

Racial/ethnic disparities in vaccination coverage by 19 months of age: An evaluation of the impact of missing data resulting from record scattering

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SUMMARY

We describe how trends in the vaccination coverage at 19 months of age vary by race/ethnicity; explore the extent to which data required to evaluate a child's up-to-date vaccination status is missing as a result of the scattering of vaccination records among many vaccination providers; evaluate how the prevalence of that missing data varies by race/ethnicity; and evaluate the impact that the missing data has on estimated race/ethnic disparities in vaccination coverage. We analyzed data from 255 043 children sampled between 1995 and 2006 by the National Immunization Survey (NIS). Among children who had 2+ vaccination providers reporting, estimated vaccination coverage was significantly lower by approximately 15 per cent among children who did not have all of their providers reporting to the NIS compared with children who had all of their vaccination providers reporting to the NIS. By comparing coverage estimates that were adjusted for missing data to unadjusted estimates, we found that unadjusted estimates consistently underestimated vaccination coverage by as much as 4.9 per cent for Asians, 4.8 per cent for Hispanics, 4.1 per cent for American Indian/Alaska Natives, 3.3 per cent for non-Hispanic blacks, and 2.8 per cent for non-Hispanic white children. Estimates of disparities in estimated vaccination coverage did not depend on whether coverage estimates were adjusted for missing data. Hispanic and non-Hispanic black children had estimated coverage rates that were significantly less than that of non-Hispanic white children, with median disparities of 4 and 9 per cent, respectively. Regardless of whether estimates are adjusted, data from the NIS show that disparities in vaccination coverage that existed in the early 1990s persist. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: disparities; missing data; record scattering; weighting class

BACKGROUND

Substantial effort is being devoted nationally to the problem of identifying and addressing health disparities. Because data from national surveys are often used to investigate cross-group differences,

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it is critical to ensure that measurement artifacts are not misinterpreted as evidence of the presence or absence of health disparities.

The National Immunization Survey (NIS) devotes considerable effort to obtain the vaccination histories from the vaccination providers of 19–35-month old children who were sampled by the survey. These provider-reported vaccination histories are used to determine each sample child's up-to-date (UTD) vaccination status with respect to vaccines recommended by the Advisory Committee on Immunization Practices [1]; to estimate vaccination coverage in each state, the District of Columbia, and five other selected cities; and to evaluate whether the *Healthy People 2010* vaccination coverage objective of eliminating racial/ethnic disparities in the U.S. has been achieved [2]. However, provider-reported vaccination histories obtained by the NIS may not be complete. In this paper, when a child has two or more (2+) vaccination providers we say that the vaccination history may be 'scattered' because these providers may not have a record of the child's entire vaccination history [3,4]. Also, among children sampled by the NIS who have 2+ vaccination providers, all of their vaccination providers may not respond to the NIS and contribute their portion of the child's vaccination history to the survey. When this happens, those sampled children's provider-reported vaccination histories may be incompletely ascertained and can result in an erroneous determination that they are not UTD because of the missing vaccination histories from the non-responding providers. A consequence of this error is that estimated vaccination coverage rates that may be too low. Further, if minority children are more likely to have vaccination records scattered among 2+ providers and are more likely to have fewer providers reporting vaccination histories to the NIS than they actually have, then estimates of vaccination coverage obtained from the NIS may be underestimated for those children.

Since 1995, the Advisory Committee on Immunization Practices has recommended that children should be administered four doses of the DTaP vaccine, three doses of the poliovirus vaccine, one dose of the MMR vaccine, and three doses of the Hib vaccine by 19 months of age [5]. In this paper, we refer to children who were administered at least the recommended number doses for each of these four vaccines by 19 months as 4:3:1:3 UTD. The purposes of this paper are (i) to describe how trends in 4:3:1:3 vaccination coverage at 19 months of age vary by racial/ethnic group; (ii) to explore the extent to which data required to evaluate a child's UTD vaccination status and vaccination coverage is missing as a result of the scattering of vaccination records among many vaccination providers; (iii) to evaluate how the prevalence of that missing data varies by race/ethnicity; and (iv) to evaluate the impact that the missing data has on estimated race/ethnic disparities in vaccination coverage. Data obtained from the annual surveys of the NIS between 1995 and 2006 are used to conduct our investigation.

METHODS

The design of the NIS

In our work we analyzed data from 255 043 children sampled by the NIS between 1995 and 2006 who had provider-reported vaccination histories. Data collection in the NIS is conducted in two phases. In the first phase, a list-assisted random-digit-dialing (RDD) survey is conducted to identify households that have a 19–35-month-old child. If the household reports having an age-eligible child, the RDD survey is conducted and collects sociodemographic information about the child, the child's mother, and the child's household. Also, household-reported vaccination

histories are collected from households' written records of the child's vaccination history when NIS respondents have a written record. At the end of the RDD interview, consent is requested from the NIS respondent to contact all of the vaccination providers of the age-eligible child in the household. If consent is obtained, the names and addresses of each provider are obtained and the second data collection phase of the NIS data collection is conducted. In the second data collection phase, providers who were listed in the NIS RDD interview are mailed a questionnaire to obtain the child's provider-reported vaccination history. The provider-reported vaccination histories obtained from the mail survey of vaccination providers are used to evaluate the vaccination status of children sampled in the NIS, and are used to obtain official estimates of vaccination coverage for 19–35-month-old children in the U.S.

The response rate of the NIS is the product of three percentages: (i) the estimated percentage of households who reported in the NIS RDD interview as having a 19–35-month-old child among households who actually have a 19–35-month-old child; (ii) the CASRO [6] rate of the RDD portion of the NIS; and (iii) the percentage of sampled children for whom sufficiently complete provider-reported vaccination histories are obtained in the NIS mail survey to vaccination providers. For the survey years that we studied, among households that had a landline telephone and a 19–35-month-old child, the estimated percentages of households who reported having a 19–35-month-old child in the RDD portion of the NIS ranged from 74 to 70 per cent and the CASRO rates ranged from 69 to 76 per cent. Among parents of age-eligible children who had a completed NIS RDD interview, the percentages of children who had a sufficiently detailed vaccination history returned from vaccination providers to accept as a complete report ranged from 62 to 70 per cent. More detailed description of the methods used by the NIS, including a description of the rules used for including sampled children's data in official vaccination coverage estimates are described by Smith *et al.* [7–9]. The NIS has been reviewed and approved by an institutional review board at the Centers for Disease Control and Prevention every year between 1994 and 2006.

Evaluation of trends in 4:3:1:3 vaccination coverage by 19 months of age

To evaluate trends in the percentage of children who were 4:3:1:3 UTD by 19 months of age, we used provider-reported vaccination histories reported to the NIS, and estimated the percentages for every annual birth cohort born between 1992 and 2004 for each racial/ethnic group using a cohort–age model described by Smith *et al.* [10] to aggregate data across the annual-independent NIS surveys conducted between 1995 and 2006. In our analyses of those trends, we used SAS software survey procedures [11] that allow the sampling weights, sampling design of the NIS, independence of sampling from year to year, and clustering within households to be taken into account in our statistical analyses.

Record scattering and missing data

To evaluate the extent of record scattering in the NIS, we used data from sampled children who are used to obtain official estimates of vaccination coverage for 19–35-month-old children in the U.S.

Among sampled children with 2+ vaccination providers who have provider-reported vaccination histories reported to the NIS, one or more of the vaccination providers may not respond to the NIS. In this case, the portion of a child's vaccination history held by the non-responding providers is missing. Also, in this case, if the vaccination histories obtained from the providers who respond to the NIS indicate that the child is UTD with respect to vaccines that were recommended at the time the child was supposed to have been administered childhood vaccines, the missing data

from the non-responding providers have no consequence because the child's UTD status can be completely ascertained from the histories of the responding providers. However, among sampled children with 2+ vaccination providers, all of whom do not respond to the NIS, if the data from the vaccination histories obtained from the responding providers indicate that the child is not UTD with respect to recommended vaccines, the missing data from the non-responding providers may have a consequence with respect to the ability to ascertain whether the sampled child is really not UTD. Moreover, a sampled child who was reported to have 2+ vaccination providers and who has provider-reported vaccination histories reported to the NIS has an 'incompletely ascertained provider-reported vaccination history' if (i) one or more of the vaccination providers listed in the NIS RDD interview did not respond to the NIS, (ii) the child was not UTD according to the provider-reported vaccination history obtained from responding providers with respect to vaccine series that were recommended when the child was 0–9 months of age, and (iii) the number of doses reported by the child's parent from their own written vaccination record of their child's vaccination history was greater than the number of provider-reported doses for any of the recommended vaccines. Among sampled children whose parent did not have a written record of their child's vaccination history, a child has an incompletely ascertained vaccination history if (i) some of the vaccination providers listed in the NIS RDD survey did not respond to the NIS mail survey, and (ii) the child was not UTD according to the provider-reported vaccination history with respect to vaccine series that were recommended when the child was 0–19 months of age.

Statistical adjustment to compensate for missing data resulting from incomplete ascertainment

When a sampled child is determined to have an incompletely ascertained vaccination history, we treated their entire provider-reported vaccination history as if it was missing. To compensate for the incompletely ascertained provider-reported vaccination histories we used the most commonly used statistical approach that is used in sample surveys to adjust for missing or incomplete data: the 'weighting class' methodology [12]. In the weighting class methodology, children with 2+ providers listed in the RDD portion of the NIS were assigned to one of the two 'weighting' classes within each of the NIS sampling strata. Within each sampling stratum, the two weighting classes were defined by the median of the distribution of the stratum's sampled children's estimated probability of having an incompletely ascertained provider-reported vaccination history. These probabilities were estimated from forward-stepwise multivariable logistic regression of the binary indicator of whether a child had an incompletely ascertained provider-reported vaccination history on the child's socio-demographic factors. Because sampled children within the same weighting class have a similar estimated probability of having an incompletely ascertained provider-reported vaccination history, they are similar with respect to the sociodemographic characteristics that were used to estimate that probability. Because of that similarity within each weighting class, the survey weights of children who had a completely ascertained provider-reported vaccination history are increased proportionally so that they represent all of the children in the weighting class. Subsequent statistical analyses that are adjusted for incompletely ascertained provider-reported vaccination histories use data from children with one provider and data from children with a completely ascertained provider-reported vaccination history, along with the revised survey weights of these children. Smith *et al.* [9] provide a more detailed description of adjustments for incompletely ascertained provider-reported vaccination histories for the NIS.

RESULTS

The extent of record scattering

Each year between 1995 and 2006, approximately 99.7 per cent of all 19–35-month-old children in the U.S. received vaccine doses. Among those children, the estimated percentage of children who had provider-reported vaccination histories scattered among 2+ vaccination providers ranged from 28.7 per cent (95 per cent CI: ± 1.0 per cent) for the annual birth cohort in 1999 to 32.8 per cent (95 per cent CI: ± 1.7 per cent) for the annual birth cohort born in 1996. Among the 252 387 children sampled by the NIS between 1995 and 2006 whose provider-reported vaccination histories have been used to estimate official vaccination coverage rates, the percentage of children who did not have all of their vaccination providers reporting vaccination histories to the NIS ranged from 16.2 per cent (95 per cent CI: ± 0.5 per cent) for the annual birth cohort born in 1997 to 17.5 per cent (95 per cent CI: ± 0.6 per cent) for the annual birth cohort born in 2004.

Association of record scattering with vaccination coverage rates

For each annual birth cohort born between 1992 and 2004, among children who had 2+ vaccination providers the estimated percentage of children who were 4:3:1:3 UTD by 19 months of age was significantly lower among children who did not have all of their vaccination providers responding to the NIS mail survey, compared with children who had all of their vaccination providers responding to the NIS mail survey (Figure 1, $p < 0.05$).

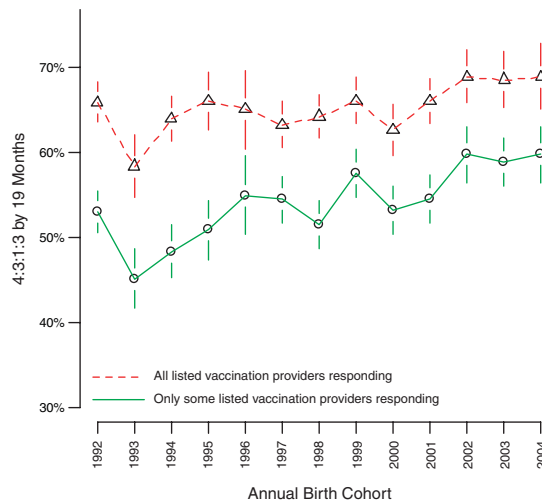
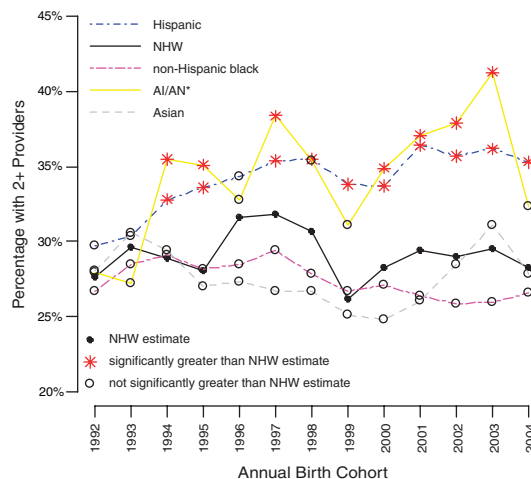


Figure 1. The unadjusted effect of record scattering on the estimated percentage of sampled children who were 4:3:1:3 UTD by 19 months of age, by annual birth cohort, among children with 2+ vaccination providers. The dashed line corresponds to the estimated rates for children who had all of their listed vaccination providers responding to the NIS mail survey. The solid line corresponds to the estimated rates of children who did not have all of their listed vaccination providers responding to the NIS mail survey. 1995–2006 National Immunization Surveys.



* AI/AN = American Indian/Alaska Native

Figure 2. Percentage of sampled children with 2+ vaccination providers by race/ethnicity and annual birth cohort. Estimates marked by an asterisk are significantly greater at the $\alpha=0.05$ level than the estimate of non-Hispanic white (NHW) children belonging to the same annual birth cohort. 1995–2006 National Immunization Surveys.

Disparities in the percentage of sampled children with scattered vaccination records

The percentage of sampled children who had provider-reported vaccination histories scattered among 2+ vaccination providers was significantly greater for Hispanic children than non-Hispanic white children for 10 of the 13 birth cohorts born between 1992 and 2004, and was significantly greater for American Indian/Alaska Native children for seven of the 13 birth cohorts (Figure 2).

Disparities in ascertainment of provider-reported vaccination histories

Among sampled children who had provider-reported vaccination histories reported to the NIS that were used to obtain official vaccination coverage estimates, the percentage of children with an incompletely ascertained vaccination history declined from approximately 6 per cent for children in the 1994 birth cohort to approximately 1 per cent for children in the 2004 birth cohort (Figure 3). This figure shows that the percentage of sampled Hispanic children with an incompletely ascertained provider-reported vaccination history was significantly greater than that of non-Hispanic white children for 11 of the 13 annual birth cohorts born between 1995 and 2004. Also, the estimated percentage of sampled non-Hispanic black children with an incompletely ascertained provider-reported vaccination history was significantly greater than that of non-Hispanic white children for eight of the 13 annual birth cohorts born between 1995 and 2004.

Effect of incomplete ascertainment on race/ethnic estimates of vaccination coverage

For every race/ethnic group and birth cohort, estimates of the percentage of children who were 4:3:1:3 UTD by 19 months of age was lower when they were not adjusted for incomplete vaccination histories (Figure 4). The degree of underestimation was as much as 4.9 per cent among Asians,

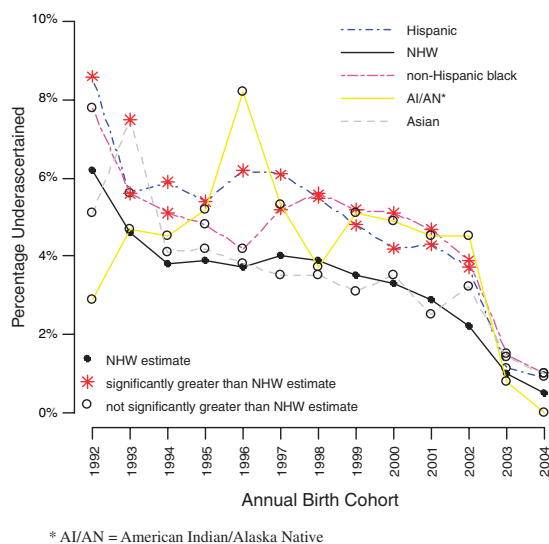


Figure 3. Percentage of sampled children with incompletely ascertained vaccination provider-reported vaccination histories by race/ethnicity and annual birth cohort. Estimates marked by an asterisk are significantly greater at the $\alpha = 0.05$ level than the estimate of non-Hispanic white (NHW) children belonging to the same annual birth cohort. 1995–2006 National Immunization Surveys.

4.8 per cent among Hispanics, 4.1 per cent among American Indian/Alaska Natives, 3.3 per cent among non-Hispanic blacks, and lowest was for non-Hispanic white children by 2.8 per cent.

Effect of incomplete ascertainment on race/ethnic disparities in estimated vaccination coverage trends

For every annual birth cohort born between 1992 and 2004, differences between non-Hispanic white and other racial/ethnic groups in the estimated percentages of children who were 4:3:1:3 UTD by 19 months of age that could be attributed to failing to adjust for incomplete ascertainment were modest (Figure 5). For each racial/ethnic group and annual birth cohort, the unadjusted estimate of percentage of children who were 4:3:1:3 UTD by 19 months was within the 95 per cent confidence interval for the adjusted estimate.

Using estimates of percentages of children who were 4:3:1:3 UTD by 19 months that were adjusted for incompletely ascertained vaccination histories, disparities in estimated coverage between non-Hispanic white children and Asian children were not statistically significant for any of the 13 annual birth cohorts born between 1992 and 2004; for American Indian–Alaska Native children estimated coverage differed significantly from those of non-Hispanic white children for two of the 13 annual birth cohorts; for Hispanic children, estimated coverage differed significantly from those of non-Hispanic white children for eight of the 13 annual birth cohorts; and for non-Hispanic black children estimated coverage differed significantly from those of non-Hispanic white children for 12 of the 13 annual birth cohorts (Figure 5). Across all of the birth cohorts born between 1992 and 2004, Hispanic children had estimated coverage rates that were as low as 8.1 per cent lower than that of non-Hispanic white children and as high as 1.2 per cent greater than that of non-Hispanic white children, and were significantly lower than the estimated coverage rates of non-Hispanic

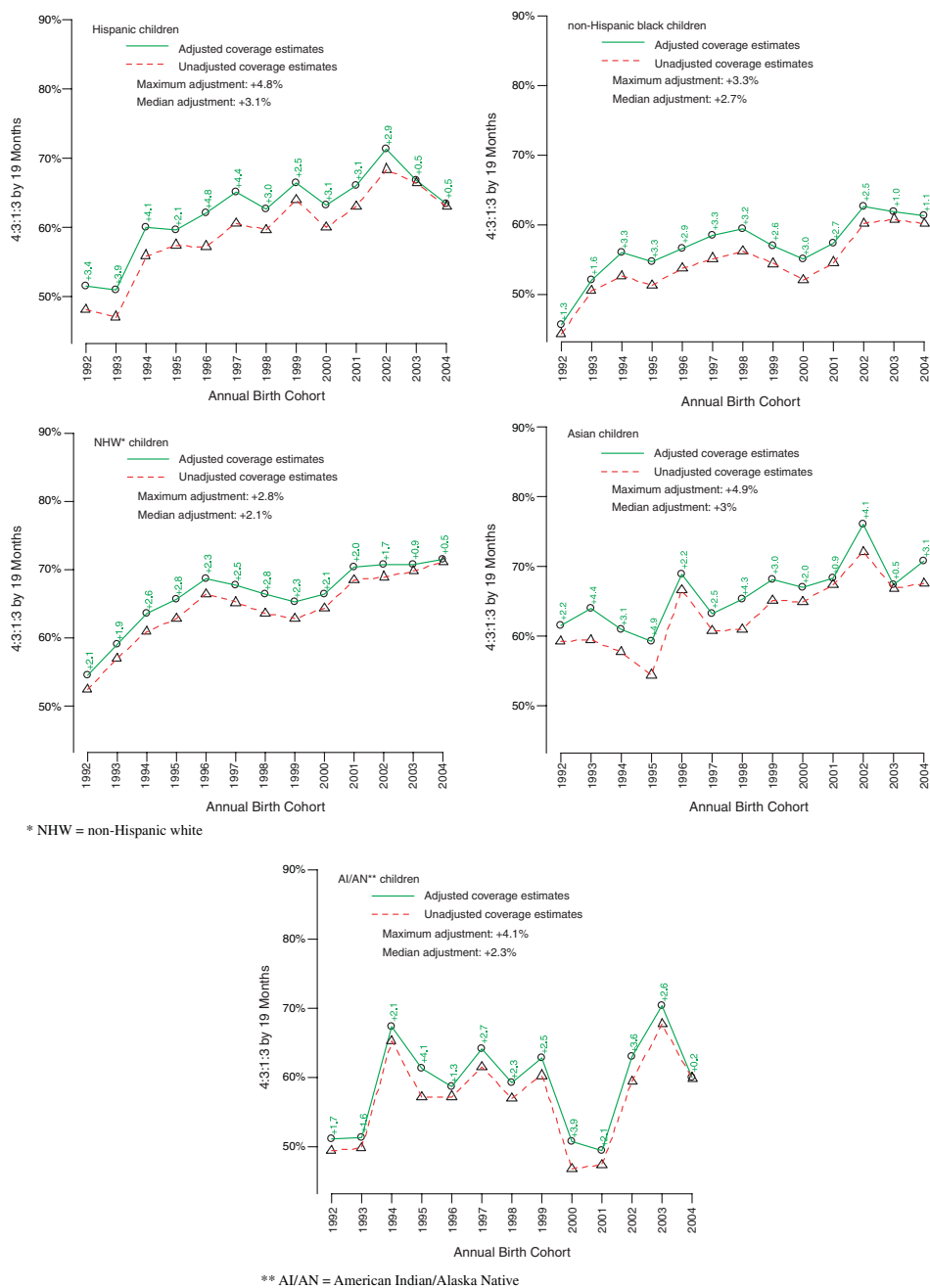


Figure 4. Estimated coverage rates of the 4:3:1:3 series by 19 months by annual birth cohort: Comparison of estimates adjusted (solid line) and not corrected (dashed line) for incomplete ascertainment. Numeric values listed below the unadjusted estimates refer to the per cent to which they differ from their associated adjusted values. 1995–2006 National Immunization Survey.

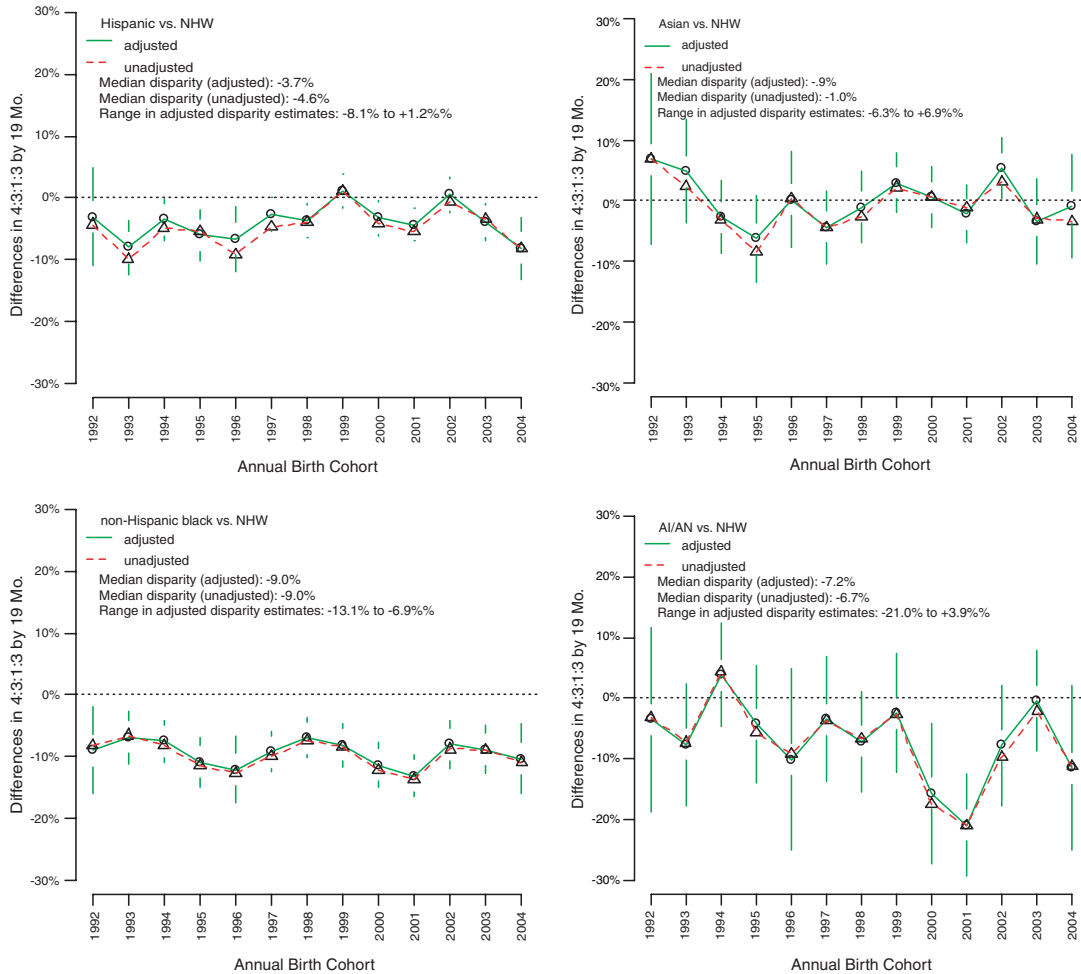


Figure 5. Estimated differences in coverage rates of the 4:3:1:3 series by 19 months between selected racial/ethnic groups and non-Hispanic white (NHW) children: Vertical bars are 95 per cent confidence intervals for the corrected differences. 1995–2006 National Immunization Surveys.

white children in 10 of the 13 birth cohorts. Also, across all of the birth cohorts born between 1992 and 2004, non-Hispanic black children had estimated coverage rates that ranged from 13.1 to 6.9 per cent lower than that of non-Hispanic white children, and were significantly lower than the estimated coverage rates of non-Hispanic white children in 13 of the 13 birth cohorts.

DISCUSSION

Summary of results

When a child has 2+ vaccination providers, the vaccination history can be ‘scattered’ so that no single provider has the entire history. Lack of a complete vaccination history is problematic for

providers who must assess those children's immunization needs. Our work shows that approximately 30 per cent of all children in the U.S. have vaccination records scattered among two or more providers and approximately 6 per cent have records scattered among 3+ providers. Compared with non-Hispanic white children, the percentage of children with scattered records is significantly higher for Hispanic and American Indian/Alaska Native children. This implies that provider's ability to assess the vaccination needs of these children is even more difficult.

Record scattering also poses a problem in measuring vaccination coverage levels not just within provider's practices but also nationally for the NIS. In the NIS, when a child's vaccination history is scattered among several providers, the child's vaccination history may be incompletely ascertained for one or more vaccines when all providers do not contribute data in the mail portion of the survey. Previous research showed that underserved children's immunization history records are more likely to be fragmented among several providers [3, 4]. Our analyses confirmed these results, and showed that the estimated vaccination coverage rates are lower than the estimates that adjust for incomplete ascertainment for every birth cohort of every race/ethnic group. Also, we found that estimated percentages of Hispanic and non-Hispanic black children with an incompletely ascertained provider-reported vaccination history was significantly greater than the estimated percentage of non-Hispanic white children with an incompletely ascertained provider-reported vaccination history for most of the annual birth cohorts born between 1992 and 2004. This paper shows that while correction for record scattering and incompletely ascertained vaccination histories increases estimated vaccination coverage rates for every annual birth cohort of every racial/ethnic group, the correction does not eliminate racial/ethnic disparities in the percentage of children who are 4:3:1:3 UTD by 19 months. Moreover, data from the NIS indicate that significant disparities in vaccination coverage that existed in the early 1990s have continued to persist into the current decade between non-Hispanic white and both Hispanic and non-Hispanic black children, regardless of whether an evaluation of the disparity is based on a correction for record scattering or not.

Also, we found that in general the percentage of children with record scattering and an incompletely ascertained vaccination history declined with successive birth cohorts. While this finding lends greater credibility to coverage estimates of more recent birth cohorts, this finding may imply that the percentage of children who were 4:3:1:3 UTD by 19 months who are not adjusted for record scattering and incomplete ascertainment may not be entirely comparable over the successive years of the NIS, since the biasing effect of incomplete ascertainment has declined over time, particularly in the most recent annual surveys of the NIS.

Strengths and weaknesses

Our work has several strengths. First, an adjustment for incomplete ascertainment may provide a more accurate depiction of vaccination coverage among 19–35-month-old children. As estimated vaccination coverage approaches the Healthy People 2010 objectives, incorporation of the adjustment for incomplete ascertainment could help to avoid misinterpretation of results from the NIS that could result in declaring that the objectives have not been achieved, when in fact they have been. Further, more accurate estimates of vaccination coverage are desirable for program planning. Estimates of vaccination coverage that consistently underestimate vaccine coverage lead to underestimates of the number of doses administered.

In addition to this study's strengths, there are weaknesses in our work as well. For example, because the missing vaccination histories from children with incomplete ascertainment are not observed, it is impossible to know the extent to which the adjusted estimates approximate the

true but unknown coverage rates. However, a statistical adjustment for underascertainment may be useful because unadjusted estimates may underestimate the true vaccination coverage. A further limitation of this work is that children sampled by the NIS could have more vaccination providers than their parents report during the NIS interview. If this is the case, then even the corrections to vaccination coverage proposed by this paper would underestimate the true but unknown coverage, but to a lesser extent than unadjusted estimates. Finally, our estimates of disparities are measured only for the 4:3:1:3 vaccination series. Estimates of disparities depend on the choice of the outcome measure, including the age by which children are considered UTD.

Relation to other research and reasons why this work is important

In a survey of inner-city children in Chicago, Dominquez *et al.* [13] found that black children had the lowest on-time immunization coverage. Even with our adjustment for incompletely ascertained provider-reported vaccination histories that increases estimates of vaccination coverage, our results were similar to those of Dominquez, and showed that non-Hispanic black children had consistently lower vaccination coverage nationally for each annual birth cohort between 1992 and 2004 compared with non-Hispanic white children. This finding is important because, as Dominquez and others have pointed out, immunization is known to be an indicator of receipt of primary care in children [14–16]. Thus, the significant disparities between non-Hispanic black and non-Hispanic white children in vaccination coverage by 19 months of age may suggest that other primary preventive care was not received by non-Hispanic black children by 19 months of age.

Reasons for racial disparities in immunization coverage continue to be incompletely understood and may be rooted in both historic and contemporary inequities. Recent research [17, 18] has suggested that the root of persistent racial disparities in childhood vaccination disparities might be attributed to differences in socioeconomic factors between racial/ethnic groups that could result in more limited access to primary care. Other research has shown that minority children see physicians at half the rate of white children [19].

The scattering of medical records among a child's many providers poses obvious problems for the provider in assessing the child's primary-care needs. In any type of public-health survey that depends on primary-care services reported by children's medical providers, record scattering can result in estimates of health-care utilization that may be too low if they are not adjusted to account for missing data resulting from record scattering. However, regardless of whether estimates are adjusted or not, data from the NIS show that disparities in vaccination coverage that existed in the early 1990s have persisted.

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