rangle|W} = \frac{\sum_{w\le W, w\in m'>m} n_w \hat{\theta}^D_{\langle m\rangle|w}}{\sum_{w\le W, w\in m'>m} n_w}$ = enhanced estimate of proportion of children that received influenza vaccination within month $m < M$, based upon NIS-Flu completes from all survey weeks $w \le W, W \in M$

NOTE: The survey weeks utilized for $\hat{\theta}^E_{\langle m\rangle|W}$ are those subsequent to the end of month m (e.g., survey weeks beginning with Jan week 1 are utilized for $\hat{\theta}^E_{\langle Dec\rangle|W}$)

$\hat{\theta}^E_{m|W} = \sum_{m'\le m} \hat{\theta}^E_{\langle m\rangle|W}$ = enhanced estimate of proportion of children that received influenza vaccination as of the end of month $m < M$, based upon NIS-Flu completes from all survey weeks $w \le W, W \in M$

NOTE: Not all survey weeks are utilized the same number of times for $\hat{\theta}^{E}_{m|W}$ (e.g., survey weeks Oct week 1-Oct week 4 or 5 are utilized only for $\hat{\theta}^{E}_{\langle Jul-Sep\rangle|W}$. Whereas survey weeks Jan week1-Jan week 4 or 5 are utilized for $\hat{\theta}^{E}_{\langle Jul-Sep\rangle|W}$, $\hat{\theta}^{E}_{\langle Oct\rangle|W}$, $\hat{\theta}^{E}_{\langle Nov\rangle|W}$, and $\hat{\theta}^{E}_{\langle Dec\rangle|W}$)

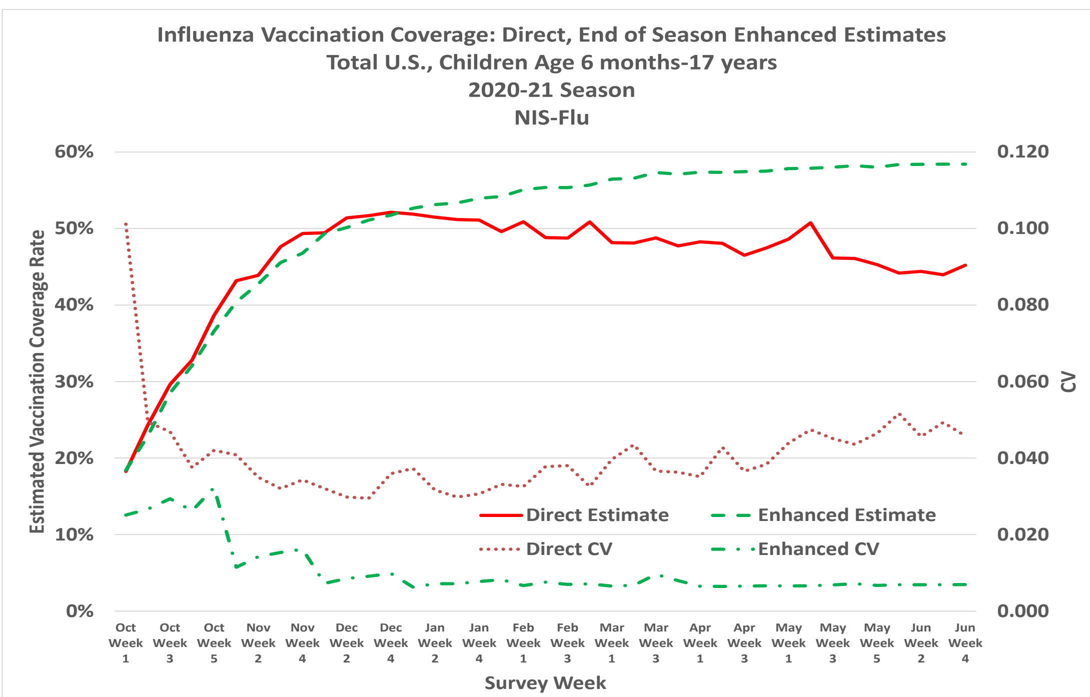
$\hat{\theta}^{E}_{W|W} = \hat{\theta}^{E}_{M-1|W} + \hat{\theta}^{D}_{\langle M\rangle W|W}$ = enhanced estimate of proportion of children that have received influenza vaccination as of week $W \in M$, based upon NIS-Flu completes from all survey weeks $w \leq W$

Each week, the enhanced estimates are updated for all weeks preceding the current week, with the estimate for the current week being a new estimate. Estimates are updated with this enhanced estimate approach because new interview data are included in the denominator. This is not the case for the direct estimates, which never change once produced. The formula for the updated enhanced estimates is:

$\hat{\theta}^{E}_{W'|W} = \sum_{m<M'} \hat{\theta}^{E}_{\langle m\rangle|W} + \hat{\theta}^{D}_{\langle M'\rangle W'|W'}$ = enhanced estimate of proportion of children that have received influenza vaccination as of week $W' \in M'$, based upon NIS-Flu completes from all survey weeks $w \leq W$ $(W' < W, M' \leq M, W \in M)$

Use of compositing for the NIS-Flu greatly reduced the variability of weekly estimates, as seen in Graph 3.2. In addition, it reduces (but does not eliminate) the occurrence of week-to-week decreases and avoids decreases later in the season. The CV of the enhanced weekly estimate of the vaccination coverage for total children at the national level ranged from 0.006 to 0.016, with the exception of the initial survey weeks for the season.

Graph 3.2:



*CV is the coefficient of variation.

Comparing direct estimates with end of season enhanced estimates for a week, CVs are reduced by 52%-87% at the national, from 43%-89% at the population demographic subgroup level, and from 28%-95% at the state/local area level.

4. Weekly Estimator Limitations and Refinements Implemented and Proposed

In this section, we describe three issues associated with the weekly enhanced estimator which existed prior to the start of the 2020-21 season, and list recently implemented and/or potential refinements which could serve to address those issues.

- Estimates are not constrained to be non-decreasing from week to week;
- Estimates for a given calendar month are subject to variability across survey weeks;
- Reported month of vaccination may be in error.

4.1 Change in Estimates from One Week to the Next

Neither the direct nor the enhanced estimators are constrained to be non-decreasing, while the true population value is non-decreasing (outside rare occurrences). Thus, there is the possibility that

$$\hat{\theta}^{E}_{W|W} < \hat{\theta}^{E}_{W-1|W}$$

This is a relatively common situation at the state level and occurs occasionally at the national level. In the 2019-20 season, at the national level, there were five occurrences of a decrease from one week to the next, while at the state level there were seven weeks for which 20 to 25 states showed a decrease from the prior week, and all but two weeks had at least one state with a decrease from the prior week.

4.1.1 Implemented Refinement 1: Extend Compositing to Within Month

To address this issue, beginning November of the 2020-21 season, if the reported month of vaccination is the current month in which the interview is taking place, the parent was asked whether the child was vaccinated in the current week or earlier in the month. This information was utilized to refine the composite estimator so as to improve the accuracy of the estimate of $\theta_{\langle M\rangle|W}$, the proportion of children that received influenza vaccination within month M as of week $W \in M$.

$\hat{\theta}^{D}_{\langle W\rangle|W}$ = direct estimate of proportion of children that received influenza vaccination within week $W \in M$, based upon NIS-Flu completes from survey week W

$\hat{\theta}^{D}_{\langle M\rangle W^{c}|W}$ = direct estimate of proportion of children that received influenza vaccination within month M, but not within week $W \in M$ based upon NIS-Flu completes from survey week W

NOTE: $\hat{\theta}^{D}_{\langle M\rangle W|W} = \hat{\theta}^{D}_{\langle W\rangle|W} + \hat{\theta}^{D}_{\langle M\rangle W^{c}|W}$

For survey week 1 of a month, enhanced estimate derivation proceeds as described in Section 3.2. For survey weeks 2 through 4 (5) of a month, enhanced estimate derivation is as follows:

$\hat{\theta}^{E}_{\langle M\rangle W-1|W} = \frac{\sigma^2_W \hat{\theta}^{E}_{\langle M\rangle W-1|W-1} + \sigma^2_{W-1|W-1} \hat{\theta}^{D}_{\langle M\rangle W^C|W}}{\sigma^2_{W-1|W-1} + \sigma^2_W}$ = enhanced estimate of proportion of children that have received influenza vaccination within month M as of survey week $W-1 \in M$, based upon NIS-Flu completes from survey weeks through survey week $W \in M$ (see NORC, 2021)

where:

$\sigma^2_W = var\left(\hat{\theta}^{D}_{\langle M\rangle W^C|W}\right)$

$\sigma^2_{W-1|W-1} = var\left(\hat{\theta}^{E}_{\langle M\rangle W-1|W-1}\right)$

$\hat{\theta}^{E}_{\langle M\rangle W-1|W-1} = \hat{\theta}^{D}_{\langle M\rangle|W-1}$ for $W-1 =$survey week 1 of a month

$\hat{\theta}^{E}_{\langle M\rangle W|W} = \hat{\theta}^{E}_{W-1|W} + \hat{\theta}^{D}_{\langle W\rangle|W}$ = enhanced estimate of proportion of children that received influenza vaccination within month M as of week $W \in M$, based upon NIS-Flu completes through survey week W

$\hat{\theta}^{E}_{W|W} = \hat{\theta}^{E}_{M-1|W} + \hat{\theta}^{E}_{\langle M\rangle W|W}$ = enhanced estimate of proportion of children that have received influenza vaccination as of week $W \in M$, based upon NIS-Flu completes from all survey weeks $w \leq W$

Use of compositing for the within-month estimation reduced the CV of weekly estimates. Comparing estimates with and without this refinement, CVs are reduced by 0% to 43% (median=32%) at the national, total children level, from -13% to 65% (median=32%) at the population demographic subgroup level, and from -155% to 85% (median=30%) at the state/local area level.

4.1.2 Implemented Refinement 2: Apply Constraint

While extension of compositing to within month served to reduce variability, it did not eliminate all occurrences of decreasing estimates. Although alternative smoothing approaches could also be used to address decreasing estimates, it was decided for 2020-21 to apply the constraint

$$\hat{\theta}'^{E}_{W-1|W} = \hat{\theta}^{E}_{W|W}, if\ \hat{\theta}^{E}_{W|W} < \hat{\theta}^{E}_{W-1|W}$$

Extending compositing to within month (as described in Section 4.1.1) did not reduce the occurrence of week to week decreases at the national, total children level, which totaled 4. At the population demographic subgroup level the occurrence of week to week decreases was reduced by 31% (from 153 to 106), and by 10% at the state/local area level (from 268 to 242). Application of the constraint described above eliminated all remaining week to week decreases.

4.2 Variability of Estimates for A Calendar Month

Direct estimates for a calendar month are subject to large variability across survey weeks; thus the enhanced estimates for a calendar month are also subject to large variability across initial survey weeks immediately following the month. As more survey weeks are added, the enhanced estimate for a given calendar month begins to stabilize. This is a relatively common situation at the state level and occurs occasionally at the national level.

4.2.1 Potential Refinement 1: Integrate Estimates from Prior Seasons

One approach to reducing the variability associated with initial estimates of vaccination coverage for a month would be to weight the estimate from the current season with estimates from prior seasons.

If there is some consistency in vaccination coverage rates from one season to the next, variability in the initial estimates for a month could be reduced by weighting the month estimate from current season data with that from prior seasons:

$$\widehat{\theta'}^{E}_{m|w} = \psi\hat{\theta}^{E}_{m|w} + (1-\psi)\hat{\theta}^{Prior}_{m}, w \in M, m = M-1$$

where

$\hat{\theta}^{\mathrm{Prior}}_{\mathrm{m}}$ = some weighted average of final $\hat{\theta}^{\mathrm{E}}_{\mathrm{m}}$ from one or more prior seasons

Typically when creating composited estimates, one derives the weighting factor proportional to the variances of the component estimates. However, doing so in this case would too heavily weight the prior seasons' estimate as it would have much smaller variance than that from the current season. As a result, some judgment-driven weighting should be used.

For the assessment of this refinement, the following weighting scheme was used, which gradually decreases the weight given to the prior seasons' estimate:

- Set $\psi = 0.25$ for the 1st week following the end of month m
- Set $\psi = 0.5$ for the 2nd week following the end of month m
- Set $\psi = 0.75$ for the 3rd week following the end of month m

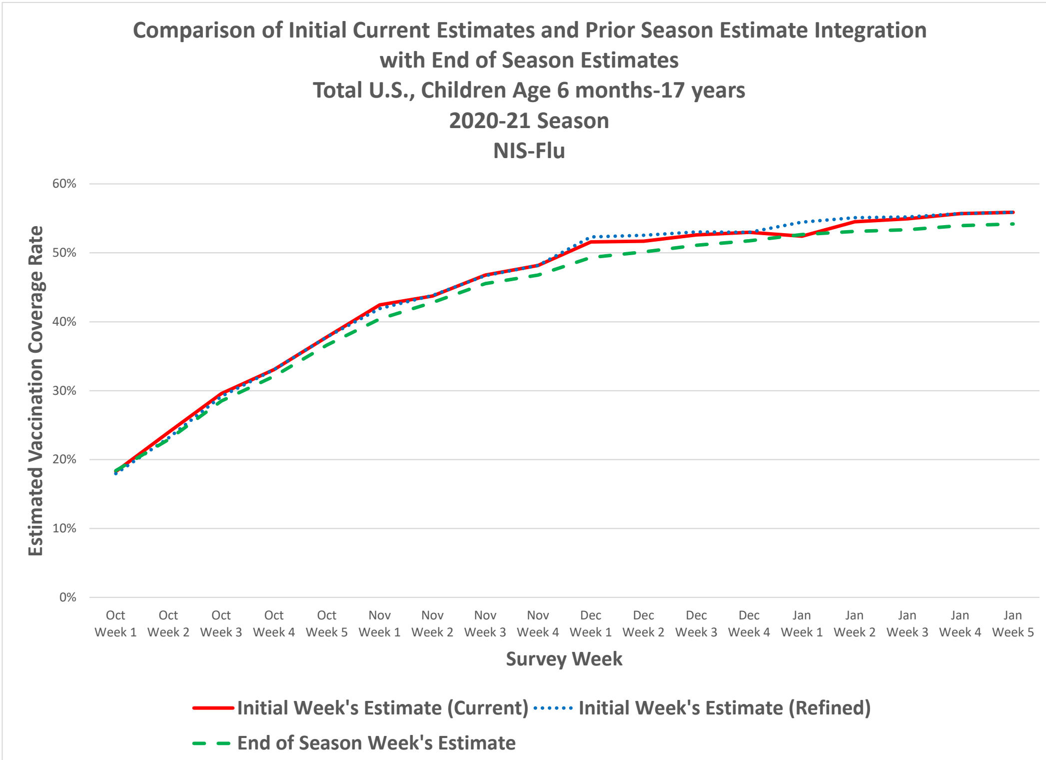
The prior seasons' estimate would no longer be utilized beginning with the 4th week following the end of month m.

At the national, total children level, integrating 2019-2020 final estimates with 2020-2021 estimates performed slightly worse than the current estimates when comparing to the final estimates. Graph 4.2.1.1 shows initial weekly estimates from current methodology and the integration methodology, along with the final enhanced estimates, for Oct week 1-Jan week 3. Of the 12 weeks of interest (Oct-Jan weeks 1-3), the integration methodology yielded initial estimates closer to the final estimates for only three weeks, although all differences were less than 0.2 percentage points.

At the population demographic subgroup level, the two approaches perform similarly when compared to the final estimates, with integrating 2019-2020 final estimates with 2020-2021 estimates being superior to the current estimates 53% of the time. At the state level, integrating 2019-2020 final estimates with 2020-2021 estimates was superior to the current estimates 62% of the time. This was most evident for Oct weeks 1-3, where integrating 2019-2020 final estimates with 2020-2021 estimates was superior to the current estimates 82% of the time and showed an improvement of more than 10 percentage points 6% of the time. The superiority declined across months (Nov weeks 1-3: 70%, Dec weeks 1-3: 53%), until for Jan weeks 1-3 it occurred only 43% of the time.

It can also be seen from Graph 5.1 that integrating 2019-20 final estimates with 2020-2021 estimates appears to yield smoother trends than do the current estimates. However, the potential for the assumption of similar vaccination rates for given periods of time across seasons is subject to error.

Graph 4.2.1.1:



4.2.2 Potential Refinement 2: Utilize Conditional Probabilities

A second approach to reducing the variability associated with initial estimates of vaccination coverage for a month would be to utilize conditional probabilities in deriving estimates of vaccination coverage for a month.

This approach entails estimating the conditional probability of being vaccinated in month *m* given not vaccinated by month *m-1*. For a given survey week *W*, the direct estimator for the conditional probability of being vaccinated in month *m* given not vaccinated prior to month *m* is given by

$$P_W^D(m|m-1) = \frac{\hat{\theta}^D_{\langle m\rangle|W}}{\left(1 - \sum_{m'<m} \hat{\theta}^D_{\langle m'\rangle|W}\right)}$$

Thus, a composite estimator for the conditional probability of being vaccinated in month *m* given not vaccinated prior to month *m* can be derived by combining across survey weeks as follows:

$$P_W^{Comp}(m|m-1) = \frac{\sum_{w\leq W, w\in m^*>m} n_w P_W^D(m|m-1)}{\sum_{w\leq W, w\in m^*>m} n_w}$$

By construction, for July-September, the enhanced estimate is identical to the conditional estimate.

A similar approach is used to estimate within month. That is, to estimate the conditional probability of being vaccinated prior to each week in month *m*, given not vaccinated by month *m*-1.

Table 4.2.2.1 provides the difference (=enhanced estimate – conditional estimate) in the cumulative monthly vaccination coverage rate for July-September through July-March for children age 6 months-17 years. Table 6.2 provides the distribution of the difference in cumulative monthly vaccination coverage rates for all subpopulations and geographic areas including states/local areas. In general, the conditional estimates are largely similar to the current enhanced estimates.

Table 4.2.2.1: Difference (=enhanced - conditional) in cumulative monthly vaccination coverage rate for the enhanced estimate and the conditional estimate for children age 6 months-17 years, 2020-2021 season, NIS-Flu.

Jul-Sep	Jul-Oct	Jul-Nov	Jul-Dec	Jul-Jan	Jul-Feb	Jul-Mar
0.0%	0.0%	0.1%	-0.8%	-0.4%	-0.3%	-0.1%

Table 4.2.2.2: Distribution of the difference (=enhanced - conditional) in cumulative monthly vaccination coverage rate for the enhanced estimate and the conditional estimate for all subpopulations and states/local areas, 2020-2021 season, NIS-Flu.

	Jul-Sep	Jul-Oct	Jul-Nov	Jul-Dec	Jul-Jan	Jul-Feb	Jul-Mar
10th percentile	0.0%	-0.1%	-0.1%	-2.4%	-2.0%	-1.8%	-2.0%
25th percentile	0.0%	0.0%	0.0%	-1.2%	-0.9%	-0.9%	-0.8%
Median	0.0%	0.0%	0.1%	-0.8%	-0.4%	-0.3%	0.0%
75th percentile	0.0%	0.1%	0.2%	-0.4%	0.2%	0.4%	0.7%
90th percentile	0.0%	0.2%	0.4%	0.6%	1.5%	1.3%	2.0%

4.3 Month of Vaccination Reporting Error

Research comparing data from the NIS-Flu (self-reported by a parent) with that from the NIS-Child and NIS-Teen (reported by a healthcare provider) has shown that self-reported month of vaccination is often inaccurate (Santibanez, et al, 2017). Errors increase across the season, with interviews conducted in January–June having 56% incorrect month. These reporting errors will tend to increase the variability in direct and composite estimates as well as introduce bias.

4.3.1 Potential Refinement 3: Terminate Compositing for a Month after Defined Time Period

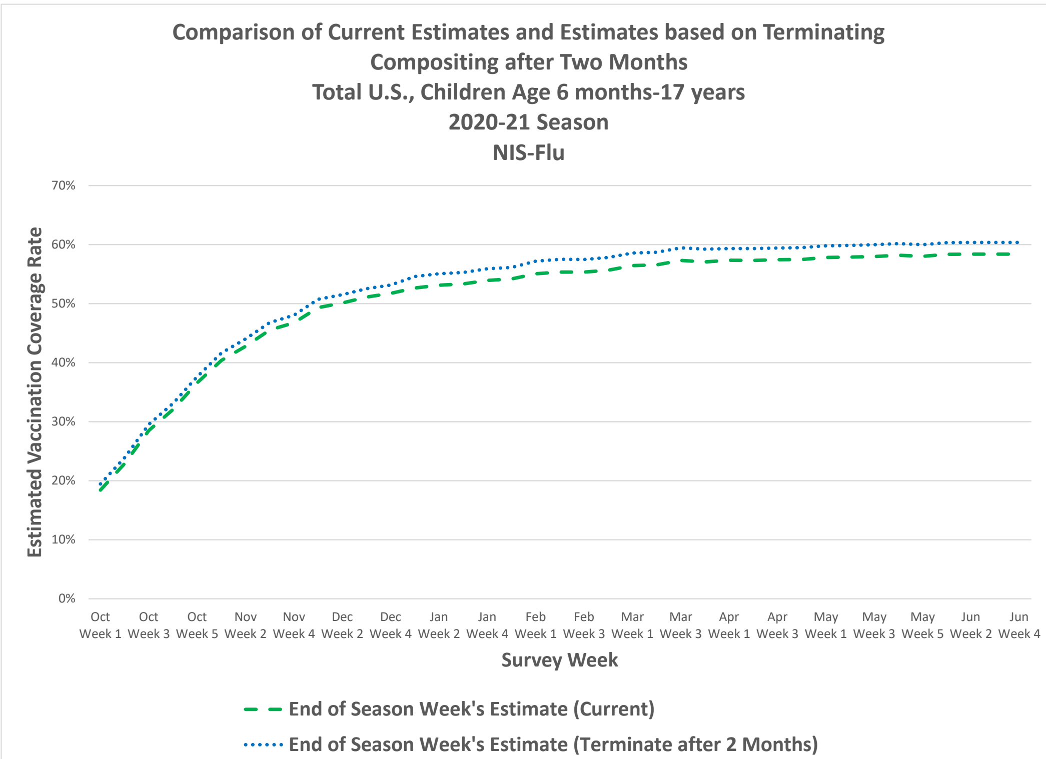
One approach to reducing the variability and bias associated with month of vaccination reporting errors would be to terminate compositing in creating a vaccination coverage rate estimate for a given month after some defined time period.

Given month of vaccination reporting errors for a given month increase across the season, terminating compositing for a given month's estimate after some defined time period could serve to reduce the bias and variability. For the assessment of this refinement, compositing for a given month was terminated after the end of the last week of the second following month.

$$\hat{\theta}^{E}_{m|w} = \hat{\theta}^{E}_{m|w-1} \text{ for } w \in M, M > m + 2$$

This refinement had a noticeable impact on the level of a month's estimate, with minimal impact on the variance of the estimate. At the national, total children level, terminating updates after two months yielded estimates two percentage points greater than those from the current estimator, as seen in Graph 4.3.1.1. The difference was one percentage point for Oct week 1, gradually increasing and by Jan week 2 was two percentage points. In light of the decline in direct estimates of cumulative vaccination rate across the season, as shown in Graph 3.1, this difference appears to be in the appropriate direction.

Graph 4.3.1.1: Comparison of Current Estimates and Estimates based on Terminating Compositing after Two Months



4.3.2 Potential Refinement 4: Utilize Cumulative Compositing Rather than Monthly Compositing

A second approach to reducing the variability and bias associated with month of vaccination reporting errors would be to refine the compositing approach so as to derive cumulative, rather than individual, month estimates.

An alternative approach to addressing month of reporting error is to assume that, while the specific month reported may be in error, reporting for some aggregate period of months is accurate. Thus, refining the compositing approach so as to require less specificity of time period could reduce variability and bias.

This approach was implemented for the assessment by dropping data from early weeks across time. For example, beginning with December week 1, data from October survey weeks were dropped, in which case the enhanced estimator becomes:

$$\widehat{\boldsymbol{\theta}}^{E}_{Nov} = \widehat{\boldsymbol{\theta}}^{E}_{\boldsymbol{Jul}-Oct|Nov\,wk1-Dec\,\boldsymbol{wk}1} + \widehat{\boldsymbol{\theta}}^{E}_{\boldsymbol{Nov}|Dec\,wk1}$$

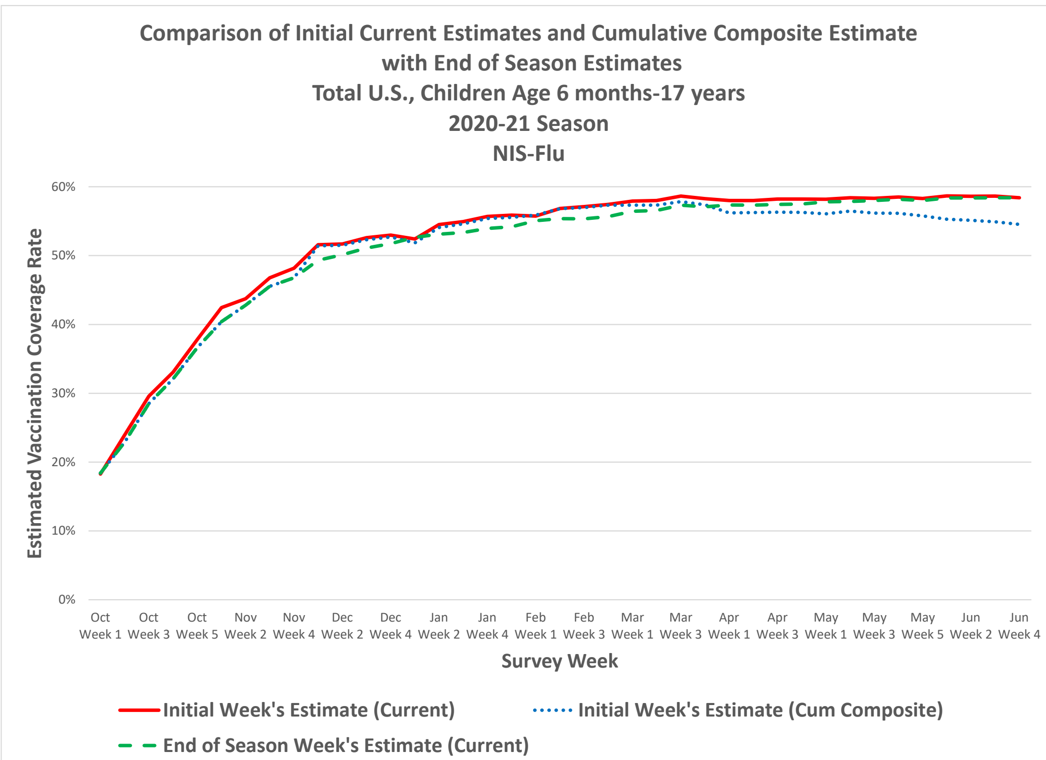
Rather than

$$\widehat{\boldsymbol{\theta}}^{E}_{Nov} = \widehat{\boldsymbol{\theta}}^{E}_{Jul-Sep|Oct\,wk1-Dec\,wk1} + \widehat{\boldsymbol{\theta}}^{E}_{Oct|Nov\,wk1-Dec\,\boldsymbol{wk}1} + \widehat{\boldsymbol{\theta}}^{E}_{Nov|Dec\,wk1}$$

Thus, this refinement is a complement to that in Section 7. The superior approach of the two should depend upon the nature of month of vaccination recall error, and the impact on variance associated with using fewer weeks.

As seen in Graph 4.3.2.1, this refinement suffers from a decline in cumulative vaccination rate late in the season similar to that seen for the direct estimates in Graph 3.1. Demographic subpopulation and state level estimates derived from the cumulative compositing approach showed similar results. As a result, this approach would not result in improved estimates.

Graph 4.3.2.1:



4.3.3 Potential Refinement 2: Utilize Conditional Probabilities

Use of conditional probabilities, as mentioned in Section 4.2.2, may also serve to reduce the variability and bias associated with month of vaccination reporting errors.

5. Discussion

Use of compositing in the NIS-Flu for generating calendar month vaccination coverage estimates yields intended benefits in terms of variance reduction and stabilization of trends. Further improvement was achieved with the 2020-21 implementation of within month compositing.

Terminating updates to composite estimates two months following a given calendar month appears to address the issue of month of vaccination recall error. Implementation of this approach would require deriving estimates for prior seasons so as to provide information relative to the trend break which would occur with the transition to a refined estimator, which is statistically possible.

Application of conditional probabilities would have minimal impact on estimates, but would offer a more intuitive approach to generating cumulative vaccination coverage rates. While the conditional probability approach, as with the current enhanced approach, can generate decreasing estimates across weeks (as a result of sampling error), conceptually it formulates an approach that is non-decreasing and easier to comprehend. One potential improvement to the conditional approach would be to further smooth the weekly estimates to be non-decreasing via isotonic regression.

Other potential refinements assessed did not yield results suggesting further consideration. None of the approaches considered would address the issue of overreporting of influenza vaccinations by respondents (Santibanez, et al, 2017). Total survey error (TSE) analysis (Davis, et al, 2016) has shown that end of season KM vaccination coverage estimates have reporting error bias on the order of 5.5 to 7.0 percentage points. Future TSE analysis would measure the resultant bias.

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