Vaccination Coverage Estimates for Selected Counties: Achievement of Healthy People 2010 Goals and Association with Indices of Access to Care, Economic Conditions, and Demographic Composition

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SYNOPSIS

Objectives. We provided vaccination coverage estimates for 181 counties; evaluated the extent to which Healthy People 2010 (HP 2010) vaccination coverage objectives were achieved; and examined how variations in those estimates depend on access to care and economic conditions.

Methods. We analyzed data for 24,031 children aged 19 to 35 months sampled from the 2004 and 2005 National Immunization Survey.

Results. Children living in the 181 counties represented 49% of all the 19- to 35-month-old children living in the U.S. None of the 181 counties had coverage for the polio, measles-mumps-rubella, *Haemophilus influenzae* type B, and hepatitis B vaccines that was significantly lower than the HP 2010 objective of 90% coverage. However, as many as 30.4% of the counties did not achieve the HP 2010 objective for diphtheria, tetanus toxoids, and acellular pertussis or diphtheria and tetanus toxoids and pertussis (DtaP/DTP), and as many as 6.6% did not achieve the goal for varicella (VAR). If children who received three doses of DtaP/DTP had received a final fourth dose, and if all children had received one dose of VAR, all of the 181 counties would have achieved the HP 2010 vaccination coverage target of 80% for the entire 4:3:1:3:3:1 vaccination series. Factors found to be associated with low county-level vaccination coverage rates were correlates of poverty, and factors found to be associated with high county-level vaccination coverage rates were correlates of access to pediatric services.

Conclusions. HP 2010 vaccination coverage goals for all 181 counties can be achieved by improving vaccination coverage for only two vaccines. Those goals may be achieved most efficiently by targeting interventions in counties where indices of poverty are high or where access to pediatric services is low.

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Public health issues originate in small geographic areas, such as counties. Outbreaks of vaccine-preventable diseases can be reduced nationally if they are reduced within these areas. Additionally, local health authorities need data to make informed health policy decisions. While a state's estimate of vaccination coverage is useful for administrative purposes, it may conceal low vaccination coverage among some of its counties, particularly in counties where many children have characteristics that are associated with low coverage. Thus, information on vaccination coverage in counties can help evaluate the extent to which children in those areas are at risk for acquiring vaccine-preventable diseases and provide local public health officials with relevant data to help improve vaccination coverage.

The purpose of this article is to explore how vaccination coverage among children 19 to 35 months of age varies among selected U.S. counties; to evaluate the extent to which Healthy People 2010 (HP 2010) objectives of 90% vaccination coverage for individual vaccines and 80% coverage for vaccine series have been achieved in those counties; and to study how variation in estimated county-level vaccination coverage rates depends on county-level indices of access to care, economic conditions, and demographic composition.

METHODS

Design of the National Immunization Survey (NIS)

For this study, the authors analyzed data collected in the NIS for the years 2004 and 2005. The NIS is a survey of U.S. children 19 to 35 months of age conducted by the Centers for Disease Control and Prevention (CDC) to monitor vaccination coverage rates in the U.S. Between 1994 and 2005, the NIS consisted of independent quarterly surveys that were conducted in defined geographic areas in all 50 states and the District of Columbia.

NIS data are collected in two phases. First, a list-assisted random-digit-dialing (RDD) survey is conducted of households with children aged 19 to 35 months that also have landline telephones. This survey is then followed by a vaccination provider record check (PRC). Cell phone numbers are not included in the list of telephone numbers from which the RDD sample is obtained. When a household with an age-eligible child is identified in the RDD phase of the survey, a telephone interview is conducted to collect demographic information about each age-eligible child in the household and the age-eligible child's mother, sociodemographic information about the household, and the street address of the household. The county

is determined from the household's street address and area code. At the end of the interview, consent is requested for contacting the age-eligible children's vaccination providers. If consent is given, the PRC phase of the NIS is conducted. In the PRC phase, all vaccination providers named by the RDD respondent are contacted by mail to obtain the child's vaccination history.

Vaccination histories obtained from the PRC were used to evaluate the vaccination status of children sampled in the NIS. The NIS was reviewed and approved by the institutional review board at CDC in 2001 and 2006. Zell et al.¹ and Smith et al.²⁻⁴ provided detailed descriptions of the statistical methods used by the NIS. In this article, the 2002 survey weighting methodology⁴ was used for both 2004 and 2005.

Coverage of 19- to 35-month-old children and NIS response rates

The response rate of the NIS is the product of three rates: (1) the estimated percentage of households that reported in the NIS RDD interview as having a 19- to 35-month-old child among those that actually had a 19- to 35-month-old child; (2) the Council of American Survey Research Organizations (CASRO) rate⁵ of the RDD portion of the NIS; and (3) among households with a completed RDD interview, the percentage of sampled children for whom an adequate provider-reported vaccination history was obtained in the PRC.

The CASRO rate is the multiplicative product of the resolution completion rate, the screener completion rate, and the RDD interview completion rate. The resolution completion rate is the proportion of telephone numbers determined to be residential, nonresidential, or nonworking among all telephone numbers in the NIS sample. The screener completion rate is the proportion of sampled households that were successfully screened as either having an age-eligible child or not, among all RDD calls made to telephone numbers determined to be residential. The RDD interview completion rate is the proportion of households that completed the NIS RDD interview, among all households with at least one child who was 19 to 35 months of age.

Among households that had a landline telephone and a 19- to 35-month-old child, the percentages of households that reported having a 19- to 35-month-old child in the RDD portion of the NIS were 70.6% in 2004 and 70.0% in 2005. Also, the CASRO rates were 65.1% in 2004 and 67.0% in 2005. Among households of age-eligible children who had a completed NIS

RDD interview, the percentages of children who had adequate provider data were 70.6% in 2004 and 63.8% in 2005.

Vaccination status of sampled children and HP 2010 vaccination coverage goals

Sampled children were determined to be up-to-date (UTD) using the following criteria: diphtheria and tetanus toxoids and acellular pertussis or diphtheria and tetanus toxoids and pertussis (DTaP/DTP) vaccine if vaccination providers reported administering ≥ 4 doses of any combination of those vaccines; polio vaccine if ≥ 3 doses were administered; measles-mumps-rubella (MMR) vaccine if ≥ 1 dose was administered; *Haemophilus influenzae* type b (Hib) vaccine if ≥ 3 doses were administered; hepatitis B (Hep B) vaccine if ≥ 3 doses were administered; and varicella (VAR) vaccine if ≥ 1 dose was administered on or after 12 months of age. Sampled children were 4:3:1:3:3 UTD if they were determined to be UTD on DTaP/DTP, polio, MMR, Hib, and Hep B, and were 4:3:1:3:3:1 UTD if they were also UTD on VAR. Sampled children were 3:3:1:3:3 UTD if they were determined to be UTD on polio, MMR, Hib, and Hep B, but received only three doses of DTaP/DTP.

The HP 2010⁶ goals for improving health specify that objectives for vaccination coverage are 90% for individual vaccines and 80% for the combination of all universally recommended vaccines. Starting with the 2005 NIS data, the series combination objective was measured based on the 4:3:1:3:3:1 series. We compared both the 4:3:1:3:3 and 4:3:1:3:3:1 series to the HP 2010 objective in this article.

Statistical analyses

We analyzed data from 24,031 children 19 to 35 months of age obtained from the combined samples 2004 and 2005 NIS who lived in 181 counties where the sample size of children with adequate provider data from the PRC portion of the NIS was ≥ 35 for the combined survey years 2004 and 2005, and ≥ 14 for each survey year. Annual direct estimates of vaccination coverage are the official estimates of vaccination coverage reported by CDC. Direct estimates are weighted averages of sampled children's binary indicators of being UTD, where the weights are the annual NIS sampling weights.

For each county, direct estimates of vaccination coverage were obtained for the 2004 and 2005 survey years. Then, for each county, a weighted average of the two annual direct estimates of annual vaccination coverage was obtained to yield a composite direct estimate of vaccination coverage across the 2004 and 2005 survey years. The weights used in that average were selected

to minimize the variance of the composite estimate and were proportional to the reciprocals of the estimated variances of the annual direct estimates. For geographic areas as small as counties, composite direct estimates from the NIS can be unreliable because few observations may be obtained within some counties.

To obtain more precise estimates of county-level vaccination coverage, we used the James-Stein methodology.⁷⁻¹¹ The James-Stein estimate of the log-odds of a county's vaccination coverage estimate is a weighted average of two estimates: (1) the log-odds of the county's composite direct estimate of vaccination coverage and (2) an indirect estimate; i.e., the predicted log-odds of the coverage rate from the regression of the log-odds of the 181 counties' composite direct estimates on county-level predictors. Therefore, the James-Stein estimate of each county's vaccination coverage is based on the 24,031 children who had adequate provider data from all of the 181 counties in the 2004 and 2005 NIS. As a result, a county's James-Stein estimate can have substantially greater precision than the county's composite direct estimates of vaccination coverage that are based only on data from that county.^{7,12} If the mathematical assumptions underlying the James-Stein methodology are fulfilled, estimators of the log-odds from that methodology have minimum variance among the class of all unbiased estimates.⁹ County-level vaccination coverage estimates were obtained by transforming the estimated log-odds obtained from the James-Stein methodology into percentages.

To obtain the indirect estimate of vaccination coverage, we first identified county-level factors associated with variation in the log-odds of composite direct estimates of vaccination coverage. Candidates for the county-level factors included 35 variables derived from the 2005 Area Resource File;¹³ economic indices collected by the Economic Research Service, U.S. Department of Agriculture;¹⁴ indices of access to care collected by the American Medical Association;^{15,16} and demographic data published by the Census Bureau.¹⁷ Table 1 lists those 35 variables along with their official definitions. The Department of Health and Human Services combines data from these three sources annually and publishes them in the Area Resource File.¹³ Forward stepwise regression was used to select predictors among the 35 candidates to explain variation in the log-odds of composite direct estimates of vaccination coverage. The Schwarz information criterion¹⁸ guided the choice of predictors at each step, and the R^2 statistic¹⁹ was used to summarize the proportion of the total variation among the log-odds of direct estimates explained by the selected predictors.

The indirect estimate of the log-odds of vaccination

Table 1. Candidate predictors and predictors identified as being correlated with low (L) or high (H) vaccination coverage^a

	Vaccine/vaccine series and regression R ² value								
Indices	4:3:1:3:3 (R ² =0.67)	4:3:1:3:3:1 (R ² =0.79)	3:3:1:3:3 (R ² =0.89)	DTaP/DTP (R ² =0.67)	Polio (R ² =0.79)	MMR (R ² =0.85)	Hep B (R ² =0.84)	Hib (R ² =0.88)	VAR (R ² =0.87)
Economic conditions									
Urban influence ^b		L							L
Farming-dependent county ^c									
Mining-dependent county ^c									
Manufacturing-dependent county ^c									
Federal/state government-dependent county ^c				H					
Service-dependent county ^c									
Nonspecialized-dependent county ^c									
Housing stress ^d	L	L	L	L	L	L	L	L	
Low education ^e									
Persistent poverty ^f									
Population loss ^g									
Nonmetro recreation ^h									
Retirement destination ⁱ									
Access to care ^j									
Per capita pediatricians	H			H	H		H		H
Per capita general practitioners					L		L		
Per capita hospitals	L								
Per capita children's hospital									
Per capita bassinets set up		L				L			
Per capita pediatric intensive care beds set up									
Demographic composition									
Percent white children among children <5 years of age ^j									
Percent black children among children <5 years of age ^j	L				L				
Percent American Indian children among children <5 years of age ^j									
Percent Asian children among children <5 years of age ^j									
Percent Hispanic children among children <5 years of age ^j									
Per capita white population ^j									
Per capita black population ^j									
Per capita American Indian population ^j									
Per capita Asian population ^j	H			H					
Per capita Hispanic population ^j									

continued on p. 159

Table 1 (continued). Candidate predictors and predictors identified as being correlated with low (L) or high (H) vaccination coverage^a

Indices	Vaccine/vaccine series and regression R^2 value								
	4:3:1:3:3 ($R^2=0.67$)	4:3:1:3:3:1 ($R^2=0.79$)	3:3:1:3:3 ($R^2=0.89$)	DTaP/DTP ($R^2=0.67$)	Polio ($R^2=0.79$)	MMR ($R^2=0.85$)	Hep B ($R^2=0.84$)	Hib ($R^2=0.88$)	VAR ($R^2=0.87$)
Per capita single-family households ⁱ									
Per capita living in group quarters ^k	H	H		H	H	H			
Average family size ^j									
Per capita female head of household ⁱ									
Per capita income ^l		H				H		H	
Per capita people aged 0–17 in poverty ^l				L					

^aL denotes that the regression coefficient from the regression of the log-odds of the direct estimate on the predictor variable was negative and H denotes that the regression coefficient was positive. 2005 Area Resource File.

^bUrban influence is designated by either (1) a county designated as a metropolitan area with at least one million residents or more, (2) a county designated as a metropolitan area with fewer than one million residents, (3) designation as a micropolitan area (i.e., an urban area based around a core city or town with a population of 10,000 to 49,999) adjacent to a large metro area, or (4) designation as a noncore adjacent to a large metro area. Designations made by the U.S. Department of Agriculture's Economic Research Service (ERS) are available from: URL: <http://www.ers.usda.gov/Data/UrbanInfluenceCodes> [cited 2007 Oct 25].

^cERS economic-dependent 2004 typology codes are available from: URL: <http://www.ers.usda.gov/briefing/rurality/typology> [cited 2007 Oct 25] and http://www.ers.usda.gov/Data/TypologyCodes/2004/all_final_codes.xls [cited 2007 Oct 25].

^dHousing stress is defined by the ERS as 30% or more of households that had one or more of these housing conditions in 2000: lacked complete plumbing, lacked complete kitchen, paid 30% or more of income for owner costs or rent, or had more than one person per room. The ERS designations of county-level housing stress are available from: URL: <http://www.ers.usda.gov/briefing/rurality/typology/maps/Housing.htm> [cited 2007 Oct 25] and http://www.ers.usda.gov/Data/TypologyCodes/2004/all_final_codes.xls [cited 2007 Oct 25].

^eLow education is defined by the ERS as 25% or more of residents aged 25 through 64 who had neither a high school diploma nor general education development in 2000. The ERS designations of county-level low education are available from: URL: <http://www.ers.usda.gov/briefing/rurality/typology/maps/Education.htm> [cited 2007 Oct 25] and http://www.ers.usda.gov/Data/TypologyCodes/2004/all_final_codes.xls [cited 2007 Oct 25].

^fPersistent poverty is defined by the ERS as 20% or more of residents who were poor as measured by each of the last four censuses: 1970, 1980, 1990, and 2000. The ERS designations of county-level persistent poverty are available from: URL: <http://www.ers.usda.gov/briefing/rurality/typology/maps/Poverty.htm> [cited 2007 Oct 25] and http://www.ers.usda.gov/Data/TypologyCodes/2004/all_final_codes.xls [cited 2007 Oct 25].

^gPopulation loss is defined by the ERS as counties where the number of residents declined both between the 1980 and 1990 censuses and between the 1990 and 2000 censuses. The ERS designations of county-level population loss are available from: URL: <http://www.ers.usda.gov/briefing/rurality/typology/maps/Population.htm> [cited 2007 Oct 25] and http://www.ers.usda.gov/Data/TypologyCodes/2004/all_final_codes.xls [cited 2007 Oct 25].

^hNonmetro recreation is defined by the ERS using a combination of factors, including share of employment or share of earnings in recreation-related industries in 1999, share of seasonal or occasional-use housing units in 2000, and per capita receipts from motels and hotels in 1997. The ERS designations of nonmetro recreation are available from: URL: <http://www.ers.usda.gov/briefing/rurality/typology/maps/Recreation.htm> [cited 2007 Oct 25] and http://www.ers.usda.gov/Data/TypologyCodes/2004/all_final_codes.xls [cited 2007 Oct 25].

ⁱRetirement destination is defined by the ERS as counties where the number of residents aged 60 and older grew by 15% or more between 1990 and 2000 due to immigration. The ERS designations of retirement destination are available from: URL: <http://www.ers.usda.gov/briefing/rurality/typology/maps/Retirement.htm> [cited 2007 Oct 25] and http://www.ers.usda.gov/Data/TypologyCodes/2004/all_final_codes.xls [cited 2007 Oct 25].

^jDepartment of Health and Human Services (US). Area Resource File. 2005 [cited 2007 Jul 17]. Available from: URL: <http://www.arfsys.com>

^kThe Census Bureau uses the following definition for group quarters: a group quarters is a place where people live or stay that is normally owned or managed by an entity or organization providing housing and/or services for the residents. These services may include custodial or medical care as well as other types of assistance, and residency is commonly restricted to those receiving these services. People living in group quarters are usually not related to each other. Group quarters include such places as college residence halls, residential treatment centers, skilled nursing facilities, group homes, military barracks, correctional facilities, workers' dormitories, and facilities for people experiencing homelessness. Available from: URL: <http://www.census.gov/acs/www/UseData/GQ/def.htm> [cited 2007 Oct 25].

DTaP = diphtheria and tetanus toxoids and acellular pertussis

DTP = diphtheria and tetanus toxoids and pertussis

MMR = measles-mumps-rubella

Hep B = hepatitis B

Hib = *Haemophilus influenzae* type b

VAR = varicella

coverage rate required by the James-Stein methodology was obtained using those selected predictors. Because the log-odds of vaccination coverage increase monotonically with increasing vaccination coverage, in this article we report predictors found to be positively associated with the log-odds of direct estimates as being positively associated with vaccination coverage. We used the R statistical software package^{20,21} for all calculations.

The Figure provides further mathematical details of the James-Stein methodology.

Combined data from the 2004 and 2005 NIS include children born from February 2001 through July 2004, and the estimated coverage rates obtained from the James-Stein methodology represent vaccination coverage rates as of January 1, 2005. A one-sided statistical test was used to evaluate the null hypothesis—whether

Figure. Mathematical details of the James-Stein methodology

For a specific vaccine, we let Y_i denote the log-odds of the i -th county's composite direct estimate of vaccination coverage that accounts for the National Immunization Survey design and sampling weights. Also, let $Y=(Y_1, \dots, Y_{181})^T$ denote the vector of composite direct vaccination coverage estimates for the 181 counties. We assume that Y has a multivariate normal distribution with mean vector θ and diagonal variance-covariance matrix $D=\text{diag}(d_{1,1}, \dots, d_{181,181})$, where the $d_{i,i}$ are known. In our work we take $d_{i,i}$ equal to the estimated variance of Y that accounts for the survey design and sampling weights, $i = 1, \dots, 181$. Next, we assume that the vector θ is a random variable drawn from a superpopulation model that has a multivariate normal distribution with mean vector $X\beta$ and variance covariance matrix $\sigma^2 I$, where X is a matrix of predictor variables, β is an unknown vector of regression coefficients, σ^2 is an unknown scalar, and I is a 181×181 identity matrix. When σ^2 is known, the James-Stein estimator of the log-odds of vaccination coverage is

$$\hat{\theta} = (D^{-1} + \sigma^{-2}I)^{-1}[D^{-1}Y + \sigma^{-2}X(X^T(D + \sigma^2 I)^{-1}X)^{-1}X^T(D + \sigma^2 I)^{-1}Y]$$

and has minimum variance among the class of linear estimators that are unbiased.^a The variance associated with θ is

$$V(\hat{\theta}) = (D^{-1} + \sigma^{-2}I)^{-1}[D^{-1}Y + \sigma^{-2}X(X^T(D + \sigma^2 I)^{-1}X)^{-1}X^T(D + \sigma^2 I)^{-1}]D.$$

Ignoring additive constants, the log-likelihood is

$$L(\sigma^{-2}) = -\frac{1}{2} \log[\det(D + \sigma^2 I)] - \frac{1}{2}(Y - X\hat{\beta})^T(D\sigma^2 I)^{-1}(Y - X\hat{\beta})$$

where $\hat{\beta} = X(X^T(D\sigma^2 I)^{-1}X)^{-1}X^T(D + \sigma^2 I)^{-1}Y$. Using the profile likelihood method,^b estimates for $\hat{\theta}$ and $V(\hat{\theta})$ are obtained by choosing the value of σ^2 that maximizes $L(\sigma^2)$. The James-Stein estimator of the log-odds of vaccination coverage, $\hat{\theta}$, is a weighted average of the composite direct estimators, Y , and the predicted value of Y obtained from the weighted least squares regression of Y on X : $X(X^T(D + \sigma^2 I)^{-1}X)^{-1}X^T(D + \sigma^2 I)^{-1}Y$. The corresponding estimate of vaccination coverage, $\hat{P}$, is $\hat{P} = e^{\hat{\theta}}/(1 + e^{\hat{\theta}})$ and to a first-order Taylor series approximation, its corresponding variance estimate is $V(\hat{P}) = [\hat{P}(1 - \hat{P})]^2 V(\hat{\theta})$. The James-Stein methodology has been applied to the problem of estimating the 1980 Decennial Census undercount,^{c,d} estimating average county-level income,^e evaluating the association between blood-lead concentrations and cognitive development,^f and other public health applications.

As candidates for the predictor variables X , we used 35 variables derived from the 2005 Area Resource File.^g Forward stepwise regression was used to select predictors among these candidates. At each step of the stepwise selection process, the regression model examined all main effects and allowable second-order interactions among the candidate predictors, and reexamined each regressor in the model to determine whether any predictor that entered at a previous step could be dropped. The Schwarz information criterion^h guided the choice of the optimal set of candidate regressors at each step. We noted the proportion R^2 of the total variation in the estimated log-odds that was explained by the predictors selected in the final model. Across all individual vaccines and vaccine series we report, the interquartile range of the difference between the percentage estimate obtained from the James-Stein methodology and the direct estimate generally ranged from -5% to $+5\%$. Also, the percentage by which the standard error was reduced using the James-Stein methodology, compared to the standard error of the direct estimate, was approximately 55%.

^aHarville DA. Extension to the Gauss-Markov theorem to include the estimation of random effects. *Ann Stat* 1976;4:384-95.

^bMcCullagh P, Nelder JA. Generalized linear models. 2nd ed. London: Chapman & Hall/CRC; 1989.

^cEricksen EP, Kadane JB. Estimating the population in a census year: 1980 and beyond. *J Am Stat Assn* 1985;80:98-109.

^dIsaki CT, Schultz L, Smith PJ, Diffendal G. Small area research for census undercount. In: Platek R, Rao JNK, Sarndal CE, Singh MP, editors. Small area statistics: an international symposium. New York: John Wiley & Sons; 1987. p. 219-38.

^eFay RE, Herriot RA. Estimates of income for small places: an application of James-Stein procedures to census data. *J Am Stat Assn* 1979;74:269-77.

^fWaternaux C, Laird NM, Ware JH. Methods for analysis of longitudinal data: blood-lead concentrations and cognitive development. *J Am Stat Assn* 1989;84:33-41.

^gCensus Bureau (US). Population estimates [cited 2007 Jul 17]. Available from: URL: <http://www.census.gov/popest/estimates.php>

^hSchwarz G. Estimating the dimension of a model. *Ann Stat* 1978;6:461-4.

the estimated coverage rates obtained from the James-Stein methodology met or exceeded the vaccination coverage objectives. To account for multiple testing in our evaluation of whether a county-level estimated vaccination coverage rate was significantly less than the HP 2010 vaccination coverage objective for each of the 181 counties, we used the Benjamini-Hochberg multiple comparison method.²² Our use of the Benjamini-Hochberg method ensures that no more than 5%, on average, of the counties identified by the method as achieving the vaccination coverage objective are falsely identified.

RESULTS

Representation of the 181 counties

A total of 24,031 sampled children aged 19 to 35 months in the combined 2004 and 2005 NIS had adequate provider data returned in the PRC portion of the NIS and lived in the 181 counties where the sample size for the 2004 and 2005 NIS was ≥ 35 for the combined years and ≥ 14 for each survey year. In 2005, the 19- to 35-month-old children living in those 181 counties made up 49% of all of the 19- to 35-month-old children living in the U.S. Table 2 lists the rank of each of the 181 counties in terms of 2005 population size of children 19 to 35 months of age. Our analysis includes 83 of the 100 U.S. counties with the largest populations of 19- to 35-month-old children.

A statistically significant difference was found between the direct estimates of vaccination coverage of the selected 181 counties combined and the remaining sampled counties combined for all vaccine series studied and all individual vaccines, except for MMR. However, these differences were small and less than 1% except for the 3:3:1:3:3 series, where the difference was 1.6% (Table 2).

Achievement of HP 2010 objectives and county variation in estimated vaccination coverage

Across all individual vaccines and vaccine series, the interquartile range of the difference between the James-Stein estimate and the direct estimate generally was -5% to $+5\%$. Also, estimated standard errors of James-Stein estimates were approximately 55% less than the estimated standard errors of the direct estimates.

Using the multiple comparison method, none of the 181 counties had estimated coverage for polio, MMR, Hib, and Hep B significantly lower than the HP 2010 coverage objective of 90% (Table 2). For polio, estimated vaccination coverage ranged from 84.7% $\pm$ 6.2% in Flathead, Montana, to 96.2% $\pm$ 1.9% in New

York, New York, and 96.2% $\pm$ 2.1% in Washington, Rhode Island. For MMR, estimated vaccination coverage ranged from 84.6% $\pm$ 5.7% in Flathead, Montana, to 96.6% $\pm$ 2.1% in New York, New York. For Hib, estimated vaccination coverage ranged from 87.8% $\pm$ 5.3% in Clackamas, Oregon, and 87.8% $\pm$ 5.6% in Lane, Oregon, to 97.1% $\pm$ 2.2% in New York, New York. And for Hep B, estimated vaccination coverage ranged from 82.6% $\pm$ 8.8% in Albany, Wyoming, to 96.9% $\pm$ 0.5% in Charleston, South Carolina.

Among the 181 counties, as many as 55 counties (30.4%) had estimated DTaP/DTP coverage significantly below the HP 2010 objective of 90%, and as many as 12 (6.6%) had estimated VAR coverage lower than the 90% objective. Compared with the polio, MMR, Hib, and Hep B vaccines, estimated coverage varied more widely for DTaP/DTP and VAR. In particular, DTaP/DTP coverage ranged from 73.3% $\pm$ 4.4% in Clark, Nevada, to 94.7% $\pm$ 2.3% in Chittenden, Vermont; and VAR coverage ranged from 67.4% $\pm$ 10% in Flathead, Montana, to 95.2% $\pm$ 1.7% in Allegheny, Pennsylvania.

For the 4:3:1:3:3 vaccine series, the multiple comparison method determined that as many as five out of 181 counties (2.8%) had an estimated vaccination coverage rate that was significantly lower than the HP 2010 objective of 80%. For the 4:3:1:3:3 vaccine series, estimated coverage rates varied from 66.4% $\pm$ 4.6% in Clark, Nevada, to 91% $\pm$ 3.3% in Chittenden, Vermont. For the 4:3:1:3:3:1 vaccination series, the multiple comparison method determined that as many as 26 (14.4%) of the 181 counties did not achieve 80% vaccination coverage. For the 4:3:1:3:3:1 vaccination series, estimated coverage rates varied from 55.6% $\pm$ 9.6% in Flathead, Montana, to 87.9% $\pm$ 5.1% in New York, New York.

Among children who were not 4:3:1:3:3:1 UTD, however, 49.2% $\pm$ 1.8% were UTD on all vaccines in the series, except for one. In particular, among children who were not 4:3:1:3:3:1 UTD, children were least likely to be UTD on VAR (48.4% $\pm$ 1.8%) and DTaP/DTP (40.6% $\pm$ 1.7%). If children who received three doses of DTaP/DTP had received a final fourth dose, and if all children had received one dose of VAR, the estimated hypothetical 4:3:1:3:3:1 vaccination coverage rate would be exactly what the estimated 3:3:1:3:3 vaccination coverage rate is (Table 2). The estimated 3:3:1:3:3 vaccination coverage rates varied from 74.6% $\pm$ 4% in Clark, Nevada, to 89.8% $\pm$ 2.7% in Davidson, Tennessee. The multiple comparison method determined that none of the 181 counties had 3:3:1:3:3 coverage significantly less than 80% for this series.

Table 2. Estimated vaccination coverage obtained from the James-Stein methodology for 181 selected counties for three vaccine series and six individual vaccines, 2004–2005 National Immunization Survey

	Vaccine series			Individual vaccines					
	4:3:1:3:3	4:3:1:3:3:1	3:3:1:3:3	≥4 doses DTaP/DTP	≥3 doses Polio	≥1 dose MMR	≥3 doses Hib	≥3doses Hep B	≥1 dose VAR
	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)
National estimate ^a	81.0 ± 0.7	76.2 ± 0.7	84.8 ± 0.6	85.9 ± 0.6	91.8 ± 0.5	92.3 ± 0.5	93.7 ± 0.4	92.7 ± 0.4	87.7 ± 0.5
Direct estimate: selected 181 counties combined	80.1 ± 0.5 ^b	75.8 ± 0.5 ^b	84.0 ± 0.4 ^b	85.5 ± 0.3 ^b	91.4 ± 0.2 ^b	92.3 ± 0.2	93.3 ± 0.2 ^b	92.1 ± 0.2 ^b	88.1 ± 0.3 ^b
Direct estimate: remaining sampled counties combined	81.9 ± 0.5	76.7 ± 0.6	85.6 ± 0.4	86.2 ± 0.4	92.1 ± 0.3	92.4 ± 0.2	94.1 ± 0.2	93.3 ± 0.2	87.4 ± 0.3
Range of county estimates	66.4 to 91.0	55.6 to 87.9	74.6 to 89.8	73.3 to 94.7	84.7 to 96.2	84.6 to 96.6	87.8 to 97.1	82.6 to 96.9	67.4 to 95.2
County name (rank ^c)									
Jefferson, AL (92)	82.4 ± 3.9	79.7 ± 4.3	84.3 ± 3.7	87.8 ± 3.3	91.2 ± 2.7	91.5 ± 2.7	95.0 ± 2.0	93.6 ± 2.2	91.9 ± 2.7
Mobile, AL (146)	79.3 ± 6.6	74.2 ± 8.0	87.4 ± 4.9	79.7 ± 7.5 ^d	93.1 ± 3.5	92.1 ± 3.8	93.8 ± 3.8	93.8 ± 3.3	86.4 ± 6.4
Anchorage, AK (194)	78.1 ± 5.6	74.8 ± 5.7	84.4 ± 4.5	84.3 ± 4.6 ^d	92.3 ± 3.1	92.7 ± 2.9	92.8 ± 2.9	90.1 ± 3.7	87.2 ± 4.4
Fairbanks North Star, AK (496)	73.6 ± 6.9	70.2 ± 7.2 ^d	80.1 ± 5.8	79.8 ± 6.0 ^d	85.6 ± 5.4	90.5 ± 3.9	88.1 ± 4.7	85.4 ± 5.6	83.2 ± 6.2
Matanuska-Susitna, AK (710)	79.7 ± 6.5	73.0 ± 7.8	84.1 ± 5.8	85.1 ± 5.6	91.0 ± 4.4	91.7 ± 3.8	92.3 ± 4.0	90.7 ± 4.6	84.4 ± 6.9
Coconino, AZ (388)	88.4 ± 7.4	69.6 ± 9.1	83.9 ± 6.1	87.9 ± 7.9	89.5 ± 5.4	89.1 ± 5.3	91.5 ± 4.6	88.5 ± 5.7	83.2 ± 7.6
Maricopa, AZ (4)	78.4 ± 3.7	74.1 ± 4.1 ^d	82.6 ± 3.4	83.2 ± 3.4 ^d	90.4 ± 2.6	90.0 ± 2.6	93.3 ± 2.1	91.0 ± 2.5	84.4 ± 3.5 ^d
Pima, AZ (51)	80.0 ± 5.1	74.3 ± 6.1	83.5 ± 4.7	84.8 ± 4.5 ^d	90.9 ± 3.7	92.1 ± 3.1	90.9 ± 3.7	90.7 ± 3.8	89.0 ± 4.3
Pinal, AZ (268)	82.3 ± 6.6	77.3 ± 7.7	81.8 ± 6.1	86.5 ± 5.8	92.6 ± 4.0	94.4 ± 3.1	91.6 ± 4.5	91.5 ± 4.3	83.7 ± 7.0
Yavapai, AZ (376)	78.1 ± 6.5	69.6 ± 8.3 ^d	80.8 ± 6.5	82.6 ± 5.8 ^d	91.6 ± 4.1	89.7 ± 4.5	90.5 ± 4.9	89.2 ± 4.9	81.5 ± 7.5
Yuma, AZ (255)	81.0 ± 6.4	74.9 ± 8.3	84.3 ± 5.8	79.1 ± 8.0 ^d	94.2 ± 2.7	91.5 ± 4.2	91.8 ± 4.7	93.6 ± 3.1	88.5 ± 5.9
Benton, AR (296)	81.2 ± 6.0	76.2 ± 7.6	87.7 ± 4.9	85.0 ± 5.4	92.3 ± 4.3	92.4 ± 3.6	95.6 ± 2.1	93.2 ± 3.7	87.9 ± 6.6
Pulaski, AR (154)	79.2 ± 6.9	74.4 ± 8.0	84.5 ± 5.6	83.1 ± 6.7	92.1 ± 4.1	90.3 ± 4.5	94.8 ± 3.1	93.9 ± 3.2	90.1 ± 5.6
Alameda, CA (20)	80.6 ± 5.7	77.5 ± 6.6	83.3 ± 5.6	86.3 ± 4.8	90.6 ± 4.4	91.3 ± 3.6	93.1 ± 3.7	90.8 ± 4.3	88.9 ± 5.3
Los Angeles, CA (1)	79.0 ± 3.5	76.6 ± 3.7	84.0 ± 3.1	84.2 ± 3.2 ^d	92.0 ± 2.3	93.3 ± 1.9	91.9 ± 2.3	92.0 ± 2.2	90.4 ± 2.5
Orange, CA (5)	79.3 ± 6.2	76.0 ± 7.3	83.0 ± 6.0	83.6 ± 5.6 ^d	90.2 ± 4.5	92.1 ± 3.4	93.9 ± 3.3	92.3 ± 3.7	89.4 ± 5.3
Riverside, CA (13)	75.5 ± 6.7	72.3 ± 7.7	81.4 ± 6.2	81.3 ± 5.9 ^d	89.6 ± 4.8	90.8 ± 4.1	90.4 ± 4.5	89.2 ± 4.8	88.3 ± 5.8
San Bernardino, CA (10)	76.3 ± 5.7	70.7 ± 7.0 ^d	80.9 ± 5.3	80.7 ± 5.3 ^d	87.2 ± 4.8	89.3 ± 4.0	88.3 ± 4.6	87.6 ± 4.7	82.6 ± 6.4
San Diego, CA (6)	80.6 ± 5.0	75.3 ± 6.3	82.0 ± 5.1	86.3 ± 4.1	92.6 ± 2.7	92.0 ± 3.0	94.0 ± 2.5	90.2 ± 3.9	86.7 ± 5.5
Santa Clara, CA (15)	81.5 ± 5.4	78.0 ± 6.2	85.7 ± 4.5	85.7 ± 4.9	93.6 ± 2.7	92.9 ± 2.9	94.3 ± 2.8	93.9 ± 2.5	89.6 ± 3.9
Adams, CO (130)	76.9 ± 7.0	74.5 ± 7.8	83.8 ± 5.9	83.1 ± 6.3	90.0 ± 5.1	91.0 ± 4.2	93.1 ± 3.9	91.0 ± 4.6	85.9 ± 6.8
Arapahoe, CO (107)	84.0 ± 5.1	80.8 ± 6.1	87.7 ± 4.6	88.6 ± 4.1	92.0 ± 4.0	93.1 ± 3.1	95.5 ± 2.5	93.2 ± 3.5	87.7 ± 5.6

continued on p. 163

Table 2 (continued). Estimated vaccination coverage obtained from the James-Stein methodology for 181 selected counties for three vaccine series and six individual vaccines, 2004–2005 National Immunization Survey

	Vaccine series			Individual vaccines					
	4:3:1:3:3	4:3:1:3:3:1	3:3:1:3:3	≥4 doses DTaP/DTP	≥3 doses Polio	≥1 dose MMR	≥3 doses Hib	≥3doses Hep B	≥1 dose VAR
	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)
Boulder, CO (232)	80.9 ± 5.8	76.9 ± 7.0	85.3 ± 5.3	85.2 ± 5.2	92.3 ± 3.9	93.5 ± 3.0	94.5 ± 3.1	91.3 ± 4.4	91.1 ± 4.5
Denver, CO (73)	79.9 ± 6.2	74.8 ± 7.4	85.0 ± 5.3	86.9 ± 4.8	92.6 ± 3.6	92.0 ± 3.7	94.9 ± 2.8	93.9 ± 3.2	89.3 ± 4.9
Douglas, CO (200)	82.1 ± 5.8	77.7 ± 7.0	86.4 ± 5.0	90.1 ± 4.0	91.8 ± 4.3	93.2 ± 3.2	96.5 ± 1.3	94.9 ± 2.4	85.8 ± 6.3
El Paso, CO (94)	77.6 ± 6.2	72.9 ± 7.3	83.2 ± 5.7	79.5 ± 6.4 ^d	88.9 ± 4.7	91.5 ± 3.7	92.7 ± 3.6	91.4 ± 4.0	86.5 ± 6.0
Jefferson, CO (131)	84.1 ± 5.1	79.1 ± 6.6	85.1 ± 5.3	90.5 ± 3.8	92.5 ± 3.9	94.1 ± 2.8	95.0 ± 2.8	89.8 ± 4.5	88.8 ± 5.3
Larimer, CO (239)	80.6 ± 6.3	75.7 ± 7.8	84.0 ± 6.0	85.5 ± 5.5	91.5 ± 4.6	92.2 ± 3.7	93.3 ± 3.9	89.7 ± 5.1	86.4 ± 6.7
Fairfield, CT (57)	83.1 ± 4.9	83.7 ± 5.2	85.2 ± 4.8	87.9 ± 4.1	92.9 ± 3.2	95.1 ± 2.5	96.5 ± 1.8	93.5 ± 3.2	91.0 ± 4.4
Hartford, CT (68)	87.3 ± 3.9	84.4 ± 4.9	89.7 ± 3.9	90.8 ± 3.3	94.9 ± 2.6	95.2 ± 2.2	95.9 ± 2.2	94.9 ± 2.6	91.8 ± 4.0
New Haven, CT (71)	82.7 ± 5.4	77.1 ± 6.7	83.5 ± 5.8	87.9 ± 4.6	93.6 ± 3.4	94.1 ± 2.6	95.3 ± 2.1	92.0 ± 3.8	90.0 ± 4.4
New London, CT (245)	87.1 ± 4.8	82.1 ± 6.2	87.6 ± 4.9	92.3 ± 3.3	94.4 ± 3.1	94.8 ± 2.6	95.1 ± 3.0	91.6 ± 4.3	87.6 ± 6.2
Kent, DE (391)	82.4 ± 5.7	77.2 ± 7.1	88.0 ± 4.7	82.8 ± 6.2 ^d	92.1 ± 4.0	92.2 ± 3.5	94.0 ± 3.3	92.7 ± 3.8	86.4 ± 5.9
New Castle, DE (126)	86.3 ± 3.6	83.8 ± 4.3	88.1 ± 3.6	90.1 ± 3.0	93.0 ± 2.7	95.4 ± 1.9	94.8 ± 2.2	94.0 ± 2.4	90.5 ± 3.7
Sussex, DE (371)	82.8 ± 4.9	73.2 ± 7.5	86.7 ± 4.4	87.0 ± 4.4	93.1 ± 3.1	93.3 ± 3.0	93.9 ± 3.0	92.3 ± 3.3	80.3 ± 7.7
Broward, FL (18)	78.0 ± 6.6	74.3 ± 7.8	82.6 ± 6.0	84.1 ± 5.6	89.9 ± 4.7	92.3 ± 3.5	94.8 ± 2.6	93.4 ± 3.4	88.7 ± 5.8
Duval, FL (52)	77.8 ± 3.9	73.5 ± 4.3 ^d	82.8 ± 3.6	83.3 ± 3.5 ^d	90.0 ± 2.9	90.1 ± 2.7	93.3 ± 2.2	93.4 ± 2.2	85.3 ± 3.7
Hillsborough, FL (31)	79.2 ± 6.3	74.4 ± 7.7	82.2 ± 6.1	84.7 ± 5.4	90.0 ± 4.6	89.9 ± 4.3	91.5 ± 4.3	90.1 ± 4.6	87.7 ± 5.9
Dade, FL (9)	82.9 ± 4.5	75.6 ± 5.5	87.9 ± 3.6	86.6 ± 4.2	93.2 ± 2.8	92.8 ± 2.9	96.5 ± 0.8	94.6 ± 2.6	86.4 ± 4.3
Palm Beach, FL (36)	79.3 ± 6.6	79.2 ± 7.1	83.6 ± 6.1	84.9 ± 5.4	91.3 ± 4.4	93.1 ± 3.3	94.4 ± 3.5	93.0 ± 3.7	88.5 ± 6.2
Cobb, GA (70)	82.2 ± 5.5	77.5 ± 6.7	87.0 ± 4.9	88.2 ± 4.2	92.2 ± 3.9	93.4 ± 3.2	95.1 ± 2.7	93.1 ± 3.5	86.6 ± 5.9
De Kalb, GA (63)	78.6 ± 5.3	75.4 ± 5.7	82.2 ± 4.9	85.1 ± 4.2 ^d	86.0 ± 5.2	93.0 ± 3.0	91.0 ± 3.7	90.2 ± 4.2	90.1 ± 4.3
Fulton, GA (47)	82.3 ± 4.7	78.7 ± 5.4	85.6 ± 4.1	88.1 ± 3.8	93.0 ± 2.9	92.4 ± 3.2	94.6 ± 2.4	93.0 ± 2.8	89.7 ± 3.7
Gwinnett, GA (59)	83.0 ± 5.4	78.4 ± 6.7	87.0 ± 4.8	87.8 ± 4.5	91.1 ± 4.5	93.0 ± 3.2	93.1 ± 3.5	92.2 ± 3.9	90.1 ± 4.9
Hawaii, HI (333)	78.2 ± 6.7	70.2 ± 8.6	84.0 ± 5.4	81.9 ± 6.1 ^d	90.6 ± 4.3	91.2 ± 4.0	91.7 ± 4.2	90.1 ± 4.4	84.1 ± 7.2
Honolulu, HI (48)	81.4 ± 3.8	78.3 ± 4.3	83.2 ± 3.8	84.7 ± 3.7 ^d	89.3 ± 3.1	92.9 ± 2.4	91.1 ± 2.8	90.2 ± 3.1	90.5 ± 3.0
Maui, HI (390)	77.0 ± 6.9	68.6 ± 9.4	82.7 ± 6.0	84.7 ± 5.3	88.9 ± 5.3	90.1 ± 4.4	92.8 ± 3.9	88.7 ± 5.3	81.7 ± 8.8
Ada, ID (174)	82.7 ± 4.8	75.3 ± 6.0	86.4 ± 4.5	86.8 ± 4.1	93.9 ± 2.9	92.8 ± 3.0	95.1 ± 2.6	92.9 ± 3.3	81.1 ± 6.0 ^d
Bonneville, ID (487)	80.8 ± 6.1	76.2 ± 7.3	87.0 ± 4.9	84.5 ± 5.5	90.6 ± 4.5	92.2 ± 3.6	93.4 ± 3.5	92.4 ± 3.9	84.8 ± 6.8
Canyon, ID (277)	73.3 ± 6.7	65.6 ± 7.9 ^d	81.3 ± 5.9	78.6 ± 6.2 ^d	89.3 ± 4.6	88.8 ± 4.4	90.1 ± 4.8	90.8 ± 4.5	80.3 ± 7.2
Cook, IL (2)	76.6 ± 4.6	70.3 ± 5.1 ^d	80.5 ± 4.4	85.8 ± 3.4 ^d	88.7 ± 3.8	91.7 ± 2.4	93.6 ± 2.1	93.2 ± 2.1	85.6 ± 3.9
Will, IL (88)	83.7 ± 5.6	78.6 ± 7.0	87.8 ± 4.8	88.9 ± 4.4	91.9 ± 4.1	93.6 ± 3.1	94.3 ± 3.2	92.8 ± 3.7	87.1 ± 6.3

continued on p. 164

Table 2 (continued). Estimated vaccination coverage obtained from the James-Stein methodology for 181 selected counties for three vaccine series and six individual vaccines, 2004–2005 National Immunization Survey

	Vaccine series			Individual vaccines					
	4:3:1:3:3	4:3:1:3:3:1	3:3:1:3:3	≥4 doses DTaP/DTP	≥3 doses Polio	≥1 dose MMR	≥3 doses Hib	≥3doses Hep B	≥1 dose VAR
	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)
Allen, IN (165)	78.7 ± 6.5	70.4 ± 8.4	85.3 ± 5.3	85.8 ± 5.1	91.9 ± 4.1	91.2 ± 4.0	94.7 ± 3.0	90.6 ± 4.4	83.7 ± 7.4
Hamilton, IN (224)	83.9 ± 5.5	80.7 ± 6.8	87.7 ± 5.0	91.1 ± 3.8	92.6 ± 4.0	94.6 ± 2.6	95.6 ± 2.6	93.9 ± 3.4	87.6 ± 6.2
Marion, IN (38)	82.3 ± 5.0	75.6 ± 6.3	86.3 ± 4.6	86.2 ± 4.6	93.0 ± 3.1	91.7 ± 3.5	95.8 ± 2.0	94.2 ± 2.2	85.9 ± 5.3
Polk, IA (143)	84.8 ± 4.8	77.1 ± 6.9	87.8 ± 4.4	89.7 ± 3.8	92.0 ± 3.5	93.0 ± 3.1	95.2 ± 2.6	93.9 ± 3.1	85.1 ± 6.7
Johnson, KS (119)	85.2 ± 4.5	81.5 ± 5.3	88.4 ± 3.9	92.4 ± 3.0	94.3 ± 2.8	94.7 ± 2.3	96.1 ± 2.0	94.8 ± 2.5	90.8 ± 3.9
Sedgwick, KS (113)	79.0 ± 6.2	72.7 ± 7.6	86.5 ± 4.9	84.8 ± 5.3	90.7 ± 4.4	92.7 ± 3.3	93.9 ± 3.3	92.8 ± 3.6	83.9 ± 6.7
Jefferson, KY (83)	82.6 ± 5.3	76.0 ± 7.0	86.7 ± 4.9	85.9 ± 5.0	93.9 ± 3.1	92.0 ± 3.5	96.0 ± 1.9	94.9 ± 2.6	85.8 ± 6.1
Caddo, LA (217)	78.5 ± 7.2	73.9 ± 8.3	86.3 ± 5.1	80.4 ± 7.7 ^d	93.0 ± 3.7	90.3 ± 4.6	92.7 ± 3.8	94.1 ± 3.0	88.6 ± 5.8
Calcasieu, LA (286)	76.0 ± 7.4	73.8 ± 7.9	86.4 ± 5.2	79.5 ± 7.0 ^d	91.0 ± 4.6	90.1 ± 4.5	93.0 ± 3.8	91.6 ± 4.2	85.5 ± 7.2
East Baton Rouge, LA (145)	81.8 ± 5.9	77.7 ± 7.0	88.1 ± 4.6	82.5 ± 6.2 ^d	93.1 ± 3.4	94.1 ± 2.8	95.3 ± 2.6	94.3 ± 2.9	85.8 ± 6.3
Jefferson, LA (137)	78.8 ± 6.4	71.1 ± 8.2	84.6 ± 5.4	80.1 ± 7.0 ^d	91.1 ± 4.1	90.1 ± 4.5	94.9 ± 3.1	94.6 ± 3.0	87.8 ± 6.0
Lafayette, LA (275)	77.7 ± 6.9	74.8 ± 7.3	85.2 ± 5.2	81.4 ± 6.1 ^d	91.4 ± 4.1	92.4 ± 3.4	92.8 ± 3.6	92.2 ± 3.7	86.1 ± 6.1
Orleans, LA (118)	71.3 ± 5.5 ^d	68.6 ± 5.5 ^d	79.2 ± 4.4	79.6 ± 4.7 ^d	87.2 ± 4.0	89.2 ± 3.3	92.3 ± 2.6	90.3 ± 3.0	84.3 ± 4.3
St. Tammany, LA (278)	82.5 ± 5.7	76.7 ± 7.4	87.0 ± 5.0	85.6 ± 5.1	93.1 ± 3.6	90.6 ± 4.1	94.9 ± 2.8	95.3 ± 2.5	87.3 ± 6.0
Androscoggin, ME (565)	84.0 ± 5.5	77.1 ± 7.5	86.8 ± 5.1	87.2 ± 5.0	93.9 ± 3.5	92.4 ± 3.8	94.8 ± 3.0	92.1 ± 4.0	86.9 ± 6.4
Cumberland, ME (267)	84.4 ± 4.5	75.0 ± 6.3	84.0 ± 4.9	90.3 ± 3.3	93.7 ± 2.8	90.9 ± 3.4	94.4 ± 2.8	91.8 ± 3.4	82.1 ± 6.0
Penobscot, ME (485)	84.8 ± 5.3	81.1 ± 6.5	87.8 ± 4.6	89.6 ± 4.4	96.1 ± 2.3	95.2 ± 2.5	94.9 ± 2.9	94.5 ± 3.0	89.8 ± 5.4
York, ME (353)	83.2 ± 5.0	77.4 ± 6.5	86.6 ± 4.6	88.4 ± 4.1	93.6 ± 3.2	92.6 ± 3.2	93.6 ± 3.1	93.3 ± 3.1	86.5 ± 5.8
Anne Arundel, MD (125)	85.6 ± 4.8	83.7 ± 5.7	86.5 ± 4.8	89.5 ± 4.2	93.1 ± 3.4	94.4 ± 2.6	95.1 ± 2.6	93.0 ± 3.5	89.3 ± 5.6
Baltimore, MD (85)	84.0 ± 5.0	78.8 ± 6.4	84.2 ± 5.3	90.4 ± 3.5	91.6 ± 3.8	94.4 ± 2.6	95.3 ± 2.6	91.9 ± 3.7	88.9 ± 5.1
Montgomery, MD (46)	87.6 ± 4.2	80.1 ± 5.8	87.5 ± 4.4	93.7 ± 2.7	93.0 ± 3.9	94.4 ± 2.7	96.7 ± 2.0	94.5 ± 3.1	91.7 ± 4.1
Prince George's, MD (50)	71.8 ± 7.7	72.8 ± 7.3	83.2 ± 5.9	80.5 ± 6.5 ^d	87.3 ± 6.2	92.7 ± 3.4	94.2 ± 3.0	91.0 ± 4.5	87.2 ± 6.1
Bristol, MA (132)	84.7 ± 5.1	80.3 ± 6.5	87.6 ± 4.7	88.2 ± 4.6	93.2 ± 3.4	93.3 ± 3.2	94.9 ± 2.9	93.4 ± 3.5	88.9 ± 5.9
Essex, MA (74)	81.6 ± 5.9	78.5 ± 6.6	85.2 ± 5.6	86.2 ± 5.2	92.6 ± 4.1	94.0 ± 2.6	94.5 ± 3.0	93.1 ± 3.7	88.5 ± 5.6
Hampden, MA (151)	86.6 ± 4.7	82.3 ± 6.4	87.8 ± 5.0	85.0 ± 6.1	94.5 ± 3.2	93.5 ± 3.2	94.5 ± 3.3	95.0 ± 2.7	90.6 ± 5.0
Middlesex, MA (26)	89.9 ± 3.4	84.7 ± 4.7	89.1 ± 4.0	93.9 ± 2.4	95.5 ± 2.2	95.9 ± 2.0	96.6 ± 1.6	95.1 ± 2.5	90.1 ± 4.1
Norfolk, MA (102)	89.0 ± 4.0	84.9 ± 5.3	88.8 ± 4.4	94.2 ± 2.5	95.4 ± 2.5	95.4 ± 2.3	96.5 ± 1.9	95.5 ± 2.4	91.4 ± 4.4
Suffolk, MA (90)	87.7 ± 3.6	85.2 ± 3.9	87.7 ± 3.7	92.3 ± 2.9	95.9 ± 2.1	94.1 ± 2.6	95.9 ± 1.7	95.7 ± 1.8	93.7 ± 2.7
Worcester, MA (79)	86.3 ± 4.4	79.0 ± 6.3	86.6 ± 4.8	91.0 ± 3.5	94.2 ± 2.8	93.8 ± 2.8	95.3 ± 2.6	94.7 ± 2.7	87.7 ± 5.6
Kent, MI (87)	83.0 ± 5.8	76.6 ± 7.8	87.7 ± 5.0	87.6 ± 4.8	92.8 ± 4.0	91.7 ± 4.0	95.3 ± 2.5	93.5 ± 3.7	88.8 ± 6.0

continued on p. 165

Table 2 (continued). Estimated vaccination coverage obtained from the James-Stein methodology for 181 selected counties for three vaccine series and six individual vaccines, 2004–2005 National Immunization Survey

	Vaccine series			Individual vaccines					
	4:3:1:3:3	4:3:1:3:3:1	3:3:1:3:3	≥4 doses DTaP/DTP	≥3 doses Polio	≥1 dose MMR	≥3 doses Hib	≥3doses Hep B	≥1 dose VAR
	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)
Macomb, MI (75)	82.8 ± 5.6	78.5 ± 7.0	87.0 ± 4.9	88.1 ± 4.6	91.1 ± 4.3	93.1 ± 3.3	93.7 ± 3.3	92.5 ± 3.8	87.3 ± 6.3
Oakland, MI (33)	83.7 ± 5.2	79.5 ± 6.5	86.1 ± 5.0	89.5 ± 3.9	92.6 ± 3.6	93.9 ± 2.9	95.5 ± 2.4	94.4 ± 2.8	90.2 ± 4.8
Wayne, MI (12)	75.7 ± 5.4	73.8 ± 5.6	84.3 ± 4.4	80.8 ± 4.7 ^d	88.8 ± 4.4	92.7 ± 2.4	93.9 ± 2.5	94.3 ± 2.1	89.2 ± 3.4
Dakota, MN (162)	83.6 ± 5.6	79.7 ± 7.0	87.1 ± 5.0	90.1 ± 4.1	92.1 ± 4.2	92.6 ± 3.4	96.0 ± 2.0	94.6 ± 2.6	88.4 ± 6.2
Hennepin, MN (32)	86.3 ± 4.6	81.9 ± 5.8	87.2 ± 4.7	91.2 ± 3.4	94.1 ± 3.1	94.5 ± 2.6	95.3 ± 2.6	94.1 ± 3.0	88.7 ± 5.2
Ramsey, MN (116)	85.7 ± 5.0	80.1 ± 6.7	87.3 ± 5.1	89.2 ± 4.2	94.4 ± 3.2	93.2 ± 3.2	95.5 ± 2.7	93.6 ± 3.4	85.9 ± 6.6
Rankin, MS (435)	84.9 ± 5.6	82.2 ± 6.7	87.7 ± 5.1	88.0 ± 4.9	93.7 ± 3.5	95.0 ± 2.8	94.3 ± 3.5	96.5 ± 0.9	87.8 ± 6.3
Jackson, MO (77)	82.8 ± 5.4	80.0 ± 6.3	87.8 ± 4.5	87.4 ± 4.5	93.6 ± 3.2	92.3 ± 3.3	95.5 ± 2.3	93.9 ± 3.0	90.2 ± 4.7
St. Louis, MO (58)	84.4 ± 4.4	79.3 ± 5.5	85.8 ± 4.5	90.2 ± 3.2	94.3 ± 2.6	94.9 ± 2.3	96.2 ± 2.1	94.4 ± 2.7	87.7 ± 4.9
Cascade, MT (655)	85.7 ± 4.8	76.5 ± 7.4	87.4 ± 4.9	84.0 ± 5.9	94.4 ± 3.1	91.9 ± 3.8	93.6 ± 3.5	94.0 ± 3.2	85.6 ± 6.5
Flathead, MT (686)	72.1 ± 7.2	55.6 ± 9.6 ^d	78.9 ± 6.4	79.2 ± 6.3 ^d	84.7 ± 6.2	84.6 ± 5.7	90.6 ± 4.4	84.6 ± 6.2	67.4 ± 10.0 ^d
Gallatin, MT (743)	83.7 ± 5.4	68.3 ± 9.0 ^d	84.1 ± 5.8	85.5 ± 5.6	94.7 ± 3.0	93.0 ± 3.4	91.2 ± 4.4	92.5 ± 3.8	72.5 ± 9.7 ^d
Missoula, MT (641)	82.7 ± 5.4	71.3 ± 7.5	83.7 ± 5.7	87.5 ± 4.6	92.3 ± 3.6	92.5 ± 3.4	93.4 ± 3.5	90.3 ± 4.5	83.1 ± 6.6
Yellowstone, MT (444)	84.9 ± 4.4	77.1 ± 6.1	86.0 ± 4.6	86.7 ± 4.3	92.4 ± 3.3	91.2 ± 3.6	95.0 ± 2.8	93.7 ± 3.0	88.0 ± 4.9
Douglas, NE (110)	85.3 ± 4.1	81.7 ± 5.0	88.5 ± 3.8	88.5 ± 3.6	93.6 ± 2.7	93.5 ± 2.7	94.6 ± 2.5	94.1 ± 2.6	90.6 ± 3.9
Lancaster, NE (215)	86.4 ± 4.6	79.2 ± 6.2	88.5 ± 4.4	91.2 ± 3.5	95.1 ± 2.7	94.4 ± 2.6	94.9 ± 3.0	94.4 ± 3.1	84.1 ± 6.2
Clark, NV (16)	66.4 ± 4.6 ^d	62.4 ± 4.8 ^d	74.6 ± 4.0	73.3 ± 4.4 ^d	86.1 ± 3.2	87.1 ± 3.0	88.1 ± 3.0	84.2 ± 3.4	81.2 ± 3.7 ^d
Washoe, NV (163)	80.5 ± 5.5	80.2 ± 5.7	87.4 ± 4.2	85.5 ± 4.7	94.5 ± 2.3	92.8 ± 2.9	95.6 ± 1.9	94.6 ± 2.3	89.0 ± 4.7
Hillsborough, NH (170)	84.4 ± 4.3	78.5 ± 5.4	87.0 ± 4.2	91.2 ± 3.0	94.6 ± 2.6	92.8 ± 2.8	95.9 ± 2.1	93.4 ± 3.0	85.7 ± 4.9
Merrimack, NH (464)	86.2 ± 4.7	79.4 ± 6.9	87.5 ± 4.6	92.6 ± 3.1	94.5 ± 2.8	94.9 ± 2.4	95.3 ± 2.6	93.0 ± 3.4	82.9 ± 7.7
Rockingham, NH (238)	83.4 ± 4.9	78.8 ± 5.8	87.7 ± 4.2	90.3 ± 3.6	93.5 ± 3.2	92.8 ± 3.0	95.7 ± 2.3	93.8 ± 2.9	84.8 ± 5.6
Strafford, NH (518)	87.1 ± 4.7	81.0 ± 6.5	87.7 ± 4.8	91.4 ± 3.6	94.9 ± 2.8	93.8 ± 3.0	94.2 ± 3.2	96.2 ± 1.2	84.6 ± 6.7
Bergen, NJ (67)	85.1 ± 5.3	78.9 ± 6.7	84.8 ± 5.6	89.7 ± 4.3	94.3 ± 3.1	93.8 ± 3.1	95.3 ± 3.0	95.4 ± 2.9	90.6 ± 4.6
Burlington, NJ (159)	85.6 ± 4.8	81.6 ± 6.4	86.2 ± 5.2	91.3 ± 3.4	93.7 ± 3.1	94.7 ± 2.7	95.5 ± 2.7	94.8 ± 2.9	88.4 ± 6.2
Essex, NJ (55)	77.8 ± 5.9	75.4 ± 6.3	83.0 ± 5.4	84.4 ± 4.8 ^d	92.2 ± 3.2	91.7 ± 3.6	95.8 ± 1.6	95.2 ± 1.8	87.6 ± 5.1
Middlesex, NJ (65)	82.8 ± 5.7	76.6 ± 7.5	83.6 ± 6.2	87.9 ± 4.8	92.8 ± 3.7	92.4 ± 3.7	93.5 ± 3.8	93.8 ± 3.5	89.0 ± 5.7
Ocean, NJ (122)	74.7 ± 7.0	69.4 ± 8.2 ^d	78.0 ± 6.9	81.5 ± 6.2 ^d	87.0 ± 5.5	90.6 ± 4.1	89.1 ± 5.1	89.6 ± 4.8	84.0 ± 7.1
Bernalillo, NM (98)	78.4 ± 5.5	74.9 ± 6.1	82.8 ± 4.9	82.3 ± 5.2 ^d	90.4 ± 3.6	92.4 ± 3.1	90.2 ± 3.8	91.1 ± 3.5	90.5 ± 4.1
Sandoval, NM (527)	79.2 ± 7.5	70.3 ± 8.7	82.0 ± 6.4	81.9 ± 7.1 ^d	89.0 ± 5.8	89.0 ± 4.8	92.4 ± 4.2	90.0 ± 4.9	83.8 ± 7.3
San Juan, NM (382)	90.2 ± 6.9	71.5 ± 8.6	85.5 ± 5.5	89.1 ± 7.5	91.1 ± 4.5	89.3 ± 4.9	92.6 ± 4.1	92.1 ± 4.1	85.8 ± 6.6

continued on p. 166

Table 2 (continued). Estimated vaccination coverage obtained from the James-Stein methodology for 181 selected counties for three vaccine series and six individual vaccines, 2004–2005 National Immunization Survey

	Vaccine series			Individual vaccines					
	4:3:1:3:3	4:3:1:3:3:1	3:3:1:3:3	≥4 doses DTaP/DTP	≥3 doses Polio	≥1 dose MMR	≥3 doses Hib	≥3doses Hep B	≥1 dose VAR
	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)
Bronx, NY (19)	70.6 ± 7.9	69.6 ± 7.6 ^d	81.3 ± 6.0	80.4 ± 6.5 ^d	87.9 ± 5.3	91.2 ± 4.0	88.0 ± 5.3	89.5 ± 4.8	86.3 ± 6.2
Erie, NY (66)	82.3 ± 5.9	78.4 ± 7.0	84.7 ± 5.8	87.5 ± 4.9	95.0 ± 2.3	92.7 ± 3.5	93.9 ± 3.2	93.5 ± 3.5	89.7 ± 5.1
Kings, NY (8)	73.5 ± 6.1	68.6 ± 6.6 ^d	81.4 ± 5.1	81.0 ± 5.4 ^d	87.8 ± 4.4	91.4 ± 3.3	91.2 ± 3.7	91.9 ± 3.3	86.7 ± 4.6
Monroe, NY (91)	88.9 ± 3.9	80.8 ± 6.4	88.0 ± 4.7	90.4 ± 3.8	95.6 ± 2.4	93.4 ± 3.1	95.0 ± 2.7	95.5 ± 2.4	89.1 ± 5.4
Nassau, NY (30)	83.2 ± 5.7	76.0 ± 7.3	82.8 ± 6.0	89.5 ± 4.5	95.1 ± 2.9	92.8 ± 3.4	95.0 ± 2.9	95.6 ± 2.6	90.4 ± 5.0
New York, NY (25)	86.8 ± 4.7	87.9 ± 5.1	84.5 ± 5.4	91.3 ± 3.8	96.2 ± 1.9	96.6 ± 2.1	97.1 ± 2.1	94.3 ± 3.1	92.1 ± 4.2
Queens, NY (11)	80.2 ± 5.5	77.9 ± 6.0	85.6 ± 5.0	86.0 ± 4.4	93.5 ± 3.1	92.0 ± 3.5	93.8 ± 3.2	94.0 ± 3.0	90.4 ± 4.3
Suffolk, NY (23)	80.2 ± 6.3	76.0 ± 7.4	83.6 ± 6.2	87.1 ± 4.9	92.5 ± 3.9	93.0 ± 3.3	93.2 ± 3.8	93.4 ± 3.3	88.2 ± 5.7
Westchester, NY (53)	84.5 ± 5.6	81.0 ± 6.9	83.3 ± 6.2	90.2 ± 4.3	94.7 ± 3.2	95.4 ± 2.1	95.6 ± 2.9	95.5 ± 2.7	92.0 ± 4.8
Mecklenburg, NC (54)	84.3 ± 5.3	80.2 ± 6.6	87.7 ± 4.8	88.8 ± 4.4	93.1 ± 3.6	93.5 ± 3.1	95.5 ± 2.6	94.6 ± 2.9	88.4 ± 5.7
Wake, NC (62)	87.2 ± 4.5	82.8 ± 5.9	88.8 ± 4.5	91.7 ± 3.4	94.6 ± 2.8	94.4 ± 2.6	95.6 ± 2.5	94.7 ± 2.8	91.0 ± 4.9
Burleigh, ND (779)	87.7 ± 4.5	82.1 ± 6.0	88.1 ± 4.7	89.9 ± 4.1	95.0 ± 2.3	93.7 ± 3.0	94.6 ± 2.9	92.5 ± 4.1	89.4 ± 5.4
Cass, ND (460)	85.5 ± 4.1	79.2 ± 5.6	88.5 ± 3.9	90.0 ± 3.3	95.3 ± 2.2	93.8 ± 2.7	95.1 ± 2.4	95.1 ± 2.3	90.3 ± 4.0
Grand Forks, ND (800)	87.2 ± 4.6	81.5 ± 6.2	85.8 ± 5.1	89.8 ± 4.1	94.8 ± 2.7	93.4 ± 3.2	94.4 ± 3.1	94.0 ± 3.1	87.3 ± 5.8
Ward, ND (787)	83.4 ± 5.3	70.3 ± 8.4	86.1 ± 5.0	86.2 ± 5.0	94.3 ± 3.2	91.3 ± 3.8	94.6 ± 3.0	93.8 ± 3.3	75.6 ± 9.1 ^d
Cuyahoga, OH (28)	83.9 ± 3.3	77.7 ± 4.1	86.3 ± 3.2	89.6 ± 2.6	93.5 ± 2.0	93.9 ± 1.9	96.5 ± 1.3	94.5 ± 2.2	88.9 ± 3.1
Franklin, OH (29)	85.3 ± 3.2	79.0 ± 3.8	88.6 ± 2.9	88.4 ± 2.9	92.9 ± 2.4	94.2 ± 2.1	95.1 ± 1.8	94.7 ± 1.9	87.8 ± 3.1
Hamilton, OH (61)	83.8 ± 5.2	76.0 ± 7.2	84.8 ± 5.4	89.9 ± 4.0	93.5 ± 3.3	91.9 ± 3.6	94.2 ± 3.1	94.0 ± 3.1	89.0 ± 5.5
Cleveland, OK (302)	85.5 ± 5.2	82.6 ± 6.3	88.0 ± 4.7	87.8 ± 5.0	94.9 ± 2.5	94.2 ± 2.8	96.5 ± 1.1	92.1 ± 4.5	87.7 ± 6.2
Oklahoma, OK (64)	74.1 ± 7.3	73.9 ± 6.4	86.4 ± 4.5	78.0 ± 6.2 ^d	90.6 ± 3.9	91.7 ± 3.3	91.1 ± 3.7	92.8 ± 3.4	88.5 ± 4.8
Tulsa, OK (93)	76.5 ± 7.5	76.4 ± 6.5	85.5 ± 4.7	85.0 ± 4.9	92.6 ± 3.3	92.8 ± 2.9	92.2 ± 3.4	92.2 ± 3.3	85.4 ± 5.9
Clackamas, OR (197)	76.6 ± 6.7	71.8 ± 7.9	80.1 ± 6.5	82.3 ± 6.0 ^d	89.1 ± 5.0	88.9 ± 4.5	87.8 ± 5.3	87.5 ± 5.4	84.1 ± 6.8
Lane, OR (226)	78.2 ± 6.3	71.1 ± 8.1	79.5 ± 6.6	83.6 ± 5.4 ^d	90.9 ± 4.2	91.1 ± 4.0	87.8 ± 5.6	88.4 ± 5.1	88.4 ± 5.7
Marion, OR (187)	77.9 ± 6.4	71.8 ± 7.8	81.2 ± 6.1	79.1 ± 6.7 ^d	91.1 ± 4.2	90.1 ± 4.1	88.5 ± 5.1	89.0 ± 4.9	84.3 ± 6.6
Multnomah, OR (89)	79.4 ± 5.7	69.9 ± 7.3 ^d	81.0 ± 6.0	85.5 ± 4.8	90.6 ± 4.3	90.5 ± 3.8	93.8 ± 3.4	91.4 ± 3.8	81.9 ± 6.4
Washington, OR (111)	79.0 ± 5.8	72.0 ± 7.0	82.4 ± 5.6	83.8 ± 5.3 ^d	89.2 ± 4.7	88.9 ± 4.3	92.7 ± 3.9	91.2 ± 4.2	85.4 ± 5.8
Allegheny, PA (43)	86.4 ± 4.7	83.3 ± 6.0	88.0 ± 4.8	90.9 ± 3.7	94.2 ± 3.0	95.3 ± 2.1	95.4 ± 2.8	94.1 ± 3.3	95.2 ± 1.7
Montgomery, PA (84)	87.5 ± 4.4	82.3 ± 6.3	87.3 ± 5.0	94.2 ± 2.6	95.1 ± 2.6	94.4 ± 3.0	96.4 ± 2.3	95.9 ± 2.4	92.1 ± 4.5
Philadelphia, PA (21)	78.2 ± 3.8	76.2 ± 3.9	85.6 ± 3.1	84.2 ± 3.2 ^d	93.5 ± 2.1	93.9 ± 2.0	93.6 ± 2.3	93.8 ± 2.0	91.0 ± 2.6
Kent, RI (414)	86.0 ± 4.3	79.4 ± 6.0	88.2 ± 4.2	90.7 ± 3.4	94.8 ± 2.7	93.0 ± 3.1	95.0 ± 2.5	95.2 ± 2.6	91.5 ± 4.4

continued on p. 167

Table 2 (continued). Estimated vaccination coverage obtained from the James-Stein methodology for 181 selected counties for three vaccine series and six individual vaccines, 2004–2005 National Immunization Survey

	Vaccine series			Individual vaccines					
	4:3:1:3:3	4:3:1:3:3:1	3:3:1:3:3	≥4 doses DTaP/DTP	≥3 doses Polio	≥1 dose MMR	≥3 doses Hib	≥3doses Hep B	≥1 dose VAR
	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)
Providence, RI (105)	83.6 ± 3.5	80.0 ± 4.0	86.2 ± 3.4	89.4 ± 2.9	94.8 ± 2.1	95.0 ± 1.9	93.8 ± 2.4	94.2 ± 2.2	92.6 ± 2.8
Washington, RI (561)	90.2 ± 3.7	81.6 ± 5.9	88.2 ± 4.6	94.4 ± 2.5	96.2 ± 2.1	94.6 ± 2.5	95.1 ± 2.7	95.6 ± 2.4	88.9 ± 5.0
Charleston, SC (181)	81.0 ± 6.4	75.1 ± 8.0	83.9 ± 6.1	85.9 ± 5.6	94.6 ± 3.2	91.2 ± 4.2	93.6 ± 3.6	96.9 ± 0.5	91.1 ± 5.0
Greenville, SC (158)	81.7 ± 5.8	77.0 ± 7.4	86.6 ± 5.4	84.9 ± 5.3	92.9 ± 3.7	92.6 ± 3.5	93.4 ± 3.7	93.5 ± 3.5	87.0 ± 6.8
Spartanburg, SC (233)	81.8 ± 5.9	77.3 ± 7.2	87.9 ± 5.0	84.5 ± 5.6	92.5 ± 4.3	92.7 ± 3.6	94.1 ± 3.6	93.0 ± 4.0	87.3 ± 6.7
Minnehaha, SD (321)	86.5 ± 4.3	81.7 ± 5.3	89.2 ± 3.8	91.4 ± 3.2	94.8 ± 2.5	94.6 ± 2.4	95.7 ± 2.3	94.4 ± 2.6	87.3 ± 5.1
Pennington, SD (523)	87.1 ± 4.6	78.7 ± 6.3	87.7 ± 4.6	85.9 ± 5.3	93.4 ± 3.3	92.8 ± 3.1	94.2 ± 3.1	93.5 ± 3.2	85.9 ± 5.9
Davidson, TN (96)	87.0 ± 3.0	83.5 ± 3.6	89.8 ± 2.7	89.2 ± 2.8	94.2 ± 2.2	93.8 ± 2.0	95.6 ± 1.8	94.2 ± 2.2	90.3 ± 3.0
Knox, TN (177)	87.5 ± 4.4	81.6 ± 6.4	88.3 ± 4.5	90.4 ± 3.8	95.6 ± 2.3	93.1 ± 3.2	94.7 ± 3.2	95.8 ± 2.1	91.1 ± 4.8
Shelby, TN (42)	74.9 ± 4.3	73.0 ± 4.5 ^d	81.0 ± 3.8	81.4 ± 3.8 ^d	90.5 ± 2.8	89.3 ± 2.9	88.8 ± 3.0	89.9 ± 2.8	87.8 ± 3.4
Bexar, TX (17)	75.3 ± 4.3	72.0 ± 4.7 ^d	80.6 ± 4.0	78.6 ± 4.3 ^d	88.0 ± 3.4	90.0 ± 2.8	90.6 ± 3.2	90.1 ± 2.9	88.5 ± 3.2
Dallas, TX (7)	72.0 ± 4.3 ^d	70.7 ± 4.5 ^d	78.5 ± 3.9	79.3 ± 3.9 ^d	88.9 ± 3.0	89.8 ± 2.8	91.3 ± 2.5	87.6 ± 3.2	87.9 ± 3.3
El Paso, TX (44)	69.6 ± 4.0 ^d	66.5 ± 4.2 ^d	78.1 ± 3.6	76.4 ± 3.9 ^d	88.9 ± 2.8	89.1 ± 2.9	91.5 ± 2.5	86.9 ± 3.0	87.7 ± 3.0
Harris, TX (3)	71.3 ± 4.7 ^d	69.0 ± 4.9 ^d	78.4 ± 4.4	78.7 ± 3.9 ^d	87.6 ± 3.2	88.6 ± 3.3	90.6 ± 2.9	88.0 ± 2.9	83.7 ± 4.2 ^d
Tarrant, TX (14)	80.7 ± 6.0	76.0 ± 7.3	87.7 ± 4.7	83.8 ± 5.6 ^d	92.0 ± 3.9	92.5 ± 3.5	94.7 ± 2.9	93.1 ± 3.5	86.8 ± 6.4
Travis, TX (40)	78.5 ± 6.7	74.5 ± 8.0	83.2 ± 6.4	85.4 ± 5.4	92.9 ± 3.8	92.3 ± 3.7	94.3 ± 3.1	92.7 ± 4.0	89.0 ± 5.8
Davis, UT (172)	81.6 ± 5.9	75.5 ± 7.5	87.4 ± 4.6	85.4 ± 5.7	91.9 ± 4.1	91.5 ± 3.7	94.2 ± 3.2	92.2 ± 3.9	86.6 ± 6.0
Salt Lake, UT (27)	75.1 ± 5.8	68.7 ± 6.8 ^d	79.2 ± 5.7	81.0 ± 5.3 ^d	87.2 ± 4.7	89.9 ± 3.7	89.9 ± 4.3	89.3 ± 3.9	83.6 ± 5.7
Utah, UT (80)	77.2 ± 6.2	71.2 ± 7.3	82.9 ± 5.4	82.2 ± 5.8 ^d	91.8 ± 3.6	89.1 ± 4.5	92.4 ± 3.7	91.1 ± 3.7	86.0 ± 6.0
Weber, UT (210)	81.9 ± 5.8	75.4 ± 7.5	88.3 ± 4.6	83.3 ± 6.2	92.0 ± 4.0	91.5 ± 3.9	94.4 ± 3.1	92.9 ± 3.7	87.0 ± 6.3
Chittenden, VT (461)	91.0 ± 3.3	78.4 ± 5.8	88.2 ± 4.0	94.7 ± 2.3	96.0 ± 1.8	94.4 ± 2.6	96.5 ± 1.2	93.9 ± 3.0	83.8 ± 5.5
Franklin, VT (1,006)	85.1 ± 5.1	64.2 ± 9.3 ^d	87.5 ± 4.8	89.0 ± 4.3	93.8 ± 3.3	91.5 ± 3.9	94.5 ± 3.2	93.8 ± 3.1	69.7 ± 10.5 ^{d,e}
Washington, VT (979)	84.2 ± 5.3	72.8 ± 8.0	87.4 ± 4.7	88.9 ± 4.3	95.3 ± 2.6	94.0 ± 2.9	95.1 ± 2.7	92.6 ± 3.5	76.3 ± 8.9 ^d
Windsor, VT (1,086)	81.3 ± 7.5	71.0 ± 9.0	87.5 ± 4.8	89.2 ± 4.2	92.9 ± 4.1	92.7 ± 3.4	94.9 ± 3.0	92.9 ± 3.8	79.5 ± 9.1
Fairfax, VA (39)	86.5 ± 4.5	83.6 ± 5.2	89.3 ± 4.0	91.0 ± 3.4	94.0 ± 3.0	95.7 ± 2.1	96.8 ± 1.9	95.1 ± 2.6	90.9 ± 4.0
Prince William, VA (148)	81.7 ± 5.9	78.6 ± 6.9	86.7 ± 4.9	87.9 ± 4.6	89.4 ± 5.0	93.3 ± 3.3	94.9 ± 3.1	92.7 ± 3.9	86.9 ± 6.2
Clark, WA (161)	78.9 ± 6.5	72.9 ± 7.8	83.5 ± 5.9	82.5 ± 6.0 ^d	88.8 ± 5.2	90.7 ± 4.2	92.9 ± 3.9	90.3 ± 4.7	83.9 ± 6.8
King, WA (22)	79.6 ± 3.8	72.8 ± 4.3 ^d	81.6 ± 3.7	88.0 ± 3.2	91.0 ± 2.8	93.2 ± 2.3	94.6 ± 2.2	87.8 ± 3.2	83.6 ± 3.5 ^d
Pierce, WA (78)	78.5 ± 6.0	71.2 ± 7.5	84.2 ± 5.4	82.2 ± 6.0 ^d	92.1 ± 3.9	92.6 ± 3.3	93.3 ± 3.6	90.5 ± 4.2	82.6 ± 6.9
Snohomish, WA (99)	77.8 ± 6.3	70.2 ± 7.5 ^d	82.6 ± 5.7	83.4 ± 5.5 ^d	90.0 ± 4.6	92.0 ± 3.4	93.6 ± 3.6	89.9 ± 4.4	79.1 ± 7.4 ^d

continued on p. 168

Table 2 (continued). Estimated vaccination coverage obtained from the James-Stein methodology for 181 selected counties for three vaccine series and six individual vaccines, 2004–2005 National Immunization Survey

	Vaccine series			Individual vaccines					
	4:3:1:3:3	4:3:1:3:3:1	3:3:1:3:3	≥4 doses DTaP/DTP	≥3 doses Polio	≥1 dose MMR	≥3 doses Hib	≥3doses Hep B	≥1 dose VAR
	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)	Percent (95% CI)
Kanawha, WV (323)	81.1 ± 5.8	73.6 ± 7.7	85.7 ± 5.2	81.8 ± 6.2 ^d	91.8 ± 3.8	90.4 ± 4.2	94.1 ± 3.2	92.0 ± 3.7	86.4 ± 6.1
Dane, WI (153)	88.3 ± 4.1	82.5 ± 5.8	87.8 ± 4.6	91.3 ± 3.6	95.2 ± 2.5	94.6 ± 2.5	95.0 ± 2.7	94.9 ± 2.7	90.4 ± 4.9
Milwaukee, WI (41)	77.6 ± 4.4	73.5 ± 4.6 ^d	83.6 ± 3.8	83.1 ± 3.9 ^d	92.3 ± 2.4	91.4 ± 2.8	92.1 ± 3.0	92.9 ± 2.3	87.0 ± 3.7
Waukesha, WI (192)	86.2 ± 4.7	78.9 ± 6.5	86.8 ± 4.9	93.1 ± 2.9	95.2 ± 2.6	93.8 ± 2.9	96.0 ± 2.3	94.6 ± 2.8	87.1 ± 5.6
Albany, WY (1,449)	84.1 ± 6.3	73.4 ± 9.7	83.0 ± 6.1	88.2 ± 5.7	91.5 ± 5.6	92.5 ± 4.5	92.5 ± 4.2	82.6 ± 8.8	78.3 ± 9.4
Campbell, WY (1,120)	83.7 ± 5.5	67.8 ± 9.3 ^d	88.6 ± 4.7	89.8 ± 4.0	94.2 ± 3.0	91.5 ± 4.1	94.7 ± 3.2	95.0 ± 2.6	77.8 ± 9.2
Laramie, WY (610)	84.8 ± 4.6	80.4 ± 5.9	86.6 ± 4.6	86.6 ± 4.6	92.9 ± 3.2	92.6 ± 3.0	94.5 ± 2.7	92.7 ± 3.4	84.8 ± 5.9
Natrona, WY (726)	81.2 ± 5.6	71.9 ± 7.4	87.3 ± 4.7	83.5 ± 5.2 ^d	93.0 ± 3.4	91.9 ± 3.6	94.8 ± 2.8	93.4 ± 3.4	80.4 ± 7.3
Sweetwater, WY (1,064)	80.8 ± 6.1	68.0 ± 9.9	86.5 ± 5.0	87.6 ± 4.8	92.0 ± 4.1	90.8 ± 4.1	94.8 ± 3.0	92.0 ± 4.0	74.2 ± 11.1 ^{d,e}

^aNational direct estimate^bThe direct estimate among selected 181 counties combined is significantly different at the 0.05 level of statistical significance from the corresponding estimate among direct estimate-remaining sampled counties combined.^cCounty rank, U.S. population of 19- to 35-month-old children on July 1, 2005. Derived from data obtained from the Census Bureau [cited 2007 Feb 9]. Available from: URL: <http://www.census.gov/popest/datasets.html>^dVaccination coverage is significantly less than the Healthy People 2010 goal of achieving 90% vaccination coverage for individual vaccines and 80% coverage for vaccine series.^eEstimate may be unreliable.

CI = confidence interval

DTaP = diphtheria and tetanus toxoids and acellular pertussis

DTP = diphtheria and tetanus toxoids and pertussis

MMR = measles-mumps-rubella

Hib = *Haemophilus influenzae* type b

Hep B = hepatitis B

VAR = varicella

Association of county-level factors with direct estimates of county-level vaccination coverage rates

In fitting the forward stepwise regressions to obtain indirect estimates of the log-odds of county-level vaccination coverage rates for the James-Stein estimates, we found that, in general, counties with lower estimated vaccination coverage rates were designated as experiencing housing stress; had a higher number of children aged 0–17 per capita living in poverty; were home to a higher percentage of black children among children <5 years of age; had a higher number of general practitioners per capita; had a higher number of bassinets set up in hospitals per capita; or were designated as a nonmetropolitan county (Table 1). Also, in general, counties with higher estimated vaccination coverage rates were designated as having a higher number of pediatricians per capita; a higher number of people living in group quarters per capita; higher per capita income; a higher number of Asian residents per capita; or being designated as having an economy that depends on federal/state governmental activities (Table 1). County-level predictors selected in the forward stepwise regressions were highly predictive of estimated vaccination coverage with R^2 values indicating that, depending on the vaccine or vaccine series, between 67% and 88% of the total variation in estimated vaccination coverage rates was explained by the predictors selected.

DISCUSSION

This article provides estimates of vaccination coverage for 19- to 35-month-old children in each of 181 counties for six individual vaccines and three vaccine series. With respect to all of the 19- to 35-month-old children in the U.S., these counties make up 49% of the population and include 83 of the 100 most populous counties. For the individual vaccines and vaccine series we investigated, vaccination coverage for the 181 counties was very similar to the vaccination coverage in the remaining U.S. counties sampled by the NIS, but not included in our evaluation.

With respect to the MMR, Hib, and Hep B vaccines, none of the 181 counties had coverage significantly below the HP 2010 objective of 90%. Also, for the 4:3:1:3:3 vaccine series, very few of the 181 counties had an estimated vaccination coverage rate that was significantly below the HP 2010 objective of 80%. Further, our results suggest that none of the 181 counties would have an estimated 4:3:1:3:3:1 vaccination coverage rate that would be significantly less than 80% if children who had received three doses of DTaP/DTP could also receive the fourth dose and if children could

be administered one dose of VAR. These results are congruent with a previous study that found that only one more visit to a vaccination provider was required for many children to be fully vaccinated²³ according to the recommendations of CDC's Advisory Committee on Immunization Practices.²⁴

In general, our results suggest that county-level factors associated with higher county-level estimated vaccination coverage are correlates of greater access to primary care. In particular, our results show that in counties where there is a higher per capita of pediatricians, infants may have greater access to primary care traditionally provided by pediatricians, and this translates into higher vaccination coverage rates. Also, our results show that high county-level vaccination coverage rates were positively associated with per capita living in group quarters. Because the "per capita living in group quarters" variable used in our analyses (Table 1) measured the extent to which a county provided housing, custodial, medical, and other services to residents who live in group quarters, the variable provides an indirect measure of the extent to which the infrastructure of a county is organized to provide access to other medical services for other county residents, such as primary care services to infants. Insofar as this is true, in counties where the per capita living in group quarters is higher, one may expect higher vaccination coverage among infants, as we saw in our results.

Additionally, we found that at the county level, per capita income was positively and significantly associated with higher vaccination coverage rates. In other research, family income has been shown to be a significant predictor of whether individual children are UTD.²⁵ Because the likelihood of having health insurance rises with income,²⁶ so does access to primary care and, subsequently, vaccination coverage rates.^{27–29} Finally, our study shows that counties with a higher per capita Asian population have higher vaccination coverage rates. This finding is concordant with other literature that has shown that Asian children have higher estimated vaccination coverage than non-Hispanic white children.³⁰

The results also suggest that county-level factors associated with lower county-level estimated vaccination coverage include correlates of poverty, such as a higher number per capita of children aged 0–17 living in poverty. In particular, our results show that low county-level vaccination coverage rates are associated with higher levels of housing stress experienced by county residents. Because the housing stress variable used in our analyses (Table 1) measured the extent to which 30% or more of the residents in a county live in substandard housing conditions or pay a disproportion-

ate amount of their income in rent, the variable is a measure of the extent of county-level poverty. Because poverty is known to be significantly correlated with lower levels of health insurance,²⁶ access to care, and vaccination coverage,^{25–29} in counties where housing stress is pervasive, one may expect lower county-level estimates of vaccination coverage among infants, as we saw in our results.

Further, we found that lower estimates of county-level vaccination coverage were associated with the percentage of black children among children <5 years of age. After adjusting for sociodemographic factors distinguishing black infants from white infants, race/ethnicity was not a significant independent predictor of vaccination coverage.³¹ However, poverty was a significant predictor of vaccination coverage,²⁵ and the percentage of black Americans living in poverty in 2003 was 34% compared with 13% for white Americans.²⁶

The results also show that lower county-level vaccination coverage can be expected in counties where the per capita hospitals or the per capita bassinets set up in hospitals is high. These results may suggest that in counties where medical care infrastructure is focused primarily on hospitals rather than the provision of primary care in a medical home,²⁹ lower vaccination coverage rates may be expected among infants. Children were considered to have a medical home if they had a doctor, nurse, or physician's assistant who provided them with ongoing routine care, including well-child care, preventive care, and sick care.²⁹

Finally, our results show that in counties where there is a high per capita of general practitioners, lower vaccination coverage rates may be expected. These results are concordant with other studies that have shown that lower vaccination coverage is expected among infants when their vaccination providers are general practitioners compared with pediatricians.³²

County-level estimates are important because public health concerns originate in small geographic areas. For example, studies conducted in inner-city locations in Chicago³³ and Atlanta³⁴ found a high rate of unvaccinated children among racial/ethnic minority groups living in the surveyed neighborhoods. In Sullivan County, New York, an investigation by the New York State Department of Health identified a mumps outbreak of 31 cases in a population with 96% vaccination coverage.³⁵ Other work has shown that children who have received no vaccine doses cluster geographically, with the largest numbers of unvaccinated children living in counties in California, Illinois, New York, Washington, Pennsylvania, Texas, Oklahoma, Colorado, Utah, and Michigan.³⁶ In Ashland, Oregon, 12.3% of all children attending public schools and 18.8% of the

children attending day care in 2002 claimed an exemption from mandatory vaccination laws compared with 2.4% for the entire state that year.^{37,38}

Experience from the measles resurgence of the late 1980s and early 1990s^{39–42} showed that although state-level vaccination coverage rates were high, vaccination coverage rates varied in smaller geographical areas and were low among poor children living in 28 cities where the largest measles outbreaks occurred. In response to learning that vaccination coverage was low in specific subpopulations in those 28 cities, the NIS was initially designed to obtain estimates of vaccination coverage in those cities and 40 other geographic areas that make up the remainder of the states to which each of those cities belong.

This article provides estimates of vaccination coverage at a finer level of geographic aggregation and has several notable advantages. Because the data used in our analyses were drawn from a large national survey, and because we pooled that data for two consecutive years and applied the James-Stein estimation methodology, we were able to obtain precise estimates of vaccination coverage for many counties. Because the predictors of vaccination coverage selected from the Area Resource File were highly predictive of county-level vaccination coverage rates, the predicted values obtained from the regressions of the direct estimates on county-level predictors of vaccination coverage were precise and, consequently, the James-Stein estimates that used those predictions were precise, in general. Although the James-Stein methodology yields precise estimates of vaccination coverage, the sample size for many counties was insufficiently large to identify smaller geographical areas, such as towns and villages within the counties, where vaccination coverage could be lower than in the county as a whole.

Limitations

One potential limitation of our research is that the data were drawn from a survey with only moderate response rates. Although the statistical methodology⁴ of the NIS is designed to reduce potential nonresponse bias, it is not known whether that methodology is fully successful in eliminating nonresponse bias. If the methodology is not fully successful in eliminating nonresponse bias, and if nonresponse to the NIS is correlated with not being UTD, then our evaluation could have overestimated vaccination coverage. Drawbacks of conducting vaccination surveillance using the NIS telephone survey have been described by Simpson et al.⁴³ and Salmon et al.⁴⁴

A further potential limitation of our work is that estimates were derived from combining two years of

NIS data. Estimates derived from combined data years may be less sensitive to change in vaccination coverage. Also, estimates of the log-odds of vaccination coverage obtained from the James-Stein methodology have minimum variance among all unbiased estimators, if all of the mathematical assumptions specified by the methodology are fulfilled. We note that this is a hazard of all statistical modeling and is not a unique problem to the methodology we have implemented. Moreover, regardless of whether the distributional assumptions required by the methodology were fulfilled, our empirical findings demonstrate that the James-Stein methodology yields an estimated vaccination coverage rate that has greater precision than that of the direct estimate.

Finally, the coverage estimates provided in this article are estimates subject to statistical error. However, the multiple comparison method we used to evaluate whether counties have achieved vaccination coverage objectives were calibrated so that among counties found to have estimated coverage consistent with attaining or exceeding coverage objectives, only 5%, on average, of those counties had a true but unknown vaccination coverage level that was less than those objectives. Further, the estimation and multiple testing methods we applied were useful for identifying counties likely to have lower coverage than others,⁴⁵ and could be targeted for further assessment and programmatic efforts to improve vaccination coverage.

CONCLUSION

A desirable goal of a vaccination program is to sustain a sufficiently high level of vaccination coverage so that herd immunity⁴⁶ is achieved. When a community has herd immunity, if one child acquires a vaccine-preventable disease, an epidemic will not flourish because of the large numbers of other individuals in the community who are protected by vaccinations. In fact, vaccination coverage levels that are sufficiently high to establish herd immunity must exist for disease to be eliminated. The HP 2010 vaccination coverage objectives are milestones toward the goal of achieving herd immunity. Those milestones must be achieved in small areas such as counties and communities to achieve the goal of elimination in larger areas such as the 50 states and the nation. Surveillance of vaccination coverage in small geographic areas may be useful for local health authorities to make policy decisions to achieve those levels.

The authors gratefully acknowledge scientific advice during the development of this article made by Van Parsons at the National

Center for Health Statistics, Carol Gotway Crawford at the Centers for Disease Control and Prevention, and Bill Davis at the National Cancer Institute.

This article is dedicated to the memory of Beverly Causey, who was a pioneer in small area research at the U.S. Census Bureau.

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