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Children Who Have Received No Vaccines: Who Are They and Where Do They Live?

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ABSTRACT. *Context.* **Each year 2.1 million children 19 to 35 months of age are undervaccinated. Among these are children who have received no vaccinations. Unvaccinated children are at increased risk of acquiring and transmitting vaccine-preventable diseases.**

Objectives. **To assess whether the characteristics of children with no vaccinations differ from those of undervaccinated children, to monitor trends in the numbers of unvaccinated children, and to identify states with high rates and counties with large numbers of unvaccinated children.**

Design. **A nationally representative probability sample of children 19 to 35 months of age was collected annually between 1995 and 2001. Vaccination histories were ascertained from children's medical providers. Undervaccinated children had received ≥1 dose of diphtheria-tetanus-pertussis, polio, measles, *Haemophilus influenzae* type b, hepatitis B, or varicella vaccine but were not fully vaccinated. Unvaccinated children were children who were reported as having no medical providers and having received no vaccinations or children whose medical providers reported administering no vaccinations.**

Participants. **A total of 151 720 children sampled between 1995 and 2001, 795 of whom were unvaccinated.**

Results. **Undervaccinated children tended to be black, to have a younger mother who was not married and did not have a college degree, to live in a household near the poverty level, and to live in a central city. Unvaccinated children tended to be white, to have a mother who was married and had a college degree, to live in a household with an annual income exceeding $75 000, and to have parents who expressed concerns regarding the safety of vaccines and indicated that medical doctors have little influence over vaccination decisions for their children. Unvaccinated children were more likely to be male than female. Annually, ~17 000 children were unvaccinated. The largest numbers of unvaccinated children lived in counties in California, Illinois, New York, Washington, Pennsylvania, Texas, Oklahoma, Colorado, Utah, and Michigan. States that allowed philosophical exemptions to laws mandating vaccinations for children as they entered school had significantly higher estimated rates of unvaccinated children.**

Conclusions. **Unvaccinated children have characteristics that are distinctly different from those of undervaccinated children. Unvaccinated children are clustered geographically, increasing the risk of transmitting vaccine-preventable diseases to both unvaccinated and undervaccinated children.** *Pediatrics* **2004;114:187–195;** ***exemptor, undervaccinated, unvaccinated.***

ABBREVIATIONS. CI, confidence interval; NIS, National Immunization Survey; PKAM, Parental Knowledge and Attitudes topical module; RDD, random-digit dialing; UTD, up-to-date; NUTD, not up-to-date; VPD, vaccine-preventable disease; MSA, metropolitan statistical area.

Children who have received no vaccinations have not been well studied in the United States. Many studies have assumed that children with no vaccinations are similar to undervaccinated children and thus have included children with no vaccinations among the undervaccinated, to investigate factors associated with being undervaccinated. Those studies have shown that being undervaccinated is significantly associated with belonging to a racial/ethnic minority,[1,2] having a mother with low educational status,[3] and belonging to a household that is living in poverty.[4] A few studies[5,6] conducted in inner-city locations have found high rates of unvaccinated children among racial/ethnic minorities living in those neighborhoods, reinforcing the assumption that children with no vaccinations have characteristics that are similar to those of undervaccinated children.

In 2003, reports from state and local health departments again illustrated the role that children with no vaccinations can play in vaccine-preventable disease (VPD) outbreaks. In Westchester County, New York, the county health commissioner said that an outbreak of pertussis started with children who were not vaccinated because their parents had decided against it.[7,8] That outbreak subsequently spread into adjoining Putnam County, where 8 cases were confirmed, 6 involving children who were not vaccinated.[9] By the end of October 2003, 25 cases of pertussis were confirmed in Putnam County.[10]

One purpose of this article is to determine the characteristics that distinguish unvaccinated children from undervaccinated children. This information is important in designing interventions that are tailored for differences between these groups. Specifically, we identify demographic and socioeconomic differences between these groups, as well as differences regarding safety concerns and people who are important in influencing parents' decision on whether to vaccinate their children. Also, we describe trends in the numbers of unvaccinated children between 1995 and 2001 and provide state esti-

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mates of the numbers of unvaccinated children per 100 000 children. Finally, because it is sensible to target interventions in geographic areas where the largest numbers of unvaccinated children live, we present estimates of the numbers of children with no vaccinations in 50 counties in the United States with the largest communities of unvaccinated children.

METHODS

In our analyses, we use data from the National Immunization Survey (NIS), a survey of children 19 to 35 months of age. Each year, the NIS obtains an independent representative sample in 78 Immunization Action Plan areas. These areas include the 50 states, the District of Columbia, and 27 other large metropolitan statistical areas (MSAs).

The NIS includes 2 phases of data collection. In the first phase, households with ≥1 age-eligible children are identified by using list-assisted, random-digit dialing (RDD). Cellular telephone numbers are excluded from the sampling frame. When a household with an age-eligible child is identified, the RDD interview is conducted to collect demographic information about each age-eligible child in the household, demographic and socioeconomic information about the age-eligible child's mother, and sociodemographic information about the household. Also, information is obtained from the RDD respondent regarding the child's vaccination history. At the end of the NIS RDD interview, consent is asked to contact the age-eligible children's medical care providers. If consent is given, then the second data collection phase of the NIS is conducted. In the second phase, all of the providers named by the NIS RDD respondent are contacted by mail, to obtain the household's age-eligible children's provider-reported vaccination histories. Data from the provider-reported vaccination histories are used to evaluate sampled children's vaccination status, ie, whether they had received all doses of recommended vaccines,[11] and to estimate vaccination coverage rates. Zell et al[12] and Smith et al[13,14] provide a more detailed overview of the design and methods used in the NIS, and Frankel et al[15] and Smith et al[16] describe the statistical adjustment to the NIS sampling weights that account for households that do not have telephones.

Table 1 lists the 6 vaccines and the number of doses for each vaccine that were recommended[11] for birth cohorts sampled by the 2001 NIS. For each of these vaccines, children were considered to be up-to-date (UTD) on a vaccine if their vaccination providers reported administering at least the recommended number for the vaccine; they were otherwise considered not up-to-date (NUTD). In our analyses, the vaccination status of a child was designated "fully vaccinated" if the vaccination providers reported administering at least the recommended number for all 6 vaccines, "undervaccinated" if the child was NUTD on ≥1 vaccine but had received ≥1 dose of any of the 6 recommended vaccines, or "unvaccinated" if the NIS RDD respondent reported that the child had received no vaccinations and the child had no vaccination providers or all providers identified by the household reported administering no vaccinations to the child.

To evaluate the associations of vaccination status with child, maternal, and household sociodemographic characteristics, we compared the distribution of each characteristic across vaccination status levels, using data from the 2001 NIS. To evaluate how the distributions of fully vaccinated children differed from those of undervaccinated children, we used logistic regression. To evaluate how the distributions for unvaccinated children differed from those for undervaccinated children, we subdivided undervaccinated children according to their degree of undervaccination, ie, NUTD on 1 vaccine only, NUTD on 2 to 5 vaccines, or NUTD on all 6 vaccines but vaccinated with ≥1 dose of any 1 of the 6 vaccines. This allowed us to account more fully for the heterogeneity of characteristics among undervaccinated children and thus to pinpoint statistically significant differences between unvaccinated and undervaccinated children, which depended on the degree to which the children were undervaccinated. A separate logistic regression was used to compare unvaccinated children with children at each of the 3 different levels of undervaccination. In all analyses, totals, percentages, SEs, and relative risks were estimated, accounting for the survey weights and complex sampling design of the NIS.[17]

To evaluate the relationship between being unvaccinated and parents' concerns about vaccine safety and the people that influence parents' decision to vaccinate their children, we used data from the NIS Parental Knowledge and Attitudes topical module (PKAM). Data from this module were obtained by randomly selecting 21 163 of the 28 250 households that completed the NIS RDD interview between the third quarter of 2001 and the second quarter of 2002. Data collected in the PKAM included information on parents' perceptions of vaccine safety and efficacy, awareness of the recommended vaccination schedule, and perceptions of the need for vaccines. Descriptions of the design and methods of the NIS PKAM have been presented elsewhere.[18]

To identify geographic areas where unvaccinated children were most prevalent, the county in which the child lived was identified for each child sampled between 1995 and 2001. Sampling weights for the pooled 1995-2001 data were obtained by averaging the annual NIS sampling weights, using standard statistical methods.[19] To estimate the numbers of unvaccinated children 19 to 35 months of age for a specific year between 1995 and 2001, the annual NIS sampling weights of all unvaccinated sampled children observed in that year were added.

TABLE 1. Recommended Vaccines for the Birth Cohorts Sampled by the 2001 NIS

Vaccine	No. of Recommended Doses
Diphtheria-tetanus-acellular pertussis	4
Polio	3
Measles-mumps-rubella	1
Haemophilus influenzae type b	3
Hepatitis b	3
Varicella	1

RESULTS

Rates of Vaccination

In 2001, an estimated 62.8% of all children 19 to 35 months of age in the United States were fully vaccinated with ≥4 doses of diphtheria, tetanus, and acellular pertussis vaccine, ≥3 doses of polio vaccine, ≥1 dose of measles, mumps, and rubella vaccine, ≥3 doses of *Haemophilus influenzae* type b vaccine, ≥3 doses of hepatitis B vaccine, and ≥1 dose of varicella vaccine (Table 2). Among all children 19 to 35 months of age, an estimated 36.9% were undervaccinated. In the undervaccinated group, children were most frequently NUTD on varicella vaccine (23.5%), diphtheria, tetanus, and acellular pertussis vaccine (18.2%), hepatitis B vaccine (11.2%), and polio vaccine (11.0%). An estimated 0.3% of all children 19 to 35 months of age were unvaccinated.

Factors That Distinguish Fully Vaccinated Children From Undervaccinated Children (2001 NIS)

Table 3 gives the results of the logistic regression model analysis for evaluating factors associated with being undervaccinated, compared with fully vaccinated. These analyses indicated that, compared with fully vaccinated children, undervaccinated children were significantly more likely to be black than Hispanic or non-Hispanic white; younger; or foreign-born than born in the United States. Undervaccinated children were significantly more likely to have a mother who was young; widowed, divorced, or separated than married; had educational attainment that was high school or less than a college degree; and whose preferred language was English than

TABLE 2. Percentages of Fully Vaccinated, Undervaccinated, and Unvaccinated Children (2001 NIS)

Vaccination Status Level	Unweighted Sample Size*	Weighted Percent (95% CI)†
Fully vaccinated	14 742	62.8 (±1.0)
Undervaccinated	8779	36.9 (±1.0)
NUTD, 1 vaccine only	5142	20.4 (±0.8)
NUTD, 2–5 vaccines	3115	14.0 (±0.8)
NUTD, 6 vaccines	532	2.5 (±0.4)
NUTD, diphtheria-tetanus-acellular pertussis	3947	18.2 (±0.9)
NUTD, polio	2319	11.0 (±0.7)
NUTD, measles-mumps-rubella	1885	8.7 (±0.6)
NUTD, *Haemophilus influenzae* type b	1488	7.3 (±0.6)
NUTD, hepatitis B	2582	11.2 (±0.7)
NUTD, varicella	5612	23.5 (±0.9)
Unvaccinated	111	0.3 (±0.1)

* The unweighted sample sizes are the raw counts observed in the 2001 NIS sample of 23 632 children who were either unvaccinated or had sufficient data reported by their vaccination providers to determine their vaccination status.
† The weighted percent is the percent of children in the 2001 NIS, each weighted by their sampling weight.

Spanish. Finally, undervaccinated children were significantly more likely to live in a household with an annual income below the poverty level than in a household with an annual income greater than $75 000; in a household with ≥4 children than in a household in which he/she was the only child; in a household that had moved across state lines since the child's birth than in a household that did not move across state lines; or to live in a non-MSA (nonurban/nonsuburban) than in the central city of a MSA.

Factors That Distinguish Unvaccinated Children From Undervaccinated Children (2001 NIS)

Table 4 presents the results of the 3 separate logistic regressions used to compare unvaccinated children with children at the 3 different levels of undervaccination. These analyses indicated that, compared with undervaccinated children who were NUTD on ≥2 vaccines, unvaccinated children were significantly more likely to be non-Hispanic white than Hispanic, black, or non-Hispanic Asian. Compared with undervaccinated children who were NUTD on all 6 vaccines but had received ≥1 vaccine dose, unvaccinated children were significantly more likely to have a mother who had a college degree than ≤12 years of education. Compared with all undervaccinated children, unvaccinated children were significantly more likely to have a mother ≥30 years of age than 20 to 29 years of age. Finally, compared with undervaccinated children who were NUTD on all 6 vaccines but had received ≥1 vaccine dose, unvaccinated children were significantly more likely to live in a household with an annual income at or exceeding $75 000 than in a household with a lower annual income, and unvaccinated children were significantly more likely to live in a household with ≥4 children than in a household in which he/she was the only child.

Factors That Distinguish Unvaccinated Children From Fully Vaccinated Children (2001 NIS)

Table 4 presents the results of the logistic regression used to compare unvaccinated children with fully vaccinated children. These analyses indicated that, compared with fully vaccinated children, unvaccinated children were significantly more likely to be non-Hispanic white than Hispanic and more likely to live in a household with ≥4 children than in a household in which he/she was the only child. Unvaccinated children did not differ significantly from children who were fully vaccinated with respect to any other child, maternal, or household characteristics. Among unvaccinated children, the proportion of boys was 57.3% and significantly exceeded that of girls by 14.6% ($P = .05$).

Safety Concerns and Doctors' Influence on Parents' Decisions to Vaccinate Children (2001–2002 NIS PKAM Module)

Among parents of unvaccinated children, 47.5% expressed concerns regarding safety, compared with 5.1% of parents with undervaccinated children (relative risk: 17.0; 95% confidence interval [CI]: 5.2–55.7). Among parents of unvaccinated children, 70.9% said that a doctor was not influential in shaping their vaccination decisions for their children, compared with 22.9% among undervaccinated children (relative risk: 8.2; 95% CI: 2.6–25.8).

Trends in the Numbers of Unvaccinated Children (1995–2001 NIS)

Figure 1 shows trends in the estimated numbers of unvaccinated 19- to 35-month-old children each year between 1995 and 2001. Between 1995 and 2000, the estimated numbers increased significantly, from 14 719 in 1995 to 24 073 in 2000 ($P = .05$).

Rates and Numbers of Unvaccinated Children According to State

Using data collected between 1995 and 2001, Fig 2 presents estimated rates of unvaccinated children per 100 000 children 19 to 35 months of age according to state, as well as the District of Columbia. Estimated rates ranged from a low of 60 per 100 000 (Rhode Island) to 1125 per 100 000 (Utah). Among the 10 states with the highest estimated rates per 100 000 children 19

TABLE 3. Percentages of Children at Levels of Child, Maternal, and Household Characteristics According to UTD Status: Results of the Logistic Regression Analysis (2001 NIS)

	Percent (95% CI)					Odds Ratio, Undervaccinated Versus Fully Vaccinated (95% CI)
	Unvaccinated Children	Undervaccinated Children			Fully Vaccinated Children	
		NUTD on All 6 Vaccines, but 1 Dose	≥NUTD on 2–5 Vaccines	NUTD on 1 Vaccine Only		
Child characteristics						
Race/ethnicity						
Hispanic	6.8 (±5.9)	21.3 (±6.6)	20.9 (±2.5)	21.8 (±2.0)	24.4 (±1.2)	0.9 (0.8–1.0)
White, non-Hispanic*	82.0 (±10.3)	52.0 (±7.5)	54.0 (±3.1)	59.0 (±2.2)	56.8 (±1.3)	1.0 (1.0–1.0)
Black, non-Hispanic	9.3 (±8.8)	23.6 (±6.8)	19.4 (±2.6)	15.0 (±1.8)	13.5 (±1.0)	1.3 (1.2–1.5)
Asian, non-Hispanic	2.0 (±2.3)	2.5 (±1.7)	4.4 (±1.2)	3.1 (±0.6)	4.3 (±0.6)	0.9 (0.7–1.1)
Gender						
Male*	57.3 (±13.1)	47.5 (±7.4)	52.9 (±3.0)	50.4 (±2.2)	51.1 (±1.3)	1.0 (1.0–1.0)
Female	42.7 (±13.1)	52.5 (±7.4)	47.1 (±3.0)	49.6 (±2.2)	48.9 (±1.3)	1.0 (0.9–1.1)
Age of child						
19–24 mo	36.7 (±13.0)	50.7 (±7.5)	45.6 (±3.0)	36.6 (±2.1)	33.6 (±1.3)	1.5 (1.3–1.6)
25–29 mo	28.2 (±12.1)	21.1 (±5.6)	26.4 (±2.5)	28.8 (±2.0)	29.6 (±1.2)	1.1 (1.0–1.2)
30–35 mo*	35.2 (±13.5)	28.1 (±6.5)	28.0 (±2.8)	34.6 (±2.1)	36.7 (±1.3)	1.0 (1.0–1.0)
Foreign born						
Yes	1.7 (±3.0)	0.5 (±0.7)	2.7 (±0.9)	1.1 (±0.4)	1.0 (±0.3)	1.8 (1.3–2.7)
No*	98.3 (±3.0)	99.5 (±0.7)	97.3 (±0.9)	98.9 (±0.4)	99.0 (±0.3)	1.0 (1.0–1.0)
Maternal characteristics						
Marital status						
Widowed/divorced/separated	6.4 (±9.1)	12.8 (±5.4)	10.1 (±1.9)	9.8 (±1.4)	8.0 (±0.8)	1.4 (1.2–1.6)
Never married	16.9 (±10.3)	27.0 (±6.7)	25.1 (±3.0)	20.7 (±2.0)	19.6 (±1.2)	1.3 (1.1–1.5)
Married*	76.8 (±12.6)	60.2 (±7.4)	64.8 (±3.1)	69.5 (±2.2)	72.3 (±1.3)	1.0 (1.0–1.0)
Educational attainment						
<12 y	16.0 (±10.9)	18.8 (±5.2)	20.6 (±2.8)	15.3 (±1.7)	16.2 (±1.1)	1.4 (1.3–1.7)
12 y	32.1 (±12.8)	49.8 (±7.5)	39.6 (±3.1)	38.7 (±2.2)	34.8 (±1.4)	1.5 (1.3–1.6)
>12 y, non-college graduate	15.1 (±12.3)	13.7 (±5.5)	14.9 (±1.9)	15.0 (±1.5)	14.1 (±0.9)	1.3 (1.2–1.5)
College graduate*	36.8 (±12.2)	17.7 (±4.4)	24.8 (±2.3)	31.0 (±1.9)	34.8 (±1.2)	1.0 (1.0–1.0)
Preferred language						
English	92.5 (±6.5)	89.6 (±4.1)	87.4 (±2.2)	88.1 (±1.5)	85.5 (±1.1)	1.2 (1.1–1.4)
Spanish*	5.0 (±5.5)	9.6 (±4.0)	10.1 (±1.9)	10.8 (±1.4)	12.8 (±1.0)	1.0 (1.0–1.0)
Other	2.6 (±3.6)	0.9 (±0.8)	2.5 (±1.2)	1.1 (±0.4)	1.7 (±0.4)	1.3 (0.8–2.0)
Age						
≤19 y	5.7 (±8.6)	4.9 (±3.3)	4.8 (±1.8)	3.1 (±0.8)	4.1 (±0.6)	1.1 (0.8–1.5)
20–29 y	33.1 (±13.1)	59.8 (±7.1)	49.8 (±3.1)	47.4 (±2.2)	43.3 (±1.3)	1.3 (1.2–1.4)
≥30 y*	61.2 (±13.8)	35.3 (±6.8)	45.4 (±3.0)	49.6 (±2.2)	52.6 (±1.3)	1.0 (1.0–1.0)
Household characteristics						
Annual family income						
Above, >$75 000*	21.8 (±12.0)	5.8 (±2.4)	11.4 (±1.6)	14.4 (±1.4)	17.3 (±0.9)	1.0 (1.0–1.0)
Above, <$75 000	39.5 (±12.9)	49.3 (±7.5)	47.9 (±3.0)	50.2 (±2.2)	48.7 (±1.3)	1.4 (1.3–1.6)
Below	19.0 (±11.0)	29.2 (±6.6)	25.8 (±2.9)	21.9 (±2.0)	19.6 (±1.2)	1.7 (1.5–2.0)
Unknown	19.7 (±11.8)	15.7 (±7.0)	14.9 (±2.8)	13.4 (±1.7)	14.4 (±1.1)	1.4 (1.2–1.7)
No. of children ≤18 y in the household						
1 child*	9.5 (±6.3)	22.2 (±6.2)	21.1 (±2.5)	25.4 (±1.9)	29.0 (±1.2)	1.0 (1.0–1.0)
2 or 3 children	43.3 (±13.4)	53.7 (±7.5)	60.8 (±3.0)	62.0 (±2.2)	59.5 (±1.3)	1.3 (1.1–1.4)
≥4 children	47.2 (±13.9)	24.1 (±6.7)	18.1 (±2.6)	12.6 (±1.5)	11.5 (±1.0)	1.8 (1.5–2.1)
Moved from different state since child's birth						
Moved from different state	15.4 (±10.0)	12.4 (±4.8)	12.8 (±1.9)	8.3 (±1.2)	8.8 (±0.9)	1.3 (1.1–1.5)
Did not move from different state*	84.6 (±10.0)	87.6 (±4.8)	87.2 (±1.9)	91.7 (±1.2)	91.2 (±0.9)	1.0 (1.0–1.0)
Living in a MSA						
MSA, central city	32.4 (±12.9)	44.5 (±7.2)	36.6 (±2.8)	34.8 (±2.1)	36.4 (±1.3)	1.1 (1.0–1.2)
MSA, non-central city*	41.2 (±13.3)	35.3 (±7.7)	45.4 (±3.1)	42.8 (±2.2)	46.5 (±1.3)	1.0 (1.0–1.0)
Non-MSA	26.4 (±12.6)	20.2 (±5.8)	18.0 (±2.1)	22.5 (±1.7)	17.1 (±0.9)	1.2 (1.1–1.4)

* Reference level for the logistic regression analysis.

to 35 months of age, 7 were western states (Utah, Montana, Oregon, Colorado, Washington, Alaska, and Idaho). Figure 3 shows that states that allowed philosophical exemptions to laws mandating vaccinations for children as they entered school had significantly higher estimated rates of unvaccinated children 19 to 35 months of age ($P < .05$).

Using data collected between 1995 and 2001, Fig 4 presents the estimated numbers of unvaccinated children 19 to 35 months of age according to county for the 50 counties in the United States with the greatest estimated numbers of unvaccinated children. Figure 4 shows that, among the 20 counties with the greatest estimated numbers of unvaccinated children, 7 counties were in California and 5 were in other western states. The counties with the largest numbers of un-

TABLE 4. Results from the Logistic Regression Analysis: Estimated OR of Being Unvaccinated, Compared with Specified Vaccination Status Levels (2001 NIS)

Characteristic	Odds Ratio (95% CI)*			
	Unvaccinated Versus NUTD on All 6 Vaccines	Unvaccinated Versus NUTD on 2–5 Vaccines	Unvaccinated Versus NUTD on 1 Vaccine Only	Unvaccinated Versus Fully Vaccinated Children
Child characteristics				
Race/ethnicity				
Hispanic	5.0 (1.8–13.7)	4.7 (1.8–12.1)	4.5 (1.7–11.5)	5.2 (2.0–13.3)
White, non-Hispanic†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Black, non-Hispanic	4.0 (1.3–12.3)	3.2 (1.1–9.2)	2.2 (0.8–6.5)	2.1 (0.7–6.1)
Asian, non-Hispanic	2.0 (0.5–8.2)	3.4 (1.0–11.9)	2.2 (0.6–7.5)	3.1 (0.9–10.7)
Gender				
Male†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Female	1.5 (0.8–2.7)	1.2 (0.7–2.1)	1.3 (0.8–2.3)	1.3 (0.7–2.2)
Age of child				
19–24 mo	1.7 (0.8–3.6)	1.6 (0.8–3.1)	1.0 (0.5–2.0)	0.9 (0.5–1.7)
25–29 mo	0.9 (0.4–2.1)	1.2 (0.6–2.4)	1.0 (0.5–2.1)	1.0 (0.5–2.0)
30–35 mo†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Foreign born				
Yes†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
No	3.1 (0.3–29.4)	0.6 (0.1–4.0)	1.5 (0.2–9.4)	1.7 (0.3–10.8)
Maternal characteristics				
Marital status				
Widowed/divorced/separated	2.6 (0.5–12.8)	1.9 (0.4–8.8)	1.7 (0.4–7.9)	1.3 (0.3–6.2)
Never married	2.0 (0.9–4.6)	1.8 (0.8–3.8)	1.4 (0.6–2.9)	1.2 (0.6–2.6)
Married†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Educational attainment				
<12 y	2.4 (1.0–6.1)	1.9 (0.8–4.5)	1.1 (0.5–2.7)	1.1 (0.5–2.5)
12 y	3.2 (1.6–6.5)	1.8 (1.0–3.4)	1.4 (0.8–2.6)	1.1 (0.6–2.1)
>12 y, non-college graduate	1.9 (0.6–5.7)	1.5 (0.5–4.0)	1.2 (0.4–3.2)	1.0 (0.4–2.7)
College graduate†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Preferred language				
English†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Spanish	2.0 (0.6–7.0)	2.2 (0.7–7.1)	2.3 (0.7–7.4)	2.8 (0.9–9.0)
Other	0.3 (0.1–1.9)	1.0 (0.2–4.7)	0.5 (0.1–2.0)	0.7 (0.2–3.1)
Age				
≤19 y	1.5 (0.2–8.8)	1.1 (0.2–6.0)	0.7 (0.1–3.4)	0.8 (0.2–4.2)
20–29 y	3.1 (1.6–6.1)	2.0 (1.1–3.7)	1.8 (1.0–3.2)	1.5 (0.8–2.8)
≥30 y†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Household characteristics				
Annual family income				
Above, >$75 000†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Above, <$75 000	4.7 (2.0–11.3)	2.3 (1.1–5.0)	1.9 (0.9–4.1)	1.6 (0.7–3.3)
Below	5.8 (2.1–16.3)	2.6 (1.0–6.6)	1.7 (0.7–4.4)	1.3 (0.5–3.2)
Unknown	3.0 (1.0–9.4)	1.4 (0.5–3.8)	1.0 (0.4–2.7)	0.9 (0.4–2.4)
No. of children ≤18 y in the household				
1 child	4.6 (1.8–11.4)	5.8 (2.5–13.2)	9.9 (4.4–22.4)	12.5 (5.6–28.0)
2 or 3 children	2.4 (1.2–4.9)	3.7 (2.0–6.8)	5.4 (2.9–9.8)	5.7 (3.1–10.3)
≥4 children†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Moved from different state since child's birth				
Moved from different state†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Did not move from different state	1.3 (0.5–3.1)	1.2 (0.6–2.7)	2.0 (0.9–4.4)	1.9 (0.9–4.1)
Living in a MSA				
MSA, central city	1.6 (0.8–3.3)	1.0 (0.5–2.0)	1.0 (0.5–2.0)	1.0 (0.5–1.9)
MSA, non-central city†	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)	1.0 (1.0–1.0)
Non-MSA	0.9 (0.4–2.0)	0.6 (0.3–1.3)	0.8 (0.4–1.7)	0.6 (0.3–1.2)

* For a specific characteristic level, the tabulated value is the ratio of the odds of being unvaccinated for the reference.
† Reference level for the logistic regression analysis. The tabulated value for a characteristic level is the ratio of the odds of being unvaccinated for the reference level of the characteristic, compared with the odds of being unvaccinated for the characteristic level (2001 NIS).

vaccinated children were Los Angeles, CA, and Detroit, MI (including Wayne, Oakland, and Macomb Counties). The remaining counties among the 20 with the greatest numbers of unvaccinated children included the cities of Chicago, IL, Pittsburgh, PA, Dallas, TX, Houston, TX, Oklahoma City, OK, and Grand Rapids, MI. Also included among those counties were Westchester County, NY, and Lancaster County, PA. New York City was not among the 50 areas with the greatest estimated numbers of children with no vaccine doses.

DISCUSSION

Despite the efforts of state and federal agencies to increase vaccination coverage rates, 2.1 million children (36.9%) in the population of children 19 to 35 months of age were undervaccinated in 2001, and 17 000 children (0.3%) had not received any vaccina-

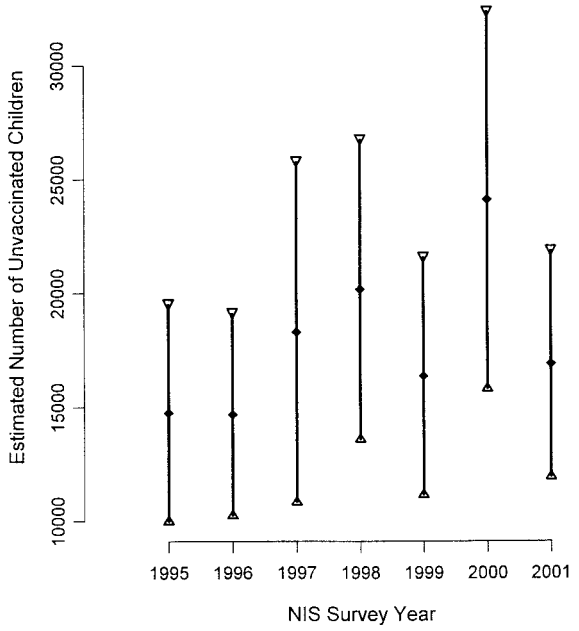

Fig 1. Estimates and 95% CIs of annual numbers of unvaccinated children in the US population.

tions. Although the NIS sampling weights are adjusted to account for households that do not have telephones,[15,16] it is known that this adjustment does not account fully for these households. Therefore, our estimate of the number of children who have not received any vaccinations is probably somewhat low.

Results from our study suggest that unvaccinated children are distinctly different from undervaccinated children. Compared with fully vaccinated children, undervaccinated children tended to be black, to have a younger mother who was not married and did not have a college degree, to be in a household near the poverty level with ≥4 children, and to live in a central city. Gender was not significant in predicting whether a child was undervaccinated. In contrast, compared with undervaccinated children, unvaccinated children tended to be disproportionately white children whose mother was married, had a college degree, and lived in a household with an annual income exceeding $75 000, were more likely to be male than female, and were even more likely than undervaccinated children to live in a household with ≥4 children.

As unvaccinated 19- to 35-month-old children become older, they may never become vaccinated. Although state laws mandate compulsory vaccinations for day care, Head Start, school, and college entrance, an estimated 850 000 children 5 to 17 years of age were home-schooled in 1999.[20] Some states do not enforce mandates for such children. Furthermore, in 2000–2001, all states allowed exemptions for medical reasons, 48 for religious reasons, and 17 for philosophical reasons.[21] In many states, it is easier to claim a religious or philosophical exemption than to adhere to mandated immunization requirements.[22] During the 1994–1995 school year, the total number of children with medical, religious, or philosophical exemptions constituted ~1% of new entrants in 42 states and the District of Columbia.[23] In Colorado, the percentage of school-entry-aged children who were exempted from compulsory vaccinations increased from 1.37% in 1987 to 2.08% in 1998. In Washington state in 2000, among schools in which ≥5% of all children had been exempted, 38.8% had no records on file at the school of their having been administered any vaccinations.[24] There is evidence that families with similar attitudes and beliefs regarding vaccinations cluster geographically. For example, 12.3% of all children attending public schools and 18.8% of children attending day care in Ashland, Oregon, in 2002 claimed exemptions from mandatory vaccination laws, compared with 2.4% for the entire state that year.[25,26] Other research[27] has shown that, once parents have established a decision not to vaccinate, they are unlikely to be persuaded to change their decision, regardless of the risks of VPDs. Our data show that parents who have children with no vaccinations are significantly more likely to report that doctors have little or no influence on their decision to vaccinate their children. Therefore, children who are not vaccinated by 19 to 35 months of age may remain unvaccinated up to and beyond school entry. As a result of parents claiming a medical, religious, or philosophical exemption to laws mandating compulsory vaccinations for their children, unvaccinated and undervaccinated children may accumulate with time and increase in numbers in the communities in which they live. Our study has shown that unvaccinated children are clustered in counties in MSAs in western states, although there are also large numbers of unvaccinated children in southern, eastern, and midwestern MSAs.

The consequences of being an "exemptor" were illustrated by a population-based, retrospective, cohort study of all reported measles and pertussis cases among children 3 to 18 years of age in Colorado in 1987–1998.[28] Results from that study showed that exemptors were 22 times more likely to contract measles and 6 times more likely to contract pertussis than were vaccinated persons. Also, the majority of recent tetanus cases have occurred been among unvaccinated children.[29] In a measles outbreak among the Amish in 1987, the attack rate was 1.7% among vaccinated individuals and 73.8% among unvaccinated individuals.[30] In the Netherlands, polio outbreaks among communities of religious people who frequently refuse vaccination have been reported, despite a national vaccination coverage rate of 97%.[31,32] The risk of acquiring a VPD is also evident in the community in which exemptors live; in 1979, a polio outbreak paralyzed 14 Amish people in the United States and the outbreak spread to unvaccinated non-Amish neighbors.[33] In states with loosely enforced state immunization laws, higher measles incidences have been observed.[34–37] A mathematical model constructed using recent data from California indicated that the incidence of acquiring measles increased from 5.5% to 30.8% as the probability of contact between nonexemptors and exemptors increased from 20% to 60%.[38] Because of the potential for unvaccinated exemptors to accumulate with time in the communities in which they live, there may be greater

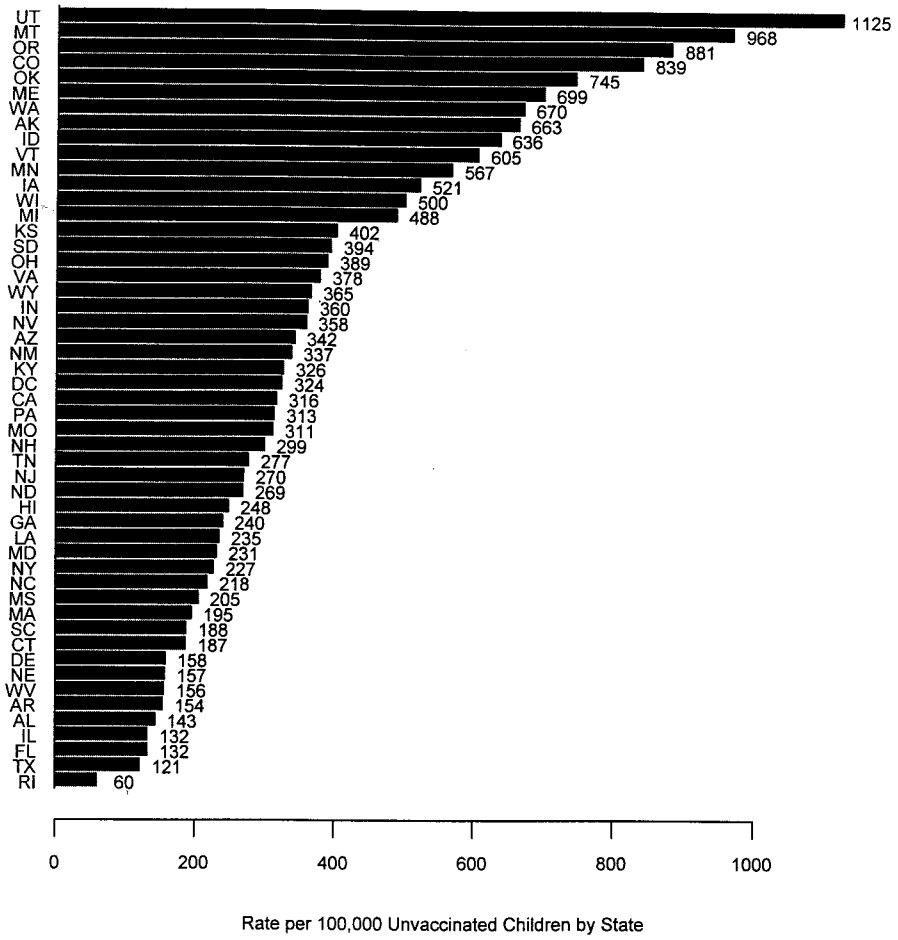

Fig 2. Estimated rates of unvaccinated children per 100 000 children 19 to 35 months of age, according to state (1995-2001 NIS).

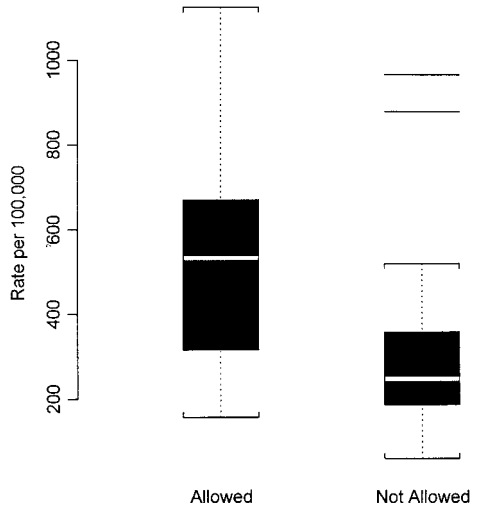

Fig 3. Estimated state rates of unvaccinated children per 100 000 children in 2001-2002, according to whether philosophical exemptions were allowed. States that allowed philosophical exemptions were Alaska, California, Colorado, Idaho, Maine, Maryland, Michigan, Minnesota, Missouri, Nebraska, New Mexico, North Dakota, Ohio, Oklahoma, Utah, Vermont, Washington, and Wisconsin.

probabilities of contact between nonexemptors and exemptors and increases in the rates of VPDs in both groups. Our results show that the proportions of unvaccinated children are significantly greater in states that allow philosophical exemptions to laws that mandate vaccinations for children as they enter school.

Why do some parents avoid vaccinating their children? Our results indicate that parents of unvaccinated children are much more concerned about vaccine safety than are parents whose children receive ≥1 vaccine dose. In a survey of parent's beliefs and practices regarding vaccinations and autism, siblings in families in which there was an autistic child were 3 times more likely to be unvaccinated, compared with siblings in families in which there was a child with attention-deficit/hyperactivity disorder.[39] In response to concerns about the perceived risk of autism resulting from vaccinations, parents might have avoided having their sons vaccinated at a higher rate than their daughters, as a result of knowing that they have risk factors for autism and knowing that the rate of autism is 4 times greater for boys than for girls. Although this explanation is conjectural, it may explain why our results show that boys are significantly more likely to be unvaccinated than girls.

Safety concerns regarding alleged links between hepatitis B vaccine and multiple sclerosis[40] or between diphtheria-tetanus-pertussis vaccine and sudden infant death syndrome[41] may be among parent's concerns that influence their decision not to vaccinate their children. Concerns regarding these issues continue to circulate,[42] although current scientific evidence does not support an association between vaccines and these conditions.[43] In addition, parents

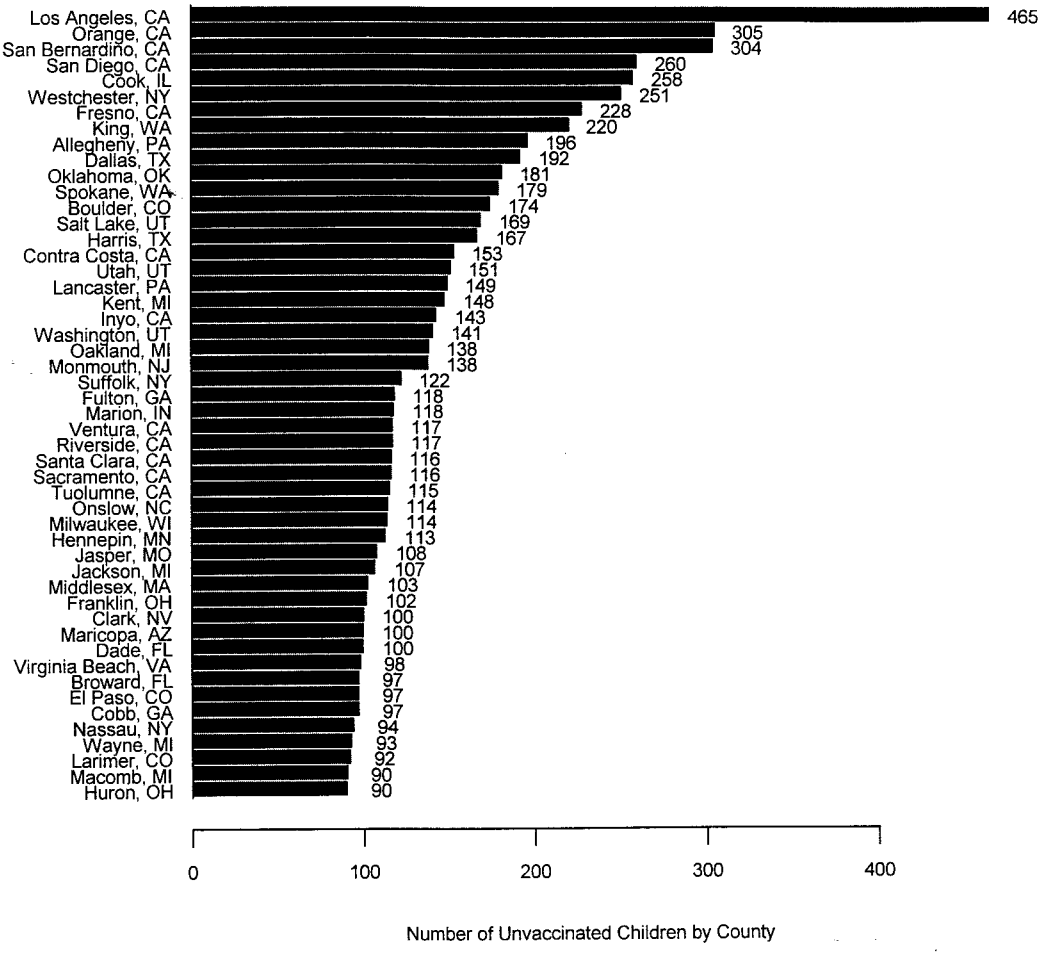

Fig 4. Estimated numbers of unvaccinated children according to county for 30 counties with the greatest numbers of unvaccinated children (1995-2001 NIS).

may choose not to vaccinate their children because of religious beliefs[44] or because of misconceptions about immunizations.[45]

The strengths of this study include a nationally representative sample obtained by the NIS, the large size of the sample, and the ongoing nature of the survey, which allows trends in vaccination coverage to be monitored. The limitations of this study include the possibility of errors in ascertaining whether children were unvaccinated. For example, parent's reports that their children did not have a vaccination provider and had received no vaccinations may be unreliable. In that case, the estimates of the numbers of unvaccinated children that we report would overestimate the true values. Also, households that choose not to respond to the NIS may be more likely to have unvaccinated children. In that case, the estimates of the numbers of unvaccinated children that we report would underestimate the true values, particularly in geographic areas in which the NIS nonresponse rates are high because of negative attitudes toward vaccinations and negative attitudes toward vaccination surveys.

Finally, although we report on the 50 counties with the largest estimated numbers of children who received no vaccinations, it is possible that there are other counties in the United States where the proportions of children with no vaccinations are large. In our analyses, we noted several sparsely populated counties inhabited primarily by racial/ethnic minorities where the proportions of unvaccinated children were large. However, these estimated values were based on very small sample sizes, which precludes publication because of confidentiality concerns.

Our study suggests that the characteristics of children who are unvaccinated are different from those of children who are undervaccinated. Other research has shown that unvaccinated children are at greater risk of both acquiring and transmitting VPDs. Because of these differences, interventions need to be specifically designed and targeted toward parents who choose for their children not to receive any vaccinations.

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Children Who Have Received No Vaccines: Who Are They and Where Do They Live?

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