An Assessment of the Performance of Self-Reported Vaccination Status for Hepatitis B, National Health and Nutrition Examination Survey 1999–2008

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Objectives. We sought to assess the performance of self-reported vaccination with hepatitis B vaccine (HepB) compared with serological status for hepatitis B markers in the general US civilian population.

Methods. Using 1999 through 2008 National Health and Nutrition Examination Survey data, we calculated 3 measures of agreement between self-reported HepB vaccination status and serological status: percent concordance, and positive (PPV) and negative predictive values (NPV) of self-report. Logistic regression was used to identify factors associated with agreement between self-report and serological status.

Results. Overall agreement was 83% (95% CI = 82.3, 83.7), NPV of self-report was high (0.95; 95% CI = 0.93, 0.95) and PPV was low (0.53; 95% CI = 0.51, 0.54). Birth year relative to the 1991 recommendation for universal infant HepB vaccination had a strong association with agreement, however, the association was positive for those who reported receiving at least 3 doses and negative for those who reported receiving no doses.

Conclusions. Although the low PPV in our study could be attributable in part to waning of vaccine-induced anti-HBs over time, national adult HepB vaccination coverage may be lower than previously estimated because national estimates usually depend on self-report of vaccine receipt. (*Am J Public Health.* 2013;103: 1865–1873. doi:10.2105/AJPH.2013.301313)

Hepatitis B virus (HBV) infection is associated with an estimated 600 000 annual deaths worldwide.[1] In the United States, during 2007 alone, hepatitis B was listed as either the underlying or contributing cause of 1815 deaths.[2] During the period 1999 to 2006, there were an estimated 730 000 US residents with active, chronic HBV infection.[3]

HBV infection is vaccine-preventable. In the United States, vaccination was first recommended for all infants in 1991.[4] Along with disease incidence, vaccination coverage is an essential component of surveillance, and both are used to guide national vaccination programs[5] by identifying populations at risk and in need of vaccination. Serological surveys supplement case-surveillance data, providing a measure of prevalence of chronic infection in the population. Furthermore, serological surveys can measure and distinguish between naturally acquired and vaccine-induced immunity, and are often considered the most reliable method of determining vaccination status outside of provider records. However, there are limitations to use of serological surveys to determine hepatitis B vaccination status because antibodies wane over time,[6] and vaccinated individuals may, therefore, appear unvaccinated as time since vaccination increases. Because serological surveys are costly to implement, public health practitioners frequently rely on self-reported vaccination status to assess immunity.

Self-reported vaccination coverage is used widely in public health to guide vaccination programs. Validation studies have found high levels of agreement between self-reported vaccination status (pneumococcal 79%[7]; influenza 89%[8]) and vaccination documented in medical records. Although some studies comparing self-reported receipt of hepatitis B vaccine (HepB) with serological status have been conducted in special populations such as injection-drug users, HIV-infected individuals and adolescents, to the best of our knowledge, no studies have assessed the performance of self-reported receipt of HepB with serological status as a measure of vaccination coverage in the general US civilian population. This was our objective in the current analysis.

METHODS

The National Health and Nutrition Examination Survey (NHANES), conducted by the US Centers for Disease Control and Prevention's National Center for Health Statistics (NCHS), collects nationally representative data on the health and nutritional status of the noninstitutionalized, civilian population of the United States. NHANES uses a complex, stratified, multistage probability sampling design and collects information from approximately 5000 persons per year using standardized household interviews, physical examinations, and tests of biologic samples. Participants were interviewed in their homes to ascertain demographic characteristics and self-reported HepB vaccination status, using the Computer-Assisted Personal Interviewing-CAPI (interviewer-administered) system. Persons aged 16 years or older and emancipated minors were interviewed directly; an adult proxy provided information for participants who were younger than 16 years and for individuals unable to answer the questions themselves. More detailed information on survey design for NHANES, including approval from the institutional review board for data collection and analysis, is available from the survey documentation at http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm. For this study we analyzed NHANES data from nonproxy respondents that were collected from 1999 through 2008. Data from proxy respondents were excluded because many previous validation studies of vaccination self-report have already investigated proxy reports.

Laboratory Testing

Serum specimens from those aged 2 years or older were tested for the antibody against hepatitis B surface antigen (anti-HBs). Presence of anti-HBs indicates immunity against HBV infection either from past infection or vaccination. Samples from 1999 through 2006 were tested with a quantitative solid phase enzyme-linked immunoassay (EIA) Abbott AUSAB EIA (Abbott Laboratories, North Chicago, IL) and samples from 2007 through 2008 were tested with quantitative chemiluminescence immunoassay using VITROS Immunodiagnostic System (Ortho-Clinical Diagnostics, Inc., Rochester, NY). Serum specimens from those aged 6 years or older that tested positive for anti-HBs were also tested for total antibody to hepatitis B core antigen (anti-HBc) using Ortho HBc ELISA (samples from 1999 through 2006) or VITROS Immunodiagnostic System (samples from 2007 through 2008, both Ortho-Clinical Diagnostics, Inc., Rochester, NY). Presence of anti-HBc indicates past or current infection. For both Abbott and Ortho assays, tests considered reactive initially were repeated in duplicate. Further details of laboratory testing are available from the survey documentation at http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm.

Definitions and Measures

Based on serological testing we classified persons as vaccinated for hepatitis B if they were anti-HBs positive and anti-HBc negative, neither vaccinated nor naturally infected if they were both anti-HBs and anti-HBc negative, and naturally infected (past or current) with HBV if they were anti-HBc positive.

We determined self-reported HepB vaccination status by asking if participants had ever received the 3-dose series of the hepatitis B vaccine. Response categories were (1) "Yes, all 3 doses" (which also included reporting receipt of more than 3 doses), (2) "Less than 3 doses," and (3) "No doses." We classified those who responded "Yes, all 3 doses" as being vaccinated against HBV and those who responded "No doses" as not being vaccinated. Those who reported receiving fewer than 3 doses were not classified as to their reported vaccination status because it is not clear what results should be expected for their serological testing. Thus, all analyses involving agreement between the 2 methods (self-reported HepB vaccination status and serological status) excluded participants who indicated they had received fewer than 3 HepB doses as well as those who responded "don't know."

For this study, agreement between self-reported vaccination status and serological status meant either that the participant reported having received at least 3 doses of HepB and was anti-HBs positive and anti-HBc negative, or that the participant reported receiving no HepB doses and was anti-HBs negative and anti-HBc negative. Participants who appeared to have been naturally infected (i.e., were anti-HBc positive) were not included in our analysis. We defined positive predictive value (PPV) as the proportion with serological testing results that indicated vaccination among those who reported having received at least 3 doses of HepB, and we defined negative predictive value (NPV) as the proportion with serological testing results that indicated they were still susceptible to HBV infection among those who reported having received no doses of HepB. Thus, we report PPV and NPV for self-reported vaccination status but not for the serological testing.

Race and ethnicity were obtained by self-report from all NHANES participants. We identified race from responses to the question "What race do you consider yourself to be? Please select 1 or more of these categories." Ethnicity was determined from responses to the question "Do you consider yourself Hispanic/Latino?" NCHS combines responses to the questions on ethnicity and race to form the following 5 categories: Mexican American, Other Hispanic, Black Non-Hispanic, White Non-Hispanic and Other Race—Including Multiracial. No data on whether a participant was born in an HBV-high-incidence African or Asian country is available in the public use data and Asian is not included as a separate racial/ethnic category.

Statistical Analysis

We used SUDAAN version 10.0, a statistical package designed to analyze complex survey data, for analysis.[9] Estimates were weighted to represent the total civilian, noninstitutionalized US population and to account for oversampling and nonresponse to the household interview and physical examination. Weights were further adjusted to account for the fact that not all examination participants were tested for anti-HBs and anti-HBc, and that multiple years of data were used. A P value $<.05$ was considered significant; no adjustments for multiple comparisons were made.

We first conducted analyses for agreement (percentage in agreement, PPV and NPV of self-report) for all nonproxy reports. We then conducted separate simple and multivariate regression analyses for self-reports of receipt of at least 3 doses of HepB and for self-reports of receipt of no doses. Measures of agreement were evaluated by age, sex, race/ethnicity, birthplace, education, survey year, and birth year relative to the 1991 universal infant HepB vaccination recommendations (i.e. birth before or during/after 1991). Birth year was analyzed instead of age in multivariate models so that results could be interpreted with respect to the 1991 recommendation. The χ^2 test was used for statistical comparisons between subgroups. Crude odds ratios were obtained using a separate logistic regression model for each of the aforementioned independent variables. Variables that were statistically significant in simple logistic models were included in multivariate logistic modeling. Variables not found to be significant in simple logistic models or at earlier stages of model building were added to the final model, 1 at a time, to test for confounding and significance.

RESULTS

Of the 54 050 persons aged 6 years or older sampled in the NHANES 1999–2008, 42 773 (79.1%) were interviewed, of which 31 377 were nonproxy interviews. Of these 31 377 interviewees 29 687 (94.6%) were examined; serum samples were available for HBV serological testing for 27 785 (93.6% of nonproxy interviewees examined).

A total of 27 774 nonproxy respondents had HBV serological testing performed. Of these, 24.4% (95% CI = 23.5, 25.3; n = 7136) reported having received at least 3 doses of HepB, 3.1% (95% CI = 2.8, 3.4; n = 838) reported receiving fewer than 3 doses, 64.4% (95% CI = 63.3, 65.6; n = 17 404) reported receiving no doses, and 8.1% (95% CI = 7.6, 8.6; n = 2387) reported not knowing whether they had been vaccinated; 6 refused to respond. Of the nonproxy respondents who had HBV testing performed, 4719 were excluded from further analyses: 838 who reported

receiving fewer than 3 HepB doses, 2387 who reported not knowing if they had been vaccinated, 6 who refused to respond, and 1488 who appeared previously infected. Demographic characteristics of 23 055 nonproxy interview respondents included in our analyses are shown in Table 1. Slightly more than half were female and nearly three quarters were White non-Hispanic. Just less than one quarter reported their highest level of education as less than high school and just more than one half reported education beyond high school. Less than 1% were born after the 1991 universal infant HepB-vaccination recommendation and just more than 10% were younger than 20 years at interview. Nearly three quarters indicated they had received no doses of HepB.

Agreement Between Self-Reported Vaccination and Serological Status

An analysis of concordance between the classifications (vaccinated/not vaccinated) obtained from self-reported vaccination status and serological status found that 14.7% (95% CI = 14.0, 15.4; n = 3585) were classified as vaccinated by both methods, 68.4% (95% CI = 67.2, 69.4; n = 15 183) were classified as not vaccinated by both methods, 13.1% (95% CI = 12.5, 13.7; n = 3250) reported receiving at least 3 doses of vaccine but appeared to be susceptible to HBV infection, and 3.9% (95% CI = 3.5, 4.4; n = 1037) reported receiving no doses of HepB but appeared vaccinated. Thus, the overall percent agreement of 83.0% (Table 2) was composed primarily of those who reported receiving no doses of HepB.

Results of the analysis of agreement between self-reported HepB-vaccination status and serological status are shown on Table 2. The most marked differences in percent agreement between the 2 methods were found for self-reported vaccination status and age. Overall, PPV of self-reported vaccination status was low, and NPV was high and did not vary much across subgroups with a few notable exceptions: PPV was much lower for participants born in Mexico and for those aged 70 years or older, and NPV was much lower for those born after the 1991 infant HepB vaccination recommendation and for those aged 14 to 19 years.

Logistic Regression Models

In simple logistic models, age, race/ethnicity, place of birth, education, and birth year were all significantly associated with agreement between self-report of receiving no HepB doses and serological status. In the final multivariate model being Mexican American, Black non-Hispanic or of other or multiple races; and birth after the 1991 vaccination recommendation were significantly associated with lower agreement and being born in Mexico or having at least a high school education was significantly associated with higher agreement. Age was not included in multivariate modeling (Table 3).

In simple logistic models, age, sex, race/ethnicity, place of birth, education, survey year, and birth year were all significantly associated with agreement between self-report of receiving at least 3 doses of HepB and serological status. In the final multivariate model, being born in Mexico, a high school graduate, Mexican American, other Hispanic, Black non-Hispanic, or male were all significantly associated with lower agreement, although birth after the 1991 recommendation was associated with higher agreement. Survey year was not significant; age was not included in multivariate modeling (Table 4).

DISCUSSION

To our knowledge this is the first study to compare self-reported HepB-vaccination status and serological evidence of vaccination using data from NHANES. We found only fair to moderate agreement between self-reported HepB vaccination status and serological status and that PPV decreased with age. This suggests that national adult HepB vaccination coverage may be lower than previously estimated because these estimates traditionally are based on self-reported vaccination status.

Several validation studies have been conducted to determine agreement of self-reported vaccination and provider records, particularly for adult pneumococcal vaccine coverage. Two studies, conducted at a Veterans Affairs Medical Center and 2 managed care organizations, sought to determine agreement between pneumococcal vaccination self-report and provider records among elderly persons. These studies found, as we did in our analysis, fair to moderate agreement (κ statistics of 0.28 to 0.57) but PPVs from 0.54 to 0.93.[8,10] The higher PPVs were seen in the 2 managed care populations. Perhaps owing to managed care's focus on primary and preventive care, including vaccination, vaccination records were more likely to be available for review. Only 1 of the aforementioned studies[10] looked at predictors of agreement; in particular, whether agreement was associated with race and ethnicity. After adjusting for sex, sex and age, and age and education, they found no differences between racial/ethnic groups for specificity of self-reported pneumococcal vaccination but found significantly lower specificity among Black (OR = 0.41; 95% CI = 0.23, 0.74) and Latino persons (OR = 0.48; 95% CI = 0.27, 0.88) when compared with White persons. On unadjusted analysis, PPV did not vary across racial/ethnic groups although NPV was significantly lower for Blacks (0.59; 95% CI = 0.50, 0.68) and Latinos (0.38; 95% CI = 0.27, 0.50) than for Whites (0.67; 95% CI = 0.61, 0.73). Another study, which used data from the Behavioral Risk Factor Surveillance System (BRFSS), found the percentage agreement between self-report pneumococcal vaccination and provider records was 79%.[7] This moderately-high level of agreement was consistent with our findings and might have been a result of recent vaccination of BRFSS survey participants because 87% of those surveyed reported receiving their vaccination in the previous 3 years.[7]

Although validation studies of self-reported pneumococcal and influenza vaccination have been conducted,[7,8,10] few such studies have looked specifically at adult HepB vaccination. One study (n = 2115), which included both self-reported vaccination status and serological testing, was conducted among adult endoscopy patients in Australia and found that one third of adults who reported being vaccinated against HBV had no serological evidence of vaccination.[11] In our study, nearly half of those who reported receiving at least 3 doses of HepB had no serological evidence of vaccination. Neither study reported information on time after vaccination. The Australian study did not ask number of doses received, thus their analysis, unlike ours, would have included individuals who were not fully vaccinated; in addition, factors associated with agreement between self-reported

TABLE 1—Estimated Demographic Characteristics and Self-Reported Hepatitis B Vaccination Status Nonproxy Interview Respondents with Hepatitis B Virus Testing Performed Who Reported Receiving ≥ 3 or No Doses of Hepatitis B Vaccine: NHANES 1999–2008

Characteristic	Total No.	rpt+/serol+	rpt+/serol-	rpt-/serol+	rpt-/serol-	Weighted % (95% CI)
Total	23 055	3585	3250	1037	15183	. . .
Age at interview, y						
14–19	4056	1881	923	326	926	7.6 (7.1, 8.1)
20–29	3401	686	780	203	1732	17.6 (16.6, 18.5)
30–39	3194	390	543	119	2142	18.4 (17.6, 19.3)
40–49	3197	291	417	96	2393	19.6 (18.8, 20.5)
50–59	2609	193	256	99	2061	15.6 (14.8, 16.4)
60–69	3008	114	219	95	2580	10.5 (9.8, 11.2)
≥ 70	3590	30	112	99	3349	10.7 (10.0, 11.4)
Birth year: born before universal infant vaccination recommendation						
Before 1930	2558	12	57	71	2418	7.4 (6.8, 8.0)
1930–1939	2695	64	150	74	2407	9.1 (8.5, 9.8)
1940–1949	2718	158	234	97	2229	12.8 (12.1, 13.6)
1950–1959	3070	259	340	113	2358	19.0 (18.1, 19.9)
1960–1969	3223	328	496	99	2300	19.6 (18.6, 20.6)
1970–1979	3328	468	673	138	2049	17.4 (16.5, 18.4)
1980–1990	5320	2199	1274	432	1415	14.2 (13.4, 15.1)
Birth year: born after universal infant vaccination recommendation (1991–2005)	143	97	26	13	7	0.5 (0.4, 0.6)
Sex						
Male	11053	1474	1543	507	7529	47.4 (46.8, 47.9)
Female	12 002	2111	1707	530	7654	52.6 (52.1, 53.2)
Race/ethnicity						
Mexican American	5333	735	817	254	3527	7.6 (6.4, 9.0)
Other Hispanic	1236	218	224	76	718	4.9 (3.7, 6.5)
White non-Hispanic	11 089	1558	1153	370	8008	72.8 (70.1, 75.4)
Black non-Hispanic	4679	891	950	286	2552	10.6 (9.1, 12.3)
Other/multiple race/ethnicity	718	183	106	51	378	4.1 (3.5, 4.9)
Place of birth						
United States	18 385	3092	2570	810	11 913	87.0 (85.2, 88.6)
Mexico	2829	211	406	122	2090	4.4 (3.8, 5.1)
Elsewhere	1832	282	274	104	1172	8.6 (7.2, 10.1)
Education						
< HS graduate	8590	1557	1294	467	5272	22.4 (21.3, 23.5)
HS graduate/GED	5301	611	696	223	3771	25.6 (24.5, 26.8)
> HS graduate	9142	1417	1258	344	6123	52.0 (50.2, 53.7)
Survey years						
1999–2000	4301	394	443	210	3254	19.0 (17.3, 20.8)
2001–2002	4865	667	559	223	3416	19.6 (18.0, 21.3)
2003–2004	4538	773	711	176	2878	20.1 (17.7, 22.8)
2005–2006	4565	987	763	225	2590	20.5 (18.2, 22.9)
2007–2008	4786	764	774	203	3045	20.8 (18.7, 23.1)
Self-report of doses received						
≥ 3 doses	6835	3585	3250			27.8 (26.7, 28.8)
No doses	16 220			1037	15 183	72.2 (71.2, 73.3)

Note. CI = confidence interval; GED = general equivalency diploma; HS = high school; NHANES = National Health and Nutrition Examination Survey; rpt+ = reported receiving at least 3 doses of hepatitis B vaccine; rpt- = reported receiving no doses of hepatitis B vaccine; serol+ = antibody against hepatitis B surface antigen positive and antibody to hepatitis B core antigen negative; serol- = antibody against hepatitis B surface antigen and antibody to hepatitis B core antigen negative.

TABLE 2—Agreement Between Nonproxy Self-Reported Hepatitis B Vaccination Status and Hepatitis B Virus Serological Testing by Selected Characteristics for Medical Examination Participants: NHANES 1999–2008

Characteristic	No.	No. in Agreement	Weighted % in Agreement (95% CI)	χ^2 (*P*)	PPV (95% CI)	NPV (95% CI)
Total	23 055	18 768	83.0 (82.3, 83.7)	. . .	0.53 (0.51, 0.54)	0.95 (0.93, 0.95)
Self-reported hepatitis B vaccination status				791.4 (< .001)		
≥ 3 doses received	6835	3585	52.8 (51.4, 54.3)		. . .	. . .
No doses received	16 220	15 183	94.6 (94.0, 95.2)		. . .	. . .
Age at interview, y				73.5 (< .001)		
14–19	4056	2807	72.1 (69.9, 74.3)		0.72 (0.69, 0.75)	0.72 (0.66, 0.77)
20–29	3401	2418	73.5 (71.6, 75.4)		0.53 (0.50, 0.56)	0.90 (0.88, 0.92)
30–39	3194	2532	80.7 (78.9, 82.3)		0.46 (0.42, 0.50)	0.95 (0.93, 0.98)
40–49	3197	2684	85.2 (83.8, 86.5)		0.47 (0.43, 0.51)	0.97 (0.96, 0.98)
50–59	2609	2254	86.6 (84.8, 88.1)		0.46 (0.41, 0.52)	0.96 (0.95, 0.97)
60–69	3008	2694	90.2 (88.5, 91.7)		0.40 (0.33, 0.47)	0.97 (0.96, 0.98)
≥ 70	3590	3379	94.2 (93.0, 95.2)		0.25 (0.15, 0.38)	0.97 (0.96, 0.98)
Sex				1.1 (.29)		
Male	11 053	9003	82.7 (81.8, 83.5)		0.48 (0.46, 0.50)	0.94 (0.93, 0.95)
Female	12 002	9765	83.3 (82.3, 84.3)		0.57 (0.54, 0.59)	0.95 (0.94, 0.96)
Race/ethnicity				49.9 (< .001)		
Mexican American	5333	4262	78.8 (77.2, 80.3)		0.39 (0.36, 0.43)	0.94 (0.92, 0.95)
Other Hispanic	1236	936	77.2 (73.3, 80.6)		0.46 (0.39, 0.53)	0.92 (0.89, 0.94)
White non-Hispanic	11 089	9566	85.4 (84.5, 86.2)		0.56 (0.54, 0.58)	0.95 (0.94, 0.96)
Black non-Hispanic	4679	3443	74.4 (72.5, 76.3)		0.43 (0.40, 0.46)	0.92 (0.91, 0.93)
Other/multiple race/ethnicity	718	561	78.3 (74.9, 81.3)		0.62 (0.54, 0.69)	0.88 (0.84, 0.91)
Place of birth				4.9 (.01)		
United States	18 385	15 005	83.4 (82.6, 84.1)		0.54 (0.52, 0.56)	0.95 (0.94, 0.96)
Mexico	2829	2301	80.2 (77.8, 82.4)		0.26 (0.21, 0.31)	0.95 (0.93, 0.96)
Elsewhere	1832	1454	80.6 (77.9, 83.1)		0.52 (0.45, 0.58)	0.92 (0.90, 0.94)
Education				11.0 (< .001)		
< HS graduate	8590	6829	81.4 (80.1, 82.6)		0.54 (0.51, 0.57)	0.93 (0.92, 0.94)
HS graduate/GED	5301	4382	84.6 (83.6, 85.6)		0.45 (0.42, 0.49)	0.96 (0.95, 0.97)
> HS graduate	9142	7540	83.0 (82.0, 83.9)		0.55 (0.53, 0.57)	0.95 (0.94, 0.96)
Survey years				15.1 (< .001)		
1999–2000	4301	3648	86.3 (84.9, 87.6)		0.49 (0.46, 0.52)	0.95 (0.93, 0.96)
2001–2002	4865	4083	85.4 (84.2, 86.6)		0.54 (0.49, 0.58)	0.95 (0.94, 0.96)
2003–2004	4538	3651	82.5 (80.3, 84.6)		0.51 (0.47, 0.54)	0.95 (0.93, 0.97)
2005–2006	4565	3577	80.4 (79.0, 81.8)		0.54 (0.51, 0.57)	0.94 (0.93, 0.95)
2007–2008	4786	3809	80.8 (79.0, 82.4)		0.55 (0.52, 0.58)	0.94 (0.93, 0.95)
Birth year				3.4 (.07)		
Before universal infant vaccination recommendation (before 1991)	22 912	18 664	83.1 (82.3, 83.8)		0.52 (0.51, 0.54)	0.95 (0.94, 0.96)
After universal infant vaccination recommendation (1991–2005)	143	104	74.6 (65.0, 82.3)		0.80 (0.70, 0.87)	0.34 (0.14, 0.62)[a]

Note. CI = confidence interval; GED = general equivalency diploma; HS = high school; NHANES = National Health and Nutrition Examination Survey; NPV = negative predictive value; PPV = positive predictive value. Agreement means either the participant reported having received ≥ 3 doses of hepatitis B vaccine and was antibody against hepatitis B surface antigen positive and antibody to hepatitis B core antigen negative or the participant reported having received no doses of hepatitis B vaccine and was antibody against hepatitis B surface antigen negative and antibody to hepatitis B core antigen negative.

[a]Estimate may be statistically unstable because it is based on fewer than 10 persons.

TABLE 3—Factors Associated With Agreement Between Nonproxy Self-Reported Hepatitis B Vaccination Status and Hepatitis B Virus Serological Testing for Those Who Reported Receiving No Doses of Hepatitis B Vaccine: NHANES 1999–2008

	Simple Logistic Model		Main Effects Multivariate Logistic Model	
Factor	COR (95% CI)	*P*	AOR (95% CI)	*P*
Age at interview, y				
14–19 (Ref)	1.00		. . .[a]	. . .[a]
20–29	3.5 (2.6, 4.8)	< .001		
30–39	6.9 (5.0, 9.7)	< .001		
40–49	11.7 (8.0, 17.0)	< .001		
50–59	8.6 (6.1, 12.2)	< .001		
60–69	12.3 (8.8, 17.2)	< .001		
≥ 70	12.6 (8.7, 18.4)	< .001		
Sex				
Male	0.9 (0.8, 1.1)	.34	0.9 (0.8, 1.1)	.27
Female (Ref)	1.00		1.00	
Race/ethnicity				
Mexican American	0.7 (0.5, 0.9)	.021	0.6 (0.4, 0.8)	.002
Other Hispanic	0.5 (0.4, 0.8)	< .001	0.7 (0.4, 1.1)	.1
White non-Hispanic (Ref)	1.00		1.00	
Black non-Hispanic	0.5 (0.4, 0.7)	< .001	0.6 (0.5, 0.7)	< .001
Other/multiple race/ethnicity	0.3 (0.2, 0.5)	< .001	0.4 (0.2, 0.5)	< .001
Place of birth				
United States (Ref)	1.00		1.00	
Mexico	1.1 (0.8, 1.5)	.7	2.0 (1.3, 3.0)	.001
Elsewhere	0.6 (0.5, 0.8)	< .001	0.9 (0.6, 1.2)	.43
Education				
< HS graduate (Ref)	1.00		1.00	
HS graduate/GED	1.7 (1.4, 2.1)	< .001	1.5 (1.2, 1.9)	< .001
> HS graduate	1.5 (1.2, 1.8)	< .001	1.4 (1.1, 1.7)	.009
Survey years				
1999–2000	1.2 (0.8, 1.7)	.36	. . .[b]	. . .[b]
2001–2002	1.3 (0.9, 1.8)	.1		
2003–2004	1.3 (0.8, 2.1)	.22		
2005–2006	1.0 (0.8, 1.3)	.95		
2007–2008 (Ref)	1.00			
Birth year				
Before universal infant vaccination recommendation (before 1991; Ref)	1.00		1.00	
After universal infant vaccination recommendation (1991–2005)	0.03 (0.01, 0.09)	< .001	0.04 (0.01, 0.13)	< .001

Note. AOR = adjusted odds ratio; CI = confidence interval; COR = crude odds ratio; GED = general equivalency diploma; HS = high school; NHANES = National Health and Nutrition Examination Survey. The sample size was n = 16 220.
[a]Variable not included in multivariate modeling because of collinearity with birth year.
[b]Variable not significant in simple or multivariate models and therefore not included in the final model.

vaccination status and serological status were not investigated.

We found that overall self-reported HepB-vaccination status has high NPV. Providers can therefore have confidence that if a client reports never having been vaccinated against HBV, then they have not been vaccinated, and therefore the provider should vaccinate as appropriate. The sole exception is among persons born after the 1991 universal infant HepB vaccination recommendations were released; these individuals have low NPV indicating that they are more likely than not to have been vaccinated regardless of a negative self-report. The low PPV for self-reported

TABLE 4—Factors Associated With Agreement Between Nonproxy Self-Reported Hepatitis B Vaccination Status and Hepatitis B Virus Serological Testing for Those Who Reported Receiving at Least 3 Doses of Hepatitis B Vaccine: NHANES 1999–2008

	Simple Logistic Model		Multivariate Logistic Model	
Factor	COR (95% CI)	*P*	AOR (95% CI)	*P*
Age at interview, y				
14–19 (Ref)	1.00		. . .[a]	. . .[a]
20–29	0.4 (0.3, 0.5)	< .001		
30–39	0.3 (0.2, 0.4)	< .001		
40–49	0.3 (0.2, 0.4)	< .001		
50–59	0.3 (0.2, 0.4)	< .001		
60–69	0.3 (0.2, 0.4)	< .001		
≥ 70	0.2 (0.1, 0.3)	< .001		
Sex				
Male	0.7 (0.6, 0.8)	< .001	0.7 (0.6, 0.8)	< .001
Female (Ref)	1.00		1.00	
Race/ethnicity				
Mexican American	0.5 (0.4, 0.6)	< .001	0.8 (0.6, 0.9)	.006
Other Hispanic	0.7 (0.5, 0.9)	.01	0.7 (0.5, 0.9)	.009
White non-Hispanic (Ref)	1.00		1.00	
Black non-Hispanic	0.6 (0.5, 0.7)	< .001	0.6 (0.5, 0.7)	< .001
Other/multiple race/ethnicity	1.2 (0.9, 1.7)	.16	1.3 (0.9, 1.8)	.11
Place of birth				
United States (Ref)	1.00		1.00	
Mexico	0.3 (0.2, 0.4)	< .001	0.4 (0.3, 0.5)	< .001
Elsewhere	0.9 (0.7, 1.2)	.51	0.9 (0.7, 1.2)	.67
Education				
< HS graduate (Ref)	1.00		1.00	
HS graduate/GED	0.7 (0.6, 0.8)	< .001	0.7 (0.6, 0.8)	< .001
> HS graduate	1.1 (0.9, 1.2)	.47	0.9 (0.8, 1.1)	0.18
Survey years				
1999–2000	0.8 (0.7, 0.9)	.002	. . .[b]	. . .[b]
2001–2002	0.9 (0.8, 1.2)	.6		
2003–2004	0.8 (0.7, 1.0)	.047		
2005–2006	1.0 (0.8, 1.1)	.59		
2007–2008 (Ref)	1.00			
Birth year				
Before universal infant vaccination recommendation (before 1991; Ref)	1.00		1.00	
After universal infant vaccination recommendation (1991–2005)	3.6 (2.1, 6.1)	< .001	3.3 (2.0, 5.5)	< .001

Note. AOR = adjusted odds ratio; CI = confidence interval; COR = crude odds ratio; GED = general equivalency diploma; HS = high school; NHANES = National Health and Nutrition Examination Survey. The sample size was n = 6835.
[a]Variable not included in multivariate modeling because of collinearity with birth year.
[b]Variable not significant in multivariate models and therefore not included in the final model.

HepB-vaccination status seen in our study poses a public health dilemma: individuals may believe that they are protected against infection when they are indeed not, causing providers to miss opportunities to vaccinate at-risk individuals. In addition, because of a lack of routine data-collection systems for adult vaccination, adult vaccination coverage is often estimated through self-report from national surveys.

Routine vaccination data collection can be improved through expansion of Immunization Information Systems (IIS) to include adult vaccination data. The Taskforce on Community Preventive Services found that the use of IISs cannot only provide consolidated vaccination histories but improve vaccination coverage as well.[12] The Guide to Community Preventive Services states that IIS are effective in increasing vaccination rates because of their ability to support client reminder and recall systems, provider assessment and feedback, and provider reminders; aid in vaccine management and accountability; determine client vaccination status; and assist in investigations on vaccination rates, missed opportunities to vaccinate, and coverage disparities.[12] Client reminders and recall systems within IIS[12] are particularly useful for multiple-dose vaccines such as HepB. However, until routine data collection systems for adult vaccination become more widespread, national surveys will continue to provide the best available estimates of adult vaccination coverage through self-report. The public health community and policymakers who utilize self-reported vaccination coverage data need to be aware of its limitations.

In multivariate analyses we found a number of differences in factors associated with agreement for self-reports of no doses of HepB and self-reports of at least 3 HepB doses. Perhaps our most notable finding was that the association with birth year was positive for self-reports of at least 3 doses and negative for self-reports of no doses. Other factors, for which differences were found, included sex, race/ethnicity, place of birth and education. Males were significantly less likely than females to have a report of receiving at least 3 doses of HepB supported by serological evidence, although the same was not true for a report of no doses. Compared with White non-Hispanics, all racial/ethnic groups except those of other or multiple races were significantly less likely to have a report of receiving at least 3 doses supported by serological evidence, and a report of receiving no doses was less likely to be supported by serological evidence for all racial/ethnic groups except Hispanics other than Mexican Americans compared with White non-Hispanics. Those with education beyond high school were more likely to have a report of

receiving no doses of HepB supported by serological evidence; conversely, those with a high school education or GED were less likely to have a report of receiving at least 3 doses supported by serological evidence. Finally, those born in Mexico were more likely to have a report of receiving no doses and less likely to have a report of receiving at least 3 doses of HepB supported by serological evidence compared with those born in the United States. These differences suggest a complex relationship. The difference in direction of association between agreement and birth year for those who self-reported no doses and those who reported receiving at least 3 doses reflects the fact that agreement was higher among those who were more likely to have reported not being vaccinated (i.e., those who are older) and the fact that those who were older (i.e., those born before the 1991 universal infant vaccination recommendation) were also less likely to have been vaccinated than those who are younger (i.e., those born after the 1991 universal infant vaccination recommendation). Reasons for the differences for other factors are unclear and are areas for future investigation. Our multivariate models explained less than 5% of the variance in agreement suggesting that factors more strongly associated with agreement were not evaluated in our analysis.

Although NHANES provides a unique opportunity to compare self-reported HepB vaccination status with serological evidence of vaccination in a large, nationally representative sample, our study is prone to a number of limitations. Poor agreement between self-reported HepB-vaccination status and serological status may be caused by factors other than poor recall. First, post-vaccination anti-HBs levels wane over time; lack of detectable antibody may be attributed to length of time after vaccination rather than lack of vaccination. Thus our results are biased toward higher NPV and lower PPV for self-report than would be obtained if all those in our study who were actually vaccinated had detectable levels of anti-HBs. Older individuals in our study had lower PPV for self-report; just as some of the low PPV might be explained by poor recall, some might be explained by loss of antibody over time. Unfortunately NHANES does not collect the information on vaccination date and vaccine type that are needed to fully assess this bias, however results from 4 follow-up studies of HepB vaccinees may be useful because they involved individuals vaccinated mainly as adolescents or adults rather than as neonates, as does our study.[13–16] Two studies of health care students in 2 US universities found that 90%[13] and 85%[14] had anti-HBs titers of at least 10 milli-international units per milliliter at 11 to 15 years and at 10 years after receiving 3 doses of HepB, respectively. A study in Spain[15] found that 85% of vaccinees had anti-HBs titers at least 10 milli-international units per milliliter 6.5 years after vaccination, and a much earlier (1988) study of a plasma-derived vaccine in Germany[16] found that 39% of vaccinees had anti-HBs titers less than 10 milli-international units per milliliter after 6 years. Taken together these studies suggest that a sizeable proportion of the 47% of self-reported vaccinees in our study with anti-HBs levels less than 10 milli-international units per milliliter may not be accounted for by loss of antibody over time. Second, 5% to 10%[17] of fully vaccinated persons will not develop antibodies (the "non-responders"); however, this would account for only a small portion of those in our study whose report of having received at least 3 doses of HepB was not supported by serological evidence. Thus, agreement between self-report and anti-HBs levels can only be used as an estimate of the validity of HepB vaccination self-report. Third, the available race/ethnicity data does not include a separate category for Asians and information on country of birth does not allow identification of those born in HBV high incidence African or Asian countries, thus it was not possible to evaluate validity of self-reported vaccination status among these important target groups for immunization. Fourth, because we focused on nonproxy reports, the number of individuals born after the 1991 recommendation was small and results for this subgroup may not be as generalizable as those for individuals born prior to 1991. Finally NHANES is representative of the civilian noninstitutionalized US population; thus, results may not apply to the entire US population.

In summary, overall agreement between nonproxy self-report of HepB vaccination status and serological evidence was fair to moderate. Black and Hispanic persons and males were more likely to have self-reported receipt of HepB vaccine not supported by serological evidence. The PPV of self-report was low, particularly among the older individuals in our study, which may lead to missed opportunities to vaccinate at-risk individuals. Our findings suggest that national adult HepB vaccination coverage may be lower than previously estimated because these estimates usually depend on self-report of vaccine receipt. These results have implications for prevention programs and policies. ■

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Contributors

M. M. Denniston, K. K. Byrd, R. M. Klevens, J. Drobeniuc, and R. B. Jiles participated in the study design, analysis and interpretation of data, and drafting and revision of the article. S. Kamili participated in the interpretation of data and revision of the article. All authors approved the final version of the article.

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Human Participant Protection

The study was approved by the National Center for Health Statistics ethical review board. Informed consent was obtained from all participants.

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