MAJOR ARTICLE

Seroprevalence of Antibody to Mumps Virus in the US Population, 1999–2004

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(See the editorial commentary by Quinlisk, on pages 655–656.)

Background. In 2006, the largest mumps outbreak in the United States in 20 years occurred. To understand prior mumps seroprevalence and factors associated with the presence of antibody to mumps virus, data from the 1999–2004 National Health and Nutrition Examination Survey (NHANES) were analyzed.

Methods. A mumps virus–specific enzyme immunoassay was used to measure the seroprevalence of serum immunoglobulin G (IgG) antibody among NHANES participants aged 6–49 years. Participants were grouped on the basis of 10-year birth cohorts, 95% confidence intervals (CIs) were calculated using SUDAAN software, and logistic regression was used to identify independent predictors.

Results. The overall age-adjusted seroprevalence of IgG antibody to mumps virus during 1999–2004 was 90.0% (95% CI, 88.8%–91.1%). Seroprevalence was higher among US-born non-Hispanic blacks (96.4% [95% CI, 95.5%–97.2%]) and non–US-born Mexican Americans (93.7% [95% CI, 92.0%–95.2%]). Seroprevalence was significantly lower in the 1967–1976 birth cohort (85.7% [95% CI, 83.5%–87.8%]). The variables sex, education, and race/ethnicity/birthplace were independent predictors in at least 1 of the birth cohorts.

Conclusions. The overall estimate of 90.0% is at the lower end of the estimated population immunity (90%–92%) needed to achieve herd immunity. Lower seroprevalence among groups suggest that they represent populations at an increased risk. For mumps control, high vaccine coverage and high population immunity must be achieved and maintained.

Mumps is an acute viral illness characterized by unilateral or bilateral parotitis preceded by nonspecific symptoms, such as fever, headache, malaise, and myalgia. Complications of mumps include deafness, mastitis, aseptic meningitis, encephalitis, and, in postpubertal age groups, oophoritis and orchitis. Mumps is endemic in most of the world, and many countries do not include mumps vaccine in their routine childhood immunization programs. As of December 2005, 110 (57%) of the 193 World Health Organization member states had included mumps vaccine in their national immunization programs, most by including the combined measles-mumps-rubella (MMR) vaccine [1]. These include a majority of industrialized nations and countries undergoing economic transition [1].

In the United States, live mumps vaccine was licensed in 1967 and was recommended for routine use in 1977 [2]. By 2000, the number of reported mumps cases in the United States had declined to 338 [3]. Because this met the Healthy People 2000 reduction goal of <500 cases [4], the United States set a goal of mumps elimination by 2010 [5]. By 2005, only 314 cases of mumps (incidence, 0.1 cases per 100,000 population) were reported in the United States, a decline of 99.7% since 1968 [6]. However, in 2006 the largest mumps outbreak in 20 years occurred, with 6584 cases (incidence, 2.2

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cases per 100,000 population) [7]. The age groups most affected were 10–19, 20–29, and 30–39 years of age, a majority of whom had been inoculated with at least 1 dose of mumps vaccine. The occurrence of this outbreak led some to question the feasibility of mumps elimination and prompted us to evaluate the seroprevalence of antibody to mumps virus in the US population, specifically in those age groups most affected by the 2006 outbreak. Data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative sampling of the US population conducted during 1999–2004, were used to assess mumps seroprevalence.

METHODS

Survey design and participants. NHANES is conducted by the National Center for Health Statistics, Centers for Disease Control and Prevention, to provide national statistics on the health and nutritional status of the noninstitutionalized US civilian population. Since 1999, NHANES has been a continuous survey, with data released every 2 years. The present analysis makes use of data collected from 1999 through 2004. The sampling plan for the survey is a stratified, multistage, probability-cluster design, to provide a sample that is representative of the US population [8]. Black Americans, Mexican Americans, adolescents, and low-income persons were sampled at higher frequencies than were other participants, to provide stable estimates for these groups. Participants in the survey undergo household interviews and then standardized physical examinations and the collection of biological samples at special mobile examination centers [8].

Serum samples from participants 6–49 years of age were available for testing for the presence of immunoglobulin G (IgG) antibody to mumps virus. Race/ethnicity was categorized on the basis of a participant's self-identification as non-Hispanic white, non-Hispanic black, or Mexican American. Participants who did not fit into one of these categories were classified as other and were analyzed with the combined population but were not analyzed separately. Other variables analyzed included the following: (1) family income, based on a poverty-index ratio calculated by dividing total family income by the poverty-threshold index adjusted for family size at the year of the interview and categorized as either below the poverty level or at or above the poverty level [9]; (2) birthplace, categorized as within or outside the United States; (3) health insurance, categorized as any or none; (4) regular source of health care, defined as having 1 or more sources of health care; (5) education, based on individual education for those aged 20–49 years and education of head of household for those aged 6–19 years, measured as last year of school completed and categorized into 2 levels (less than or equal to high school graduate or more than a high school education); and (6) crowding index, derived from household size and number of rooms in the household (not including bathrooms), calculated as the number of persons per room (PPR), and categorized as <0.5, 0.5–0.99, and $\geqslant 1$ PPR. Informed consent was obtained from all participants, and the Ethical Review Board of the National Center for Health Statistics, Centers for Disease Control and Prevention, approved the protocol.

Laboratory testing. A commercially available indirect enzyme-linked immunosorbant IgG assay (Mumps IgG ELISA II; Wampole Laboratories) was used for the detection and qualitative determination of IgG antibody to mumps virus in serum specimens. As reported by the manufacturer, the relative sensitivity of this test is 96.6% (95% confidence interval [CI], 94.0%–99.3%), and the relative specificity is 90.4% (95% CI, 82.4%–98.4%). The cutoff points for IgG antibodies to mumps virus, based on index standard ratio (ISR) values, were as follows: seronegative, ISR of $\leqslant 0.90$; indeterminate, ISR of 0.91–1.09; and seropositive, ISR of $\geqslant 1.10$. All samples with seronegative or indeterminate results for mumps virus IgG were retested with an equal number of randomly selected positive serum samples. If retested samples had positive results, they were reported as IgG seropositive. Serum samples testing either negative or indeterminate were considered negative for purposes of this study. For quality assurance purposes, a 10% random-sample repeat of the entire specimen collection set was performed.

Statistical analysis. Participants were grouped into 10-year birth cohorts based on the age groups that were affected during the 2006 mumps outbreak, to assess the seroprevalence of antibody to mumps virus, to identify differences in mumps antibody seroprevalence that might have occurred in correlation to changes in vaccination policies, and to ensure that there was a sufficient sample size for each group. The birth cohorts were 1949–1956, 1957–1966, 1967–1976, 1977–1986, and 1987–1998. Estimates of seroprevalence were weighted to represent the total civilian noninstitutionalized US household population and to account for oversampling and nonresponse to the household interview and physical examination [10]. Standard errors were calculated using SUDAAN software [11]. Estimates were considered to be unstable if the relative standard error around the proportion of participants who were not seropositive for IgG antibody to mumps virus was >30% or if the estimate was based on <10 persons negative for mumps IgG antibody. The exact binomial method was used to calculate 95% CIs [12]. Differences between seroprevalence estimates were evaluated by examination of P values calculated by a univariate t statistic obtained from a general linear contrast procedure in SUDAAN; differences with $P < .05$ were considered significant. No adjustments for multiple comparisons were made.

To identify independent predictors of mumps seropositivity in the birth cohorts that had the lowest seroprevalence of antibody to mumps virus (ie, 1967–1976, 1977–1986, and 1987–

1996 birth cohorts), a logistic modeling procedure in SUDAAN was used, with $P < .05$ from the Satterthwaite-adjusted F statistic considered to indicate significance. Because of the strong association between place of birth and mumps seroprevalence, the variables race/ethnicity and birthplace were combined (race/ethnicity/birthplace) in the modeling procedures and grouped as follows: US-born non-Hispanic whites, US-born non-Hispanic blacks, US-born Mexican Americans, and non–US-born Mexican Americans. In addition, because of the small numbers of foreign-born non-Hispanic whites and non-Hispanic blacks in the sample, these subgroups were not included in the modeling procedure. Interactions with the combined race/ethnicity/birthplace variable and each cofactor were evaluated. Odds ratios (ORs) and their 95% CIs are reported for all cofactors.

RESULTS

Response rates. Of the 22,036 participants aged 6–49 years sampled for NHANES from 1999 through 2004, 18,433 (84%) were interviewed and 17,672 (96% of those interviewed) were examined. Of those examined, 15,383 (87%) had serum samples available to test for the presence of IgG antibody to mumps virus. The percentage of participants whose serum samples were tested varied with age and was higher among those aged 12–19 years (91%) and was lower for those aged 6–11 years (83%), compared with other age groups (range, 84%-86%) ($P < .001$). In addition, the percentage tested varied by race/ethnicity (Mexican American, 88%; non-Hispanic white, 87%; non-Hispanic black, 86%), sex (male, 88%; female, 86.4%), and household crowding (≥1 PPR, 88%; 0.5–0.99 PPR, 87%; <0.5 PPR, 86%) but did not vary by place of birth, poverty index, health insurance, education, or regular source of health care.

Seroprevalence of IgG antibody to mumps virus. The age-adjusted seroprevalence of IgG antibody to mumps virus in the US population aged 6–49 years during 1999–2004 was 90.0% (95% CI, 88.8%–91.1%) (Table 1). Seropositivity was significantly higher among those in the earliest birth cohort, 1949–1956 (93.4% [95% CI, 90.7%–95.6%]), than among those born from 1967 through 1976 (85.7% [95% CI, 83.5%–87.8%]; $P < .001$) or among those in later birth cohorts (1977–1986, 90.1% [95% CI, 88.5%–91.6%]; $P < .01$) (1987–1998, 90.3% [95% CI, 88.8%–91.7%]; $P < .05$). The seroprevalence of IgG antibody to mumps virus was significantly lower among those born during 1967–1976, compared with all other birth cohorts (1949–1956, 1957–1966, 1977–1986, and 1987–1998; $P < .001$).

The pattern in mumps seropositivity by birth cohort differed for each of the combined race/ethnicity/birthplace subgroups (Figure 1). Among US-born non-Hispanic whites, the pattern over time was similar to that of the combined population: a statistically significant decline in mumps seroprevalence from the 1949–1956 cohort to the 1967–1976 cohort and a subsequent significant increase in mumps seroprevalence for the 1977–1986 and 1987–1998 cohorts. Among US-born Mexican Americans, the pattern was similar to that among non-Hispanic whites, except that there was only a statistically significant increase in mumps seroprevalence between the 1967–1976 cohort and the 1977–1986 and 1987–1998 birth cohorts ($P < .01$). Among US-born non-Hispanic blacks, seroprevalence decreased over birth cohorts and was significantly higher among those born from 1949 through 1956 than among those in the 1977–1986 and 1987–1998 birth cohorts ($P < .05$ and $P < .001$, respectively). Mexican Americans not born in the United States had a very different pattern of mumps seroprevalence across birth cohorts than did the other 3 groups. Although not statistically significant, there was an increase in seroprevalence among those born during 1949–1956 until 1967–1976 ($P > .05$) and a statistically significant decline between 1967–1976 and 1987–1998 ($P < .05$).

Mumps seroprevalence varied among the race/ethnicity/birthplace subgroups overall and by birth cohort (Table 1). US-born non-Hispanic blacks had consistently higher mumps seroprevalence than did US-born non-Hispanic whites and US-born Mexican Americans in the combined population ($P < .001$) and across all birth cohorts ($P < .05$ to $P < .001$). In addition, US-born non-Hispanic blacks had higher mumps seroprevalence than did Mexican Americans not born in the United States for both the 1949–1956 and 1957–1966 birth cohorts ($P < .05$ for both comparisons). Among Mexican Americans, those not born in the United States had higher mumps seroprevalence than did those born in the United States in the combined population ($P < .001$) as well as in the 1957–1966 ($P < .05$) and 1967–1976 ($P < .001$) cohorts. Similarly, Mexican Americans not born in the United States had consistently higher mumps seropositivity than did US-born non-Hispanic whites in the combined population ($P < .001$) as well as in the 1957–1966 ($P < .05$), 1967–1976 ($P < .001$), and 1977–1986 ($P < .001$) cohorts.

Predictors of presence of IgG antibody to mumps virus. In all birth cohorts combined, those born in the United States had lower seroprevalence than did those not born in the United States (89.0% [95% CI, 87.7%–90.3%] vs 94.7% [95% CI, 93.6%–95.7%]; $P < .001$) (Table 1). This association was consistent across birth cohorts but was statistically significant only for those born during 1967–1976 and 1977–1986 ($P < .001$). For all birth cohorts combined, mumps seropositivity was lower among males than among females (89.0% [95% CI, 87.5%–90.4%] vs 90.9% [95% CI, 89.6%–92.1%]; $P < .05$). This association was consistent across birth cohorts from 1957 on but was statistically significant only among those born during 1977–1986 and 1987–1998 ($P < .05$). Among the combined population and across the birth cohorts, no significant association between mumps seropositivity and family income, education, ability to identify a health care provider, or health insurance was found; findings for household crowding were inconsistent.

Table 1. Seroprevalence of Immunoglobulin G (IgG) Antibody to Mumps Virus in 5 Birth Cohorts, by Sociodemographic Subgroups—National Health and Nutrition Examination Survey, 1999–2004

	Combined population[a]		1949–1956		1957–1966		1967–1976		1977–1986		1987–1998	
Sociodemographic characteristic	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)	No.	% (95% CI)
Combined population[b]	15,383	90.0 (88.8–91.1)	956	93.4 (90.7–95.6)	2044	91.7 (89.7–93.3)	2107	85.7 (83.5–87.8)	5207	90.1 (88.5–91.6)	5069	90.3 (88.8–91.7)
Sex												
Male	7479	**89.0 (87.5–90.4)***	473	93.5 (89.9–96.2)	1003	90.8 (88.2–92.9)	897	85.6 (82.4–88.5)	2570	**88.1 (85.2–90.6)***	2536	**89.0 (86.9–90.8)***
Female	7904	90.9 (89.6–92.1)	483	93.3 (90.3–95.7)	1041	92.6 (89.9–94.7)	1210	85.8 (82.7–88.5)	2637	92.1 (90.4–93.7**)**	2533	91.8 (89.9–93.5)
Race/ethnicity												
Mexican American	4756	**92.1 (90.9–93.2)*****	244	91.0 (85.9–94.8)	481	92.0 (89.6–93.9)	559	**92.3 (89.8–94.3)*****	1808	**93.1 (91.1–94.7)*****	1664	**91.7 (90.4–93.0)****
Non-Hispanic black	4290	**96.4 (95.5–97.1)*****	232	**98.2 (95.5–99.5)**[c,d]**	447	**97.2 (95.1–98.5)*****	379	**96.3 (93.0–98.3)**[c]*****	1463	**95.9 (94.5–97.0)*****	1768	**95.2 (93.9–96.2)*****
Non-Hispanic white (reference)	5224	87.8 (86.2–89.3)	417	92.6 (88.8–95.5)	955	90.6 (87.9–92.9)	981	82.2 (79.1–85.1)	1551	87.5 (85.3–89.5)	1320	88.2 (85.9–90.3)
Birthplace												
In United States	12,538	89.0 (87.7–90.3)	722	93.1 (89.9–95.5)	1490	91.0 (88.7–93.0)	1513	83.4 (80.7–85.8)	4205	89.3 (87.5–90.9)	4608	90.2 (88.5–91.7)
Not in United States	2844	**94.7 (93.6–95.7)*****	234	95.6 (91.3–98.2)[c]	554	94.4 (91.4–96.6)	594	**95.5 (93.0–97.3)*****	1001	**95.0 (91.6–97.3)*****	461	92.1 (88.6–94.8)
Race/ethnicity and birthplace												
Mexican American not born in United States	1843	**93.7 (92.0–95.2)*****	146	91.0 (81.2–96.8)[c,d]	319	**94.0 (91.5–95.9)***	378	**96.4 (94.0–98.1)*****	697	94.7 **(91.7–96.8)*****	303	91.1 (85.8–94.9)
Non-Hispanic black born in United States	3999	**96.4 (95.5–97.2)*****	202	**98.6 (95.8–99.7)**[c,d]**	397	**97.3 (95.1–98.6)**[c]*****	331	**96.4 (92.7–98.5)**[c]*****	1366	**96.0 (94.7–97.1)*****	1703	**95.1 (93.9–96.2)*****
Mexican American born in United States	2913	89.4 (87.7–90.9)	98	91.0 (83.7–95.8)[c,d]	162	88.6 (83.5–92.5)	181	84.1 (79.0–88.4)	1111	**91.7 (89.0–93.9)****	1361	**91.9 (89.9–93.6)***
Non-Hispanic white born in United States (reference)	4977	87.3 (85.7–88.9)	398	92.3 (88.2–95.2)	890	90.2 (87.3–92.7)	922	81.3 (77.9–84.4)	1487	87.1 (84.9–89.2)	1280	88.1 (85.8–90.2)
Family income												
Below poverty level	4069	90.4 (88.5–92.0)	153	95.3 (89.3–98.5)[c,d]	340	92.3 (87.7–95.6)	391	86.6 (79.5–92.0)	1587	89.3 (85.6–92.3)	1598	90.6 (87.8–92.9)
At or above poverty level	10,204	89.7 (88.4–90.9)	731	93.2 (89.6–95.8)	1576	91.4 (89.3–93.2)	1588	85.6 (83.5–87.6)	3142	90.0 (88.5–91.4)	3167	90.0 (88.1–91.8)
Household crowding												
⩾1 PPR	4879	91.4 (89.6–93.0)	158	**97.2 (93.2–99.2)**[c,d]*	441	90.1 (84.9–94.0)	572	88.8 (83.7–92.7)	1805	92.6 (89.5–95.0)	1903	90.5 (87.9–92.7)
0.5–0.99 PPR	7557	89.3 (87.7–90.7)	414	93.8 (89.0–96.9)	1001	91.3 (88.7–93.4)	966	85.1 (81.3–88.4)	2585	88.4 (86.3–90.3)	2591	**89.6 (87.4–91.6)***
<0.5 PPR (reference)	2751	90.5 (89.0–91.8)	374	92.4 (88.8–95.2)	582	92.8 (87.9–96.1)	541	84.9 (81.1–88.3)	734	91.5 (88.2–94.1)	520	92.6 (90.0–94.7)
Education[e]												
Less than or equal to high school	8732	90.2 (88.7–91.5)	491	94.7 (90.6–97.3)	1024	91.9 (89.2–94.1)	1033	84.7 (81.1–87.9)	3141	90.7 (88.6–92.6)	3043	90.3 (88.5–91.9)
Above high school	6260	89.8 (88.2–91.2)	464	92.5 (88.3–95.6)	1018	91.5 (89.0–93.5)	1072	86.5 (83.7–89.0)	1833	89.4 (87.0–91.6)	1873	90.1 (87.2–92.6)
Health insurance												
Any	11,510	90.1 (88.7–91.3)	734	93.5 (90.5–95.7)	1508	92.4 (90.4–94.1)	1461	85.3 (82.7–87.7)	3615	90.3 (88.3–92.0)	4192	90.3 (88.7–91.7)
None	3670	89.3 (87.2–91.3)	212	92.9 (85.8–97.2)[c]	515	88.4 (84.0–92.0)	615	87.0 (82.6–90.7)	1509	89.2 (86.4–91.6)	819	90.5 (85.5–94.2)
Health utilization												
Able to identify health care provider	12,702	90.2 (89.0–91.3)	793	93.5 (90.7–95.6)	1669	91.9 (89.8–93.7)	1611	86.0 (83.6–88.2)	3941	90.8 (88.9–92.5)	4688	90.4 (88.9–91.7)
Not able to identify health care provider	2676	88.8 (86.2–91.0)	163	93.2 (85.3–97.7)[c]	374	90.1 (86.1–93.3)	496	84.8 (80.1–88.7)	1264	87.9 (84.5–90.8)	379	88.7 (79.5–94.7)[c]

NOTE. Data are the no. of participants analyzed and the percentage seropositive for IgG antibody to mumps virus. Statistical significance is indicated by boldface type (*$P<.05$, **$P<.01$, and ***$P<.001$ for the comparison between the indicated group and the reference group within the cohort). CI, confidence interval; PPR, persons per room.

[a] Adjusted for age.

[b] Combined population includes members of the other race/ethnic group.

[c] Estimates may be unstable because the relative standard error for the proportion of participants who were not seropositive for IgG antibody to mumps virus was >30%.

[d] Estimates may be unstable because they were based on <10 persons negative for mumps IgG antibody.

[e] Estimates by education level were based on individual education for those aged 20–49 years and head-of-household education for those aged 6–19 years (cohorts 1977–1986 and 1987–1998, respectively).

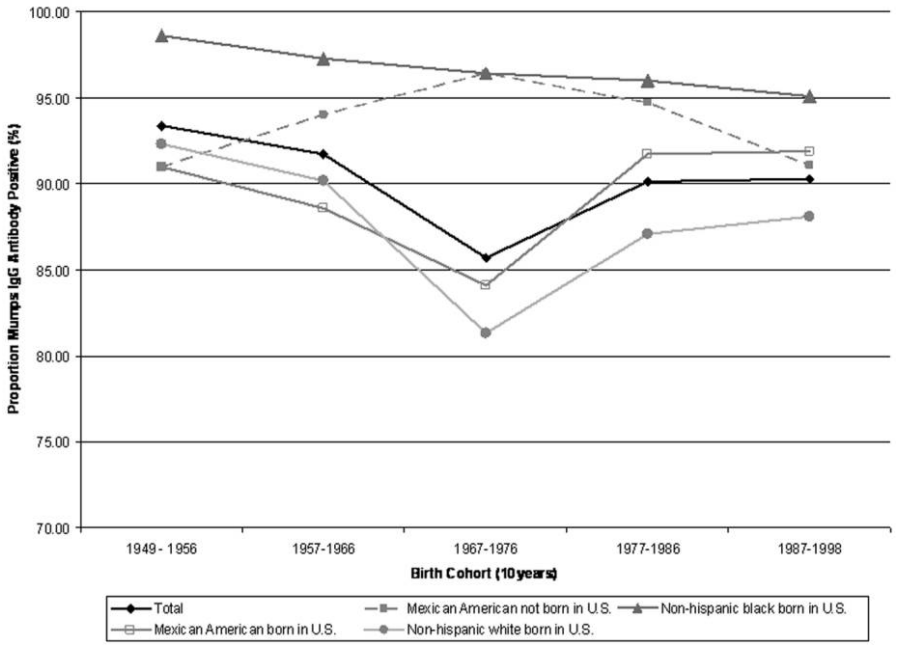

Figure 1. Seropositivity for immunoglobulin G (IgG) antibody to mumps virus, by birth cohort and the race/ethnicity/birthplace variable—National Health and Nutrition Examination Survey, 1999–2004.

In the logistic regression model for the 1967–1976 birth cohort, race/ethnicity/birthplace was the strongest predictor of the presence of antibody to mumps virus (Table 2). Mexican Americans not born in the United States (adjusted OR [aOR], 10.0 [95% CI, 4.2–23.5]; $P < .001$) and non-Hispanic blacks born in the United States (aOR, 6.8 [95% CI, 3.0–15.3]; $P < .001$) were more likely to be seropositive for IgG antibody to mumps virus than US-born non-Hispanic whites, after adjustment for all other cofactors. The estimate of the ORs for Mexican Americans not born in the United States and non-Hispanic blacks born in the United States may be unstable because they are based on 15 or fewer persons seronegative for mumps virus. In the model for this birth cohort, lower educational status was predictive of lower mumps seroprevalence (aOR, 0.7 [95% CI, 0.4–0.98]; $P = .04$).

Among those in the 1977–1986 birth cohort, the strongest predictor of mumps antibody was again race/ethnicity/birthplace (Table 2). Mexican Americans not born in the United States (aOR, 3.7 [95% CI, 2.0–6.9)]; $P < .001$), US-born Mexican Americans (aOR, 2.1 [95% CI, 1.5–2.9]; $P < .001$), and US-born non-Hispanic blacks (aOR, 4.0 [95% CI, 2.6–6.3]; $P < .001$) were more likely to be seropositive than US-born non-Hispanic whites. Male sex (aOR, 0.6 [95% CI, 0.4–0.97]; $P = .04$) was associated with lower odds of having antibody to mumps virus.

Among those in the 1987–1998 birth cohort, race/ethnicity/birthplace was again most strongly associated with mumps seropositivity (Table 2). US-born Mexican Americans (aOR, 1.7 [95% CI, 1.2–2.3]; $P = .002$) and US-born non-Hispanic blacks (aOR, 2.9 [95% CI, 2.0–4.2]; $P < .001$) both had a greater odds of being mumps seropositive than US-born non-Hispanic whites. Similar to the 1977–1986 birth cohort, male sex was associated with a lower odds of being seropositive (aOR, 0.7 [95% CI, 0.5–0.9]; $P = .02$).

DISCUSSION

As mumps continues to be endemic in most parts of the world, with the annual incidence of mumps in the absence of immunization being in the range of 100–1000 cases per 100,000 population [1], importation of mumps will continue to occur in the United States [13]. To maintain mumps control in the United States, it will be critically important to achieve and maintain high population immunity to mumps. Several studies in the United Kingdom have estimated the population immunity for mumps to range from 75% to 92% [14–16].

In the present study, the seroprevalence of IgG antibody to mumps virus was used as a measure of population immunity against mumps. The calculated seroprevalence of antibody to mumps virus in the noninstitutionalized US population aged 6–49 years during 1999–2004 was 90.0%, with a lower confidence limit of 88.8%. This value is below the estimated level of immunity (92%) [16] needed to achieve and maintain elimination. It is likely too that this value is an overestimate of the population immunity for several reasons. Individuals who have had documented positive IgG to mumps by enzyme immu-

Table 2. Independent Predictors for Seropositivity of Immuoglobulin G (IgG) Antibody to Mumps Virus for 3 Birth Cohorts Affected during the 2006 Outbreak—National Health and Nutrition Examination Survey, 1999–2004

	1967–1976		1977–1986		1987–1998	
Sociodemographic characteristic	aOR (95% CI)	*P*	aOR (95% CI)	*P*	aOR (95% CI)	*P*
Sex						
Male	1.1 (0.7–1.6)	.78	0.6 (0.4–0.97)	.04	0.7 (0.5–0.9)	.02
Female	Reference		Reference		Reference	
Race/ethnicity and birthplace						
Mexican American not born in United States	10.0 (4.2–23.5)[a]	<.001	3.7 (2.0–6.9)	<.001	1.7 (0.8–3.6)	.20
Mexican American born in United States	1.4 (0.9–2.4)	.18	2.1 (1.5–2.9)	<.001	1.7 (1.2–2.3)	.002
Non-Hispanic black born in United States	6.8 (3.0–15.3)[a]	<.001	4.0 (2.6–6.3)	<.001	2.9 (2.0–4.2)	<.001
Non-Hispanic white born in United States	Reference		Reference		Reference	
Education						
Less than or equal to high school	0.7 (0.4–0.98)	.04	1.1 (0.8–1.6)	.58	1.1 (0.7–1.5)	.81
Above high school	Reference		Reference		Reference	
Family income						
Below poverty level	0.8 (0.5–1.3)	.42	0.8 (0.5–1.1)	.17	0.8 (0.5–1.2)	.28
At or above poverty level	Reference		Reference		Reference	
Household crowding						
⩾1 PPR	0.9 (0.5–1.6)	.67	0.8 (0.5–1.3)	.38	0.6 (0.3–1.1)	.09
0.5–0.99 PPR	0.98 (0.6–1.5)	.94	0.7 (0.4–1.1)	.11	0.6 (0.4–0.8)	.005
<0.5 PPR	Reference		Reference		Reference	
Health insurance						
None	1.0 (0.6–1.6)	.96	0.8 (0.5–1.1)	.14	1.3 (0.7–2.5)	.41
Any	Reference		Reference		Reference	
Regular source of health care						
Not having at least 1 source of health care	0.7 (0.5–1.1)	.17	0.7 (0.5–1.1)	.14	0.6 (0.3–1.3)	.19
Having at least 1 source of health care	Reference		Reference		Reference	

NOTE. aOR, adjusted odds ratio; CI, confidence interval; PPR, persons per room.

[a] Estimates of aORs may be unstable because they are based on 15 or fewer persons seronegative for mumps virus in the race/ethnicity and birthplace subgroup.

noassay have developed mumps within months to years, suggesting that positive enzyme immunoassay values may not reflect immunity [17, 18]. In addition, unlike measles and rubella, no antibody level has been defined as a surrogate measure for individual immune protection from mumps disease [19].

The prevalence of antibody to mumps virus among those born during 1967–1976 (85.7%, with an upper confidence limit of 87.8%) was significantly lower than that for all other birth cohorts and was well below the estimated threshold needed to maintain herd immunity in the population. This finding is similar to findings for measles and rubella seroprevalence for this birth cohort from other NHANES 1999–2004 studies [20, 21]. The lower seroprevalence for this birth cohort might reflect changes in the epidemiology of mumps in the United States and changes in US mumps vaccination policy and practice. In 1967, when live mumps vaccine was first licensed, the Advisory Committee for Immunization Practices (ACIP) recommended that the vaccine be considered for use in children approaching puberty, in adolescents, and in adults, especially men [22]. In 1968, the recommendations were expanded to consider immunizing all susceptible children >1 year of age, but mumps vaccine was not introduced into the routine immunization schedule [23]. In 1971, the US Food and Drug Administration licensed MMR vaccine; 6 years later, in 1977, the ACIP recommended routine immunization with MMR vaccine [2] at age 15 months. During a resurgence of mumps in 1986–1987, older schoolchildren, students on college campuses, and young adults were most affected [24]. However, it was during a resurgence of measles in 1989 [25] that the ACIP recommended, starting in 1989, a second dose of MMR vaccine for children entering kindergarten or first grade (ie, 4–6 years of age) [26], thereby improving protection against both measles and mumps.

The introduction of mumps vaccine and recommendations for its routine use led to decreasing exposure to circulating mumps virus, which might explain the lower seroprevalence of IgG antibody to mumps virus in the 1967–1976 birth cohort [24]. In addition, this cohort was born too early to receive the second dose of vaccine at school entry (as recommended in 1989) and less likely to have been affected by the school immunization laws [22, 27]. These 2 factors might have contrib-

uted to the low overall seroprevalence rate among those born from 1967 through 1976.

In the present study, non-Hispanic blacks had consistently higher seroprevalence than did other race/ethnicity groups, regardless of the vaccination era. Studies examining racial disparities in vaccination coverage have found that non-Hispanic black children have significantly lower rates when compared to non-Hispanic white children [28–30]. Thus, higher seroprevalence among non-Hispanic blacks might reflect greater exposure to natural infection.

Mexican Americans not born in the United States had a higher mumps seroprevalence than did those born in the United States. This may be a reflection of greater circulation of mumps virus in Mexico, where MMR vaccine was not routinely used before 1998. Thus, the pattern of seroprevalence to mumps among non–US-born Mexican Americans might reflect virus exposure and natural infection during their early life in Mexico.

During the 2006 mumps outbreak [7], the highest incidence of mumps was seen in the age groups 14–17 and 18–24 years, corresponding to the 1987–1998 and 1977–1986 birth cohorts, respectively. The seroprevalence among persons in these birth cohorts was ~90%, the lower limit of the estimated seroprevalence needed for herd immunity. In addition, non-Hispanic whites (incidence, 9.95 cases per 100,000 population) were found to be most affected during the 2006 outbreak. One possible explanation for this finding is the lower seroprevalence found among non-Hispanic whites than among the other race/ethnicity groups. Another explanation may be that transmission of mumps occurs rapidly in close quarters, as demonstrated by the outbreaks in schools, on college campuses, and in the military [7, 31–35]. This may explain why persons in the 1967–1976 birth cohort with the lowest seroprevalence were less affected, given that they were most likely no longer in school or college.

Females had higher seropositivity of IgG antibody to mumps virus than males in NHANES 1999–2004. This may be due to targeted vaccination of women of childbearing age for the rubella component of the MMR vaccine [36]. Although males had lower seropositivity than females, they were less affected during the 2006 mumps outbreak. The incidence of mumps among male patients was 7.7 cases per 100,000 population, compared with 13.5 cases per 100,000 population among female patients. This could be partly explained by differences in social behavior, with closer interpersonal contact among females than among males [37].

There are limitations to this study. Mumps vaccination and history of mumps disease are not recorded in NHANES; hence, we do not know the effect of vaccination on mumps seropositivity. Specific data on access to immunization services was not collected; having a regular source of health care was used as a surrogate for access to immunization. Self-reported socioeconomic status and measures of health care access (such as having a regular source of health care or having insurance) at the time of the survey might not reflect the status of these factors at the time of vaccination or exposure to disease. Finally, small sample sizes in certain sociodemographic subgroups may have limited our ability to detect statistically significant associations.

Data from NHANES 1999–2004 demonstrate that the seroprevalence of antibody to mumps virus in the US population was at the low end of the estimate needed for herd immunity. Lower seroprevalence among some groups suggest that they represent populations at increased risk for mumps. To achieve mumps control in the United States, it is imperative to ensure that children and adults who are at high risk receive age-appropriate 2 doses of MMR vaccine [38, 39], to maintain the high levels of mumps immunity as well as the high seroprevalence of antibody to mumps virus in the population.

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