Children and Adolescents Unvaccinated Against Measles: Geographic Clustering, Parents' Beliefs, and Missed Opportunities

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ABSTRACT

Objective. We evaluated the extent to which children and adolescents were not vaccinated against measles ("unvaccinated"), clustering within U.S. counties, and factors associated with unvaccination, including parents' vaccine-related beliefs and missed opportunities.

Methods. We analyzed data from the 2010–2013 National Immunization Survey (NIS) and NIS-Teen Survey of households with 19- to 35-month-old children and 13- to 17-year-old adolescents, respectively. We used provider-reported vaccination histories to assess measles vaccination status.

Results. In 2013, 7.5% of children and 4.5% of adolescents were unvaccinated against measles. Four-fifths (80.0%) of unvaccinated children lived in counties containing 41.9% of the nation's children, and 80.0% of unvaccinated adolescents lived in counties containing 30.4% of the nation's adolescents. Multivariable statistical analyses found that 74.6% of children who were unvaccinated against measles missed being vaccinated for reasons other than parents' negative vaccine-related beliefs, and 89.6% could be deemed as having at least one missed opportunity for being vaccinated against measles because they were administered at least one dose of other recommended vaccines after 12 months of age. Among adolescents, multivariable analyses found that only demographic factors, not vaccine-related parental beliefs, were independently associated with being unvaccinated.

Conclusions. Reasons other than negative vaccine-related beliefs, including missed opportunities, accounted for the vast majority of unvaccinated children and adolescents.

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In 2000, the Centers for Disease Control and Prevention (CDC) declared measles to be eliminated in the United States,[1] an accomplishment achieved because of the high levels of population immunity resulting from high measles vaccination coverage levels across the United States.[2] Despite the elimination of endemic measles in the United States, sporadic outbreaks have continued as a consequence of importations from countries where measles is endemic.[3–17]

High national and state measles vaccination coverage rates may mask considerable variability in vaccination rates at the county or community level.[18] Geographic clustering of susceptible children and adolescents increases the risk of outbreaks and could lead to reestablishment of endemic measles transmission.[19]

In this article, we evaluate the extent to which children and adolescents who are unvaccinated against measles cluster within U.S. counties. Also, although the popular media[20,21] and scientific literature[22–27] have reported an association between lower vaccination coverage and negative vaccine-related parental beliefs, some literature suggests that under-immunization may result primarily from missed opportunities to vaccinate rather than from negative vaccine-related beliefs.[28] We assessed the associations among not being vaccinated against measles, parents' vaccine-related beliefs, and missed opportunities, and evaluated the extent to which not being vaccinated against measles is attributable to factors other than negative vaccine-related beliefs.

METHODS

Our analyses used the most recent data from the National Immunization Survey (NIS)[29] and NIS-Teen[30] to address our scientific objectives that provide statistically reliable estimates. The target populations of the two surveys were 19- to 35-month-old children (hereinafter referred to as children) (NIS) and 13- to 17-year-old adolescents (hereinafter referred to as adolescents) (NIS-Teen). Both surveys included a random-digit-dial survey of households with landline telephone numbers; in 2011–2013, both surveys included a random-digit-dial survey of cell phone numbers. We analyzed data from sampled children and adolescents who had adequate provider-reported vaccination histories to assess their vaccination status. We defined children and adolescents as being unvaccinated if their providers reported that no doses of measles-containing vaccine were administered. For this article, children not vaccinated against measles were deemed and defined as having a missed opportunity to be vaccinated against measles if, after 12 months of age (when eligibility for the recommendation for routine administration of the measles vaccine begins), vaccination provider records confirmed that they were administered doses of other recommended childhood vaccines but remained unvaccinated against measles. Detailed descriptions of the NIS and NIS-Teen have been published elsewhere.[31–38]

The national number and percentage of unvaccinated children and adolescents were estimated using data from 13,611 children sampled by the 2013 NIS and 18,264 adolescents sampled by the 2013 NIS-Teen. To obtain statistically reliable county-level estimates of the percentage and number of children and adolescents not vaccinated against measles, we used three consecutive years of NIS and NIS-Teen data, required the sample sizes for counties to be ≥ 35 for the three years combined, and used James-Stein statistical estimation methodology.[39] Because of reduced national sample sizes for both the 2013 NIS and NIS-Teen, county-level sample sizes for that survey year were smaller than for previous years, resulting in fewer counties achieving the sample size requirement. Among counties that achieved the sample size requirement, many county-level estimates had low precision. Because of that imprecision, we used data from 31,176 children and 38,749 adolescents sampled from the 2010–2012 NIS and NIS-Teen, respectively, to obtain county-level estimates.

Vaccine-related parental beliefs were collected in the 2011 NIS and the 2010 NIS-Teen and organized using the Health Belief Model.[22,40] Multivariable recursive partitioning (i.e., a multivariable statistical method that creates a decision tree that attempts to classify members of the population based on several independent variables) analyses[41,42] were used (*1*) to identify independent predictors of being unvaccinated against measles, (*2*) to segment the populations of children and adolescents into groups characterized by increasing risk of not being vaccinated against measles, and (*3*) to derive the percentages of children and adolescents who were unvaccinated against measles that could be attributed[43] to reasons other than parents' negative vaccine-related beliefs. All analyses accounted for the surveys' sampling weights and sampling design.[44] Estimated percentages and numbers are reported along with their 95% confidence intervals (CIs). Differences between estimates were statistically significant at $p<0.05$.

RESULTS

Children unvaccinated against measles (unvaccinated children)

In 2013, the estimated number and percentage of unvaccinated 19- to 35-month-old children in the

United States were 429,915 (95% CI 376,857, 482,973) and 7.5% (95% CI 6.6, 8.4), respectively. Among all counties in the United States in 2013, approximately 80.0% of the unvaccinated children lived in counties containing 41.9% of the national population of 19- to 35-month-old children (data not shown in tables or figures).

A total of 210 counties had combined sample sizes ≥35 across 2010–2012 for both the NIS and NIS-Teen. In 2013, children living in the 210 counties comprised 50.7% of all children nationally. Among the 210 counties, the highest decile of estimated number of unvaccinated children ranged from 18,610 in Los Angeles County, California, to 2,135 in Wake County, North Carolina, and the highest decile of the estimated percentage of unvaccinated children ranged from 18.0% in Boulder County, Colorado, to 10.3% in Allen County, Indiana, and Clackamas County, Oregon (Table 1).

Bivariable analyses found that compared with vaccinated children, unvaccinated children were significantly more likely to lack health insurance coverage and to have other statistically significant differences with respect to maternal and household characteristics that are generally associated with lower socioeconomic status (Table 2). Also, unvaccinated children were found to have parents with significantly lower assessments of (*1*) their child's risk of getting a vaccine-preventable disease (VPD), (*2*) VPDs as a concern that makes vaccinations relevant, and (*3*) vaccines' efficacy to reduce the threat of a VPD. Compared with parents of vaccinated children, parents of unvaccinated children were also significantly less likely to report that their decision to vaccinate their child was favorably influenced by a health-care provider (HCP) and significantly more likely to report concerns about vaccine safety (Table 3).

Multivariable recursive partitioning analyses (Figure 1) found that none of the 19 demographic factors and only two of the 20 vaccine-related parental belief factors (Table 3) were independently associated with a child being unvaccinated against measles. Specifically, the multivariable analysis found that the independent predictors of an unvaccinated child were (*1*) parents' belief about the necessity of vaccines to protect the health of children and (*2*) among parents who believed in the necessity of vaccines, whether or not parents reported refusing vaccine dose administration for their child (Figure 1).

The multivariable analysis segmented the U.S. population of children into three groups (Figure 1). Group 1 included children whose parents believe that vaccines are necessary to protect their children's health and did not report vaccine refusal. Group 2 included children whose parents believe that vaccines are necessary to protect their children's health and reported refusing ≥1 vaccine dose of any type. Group 3 included children whose parents do not believe that vaccines are necessary to protect their children's health. In the continuum from group 1 to group 3, there was (*1*) a statistically significant decrease in the percentages of children belonging to the groups as a percentage of the population of 19- to 35-month-old children (80.9% in group 1, to 13.6% in group 2, and to 5.5% in group 3, $p<0.05$) and (*2*) a statistically significant increase in the percentage of children unvaccinated against measles (from 6.6% in group 1, to 12.3% in group 2, and to 33.6% in group 3, $p<0.05$).

The percentage of children with parents who had negative vaccine-related beliefs also increased across the three groups. Compared with parents of children in group 1, parents of children in group 2 differed significantly on 10 of 20 vaccine-related belief factors. Parents of children in group 2 were significantly less likely than parents of children in group 1 to report that their child's HCP encouraged them to vaccinate their child, to have been satisfied with information received from their child's HCP about vaccines, and to think that vaccines are safe. Also, parents of children in group 2 were significantly more likely than parents of children in group 1 to believe that children receive too many vaccines, that their children may get autism if they vaccinate, that their children may have serious side effects if they vaccinate, that too many vaccines can overwhelm a child's immune system, and that vaccinations should be delayed if a child has a minor illness (Table 4).

Compared with parents of children in group 1, parents of children in group 3 differed on 17 of 20 vaccine-related belief factors (Table 4). In addition to differing from group 1 concerning the same vaccine-related belief factors about which group 2 differed, parents of children in group 3 were significantly less likely to believe that diseases such as measles are serious and can hurt children; that if they do not vaccinate their child, the child may get a disease such as measles; that vaccines do a good job of preventing diseases; and that medical professionals in charge of vaccinations have their child's best interest at heart. They were also less likely to report that they were given enough time with their child's doctor to discuss issues that concerned them about vaccinations and to report that they have a good relationship with their child's HCP. Also, parents of children in group 3 were significantly more likely than parents of children in group 1 to report that their decision of whether or not to vaccinate their child was influenced by a practitioner of complementary or alternative medicine (Table 4). Among unvaccinated

Table 1. Estimated number and percentage of unvaccinated[a] children and adolescents in selected counties in the United States,[b] 2010–2012 NIS and 2010–2012 NIS-Teen

	19- to 35-month-old children unvaccinated against measles		*13- to 17-year-old adolescents unvaccinated against measles*	
U.S. counties	*Estimated percentage unvaccinated against measles (95% CI)*	*Estimated number unvaccinated against measles (95% CI)*	*Estimated percentage unvaccinated against measles (95% CI)*	*Estimated number unvaccinated against measles (95% CI)*
United States[c]	7.5% (±0.9%)	429,915 (±50,058)	4.5% (±0.7%)	941,134 (±288,604)
Range across the 210 counties (from highest to lowest)[d]	18.0–3.6	18,610–29	9.1–2.8	37,612–89
Range across deciles				
1st (highest) decile	18.0–10.3	18,610–2,135	9.1–6.4	37,612–4,135
2nd decile	10.1–9.1	2,090–1,358	6.3–5.5	4,059–2,682
3rd decile	9.0–8.4	1,354–1,048	5.5–5.0	2,679–2,080
4th decile	8.4–7.8	1,040–864	5.0–4.6	2,067–1,742
5th decile	7.8–7.4	858–681	4.6–4.4	1,716–1,486
6th decile	7.4–7.1	678–584	4.4–4.2	1,475–1,206
7th decile	7.0–6.7	556–406	4.2–3.9	1,192–828
8th decile	6.7–6.2	399–288	3.9–3.8	824–577
9th decile	6.2–5.8	284–164	3.8–3.4	573–369
10th (lowest) decile	5.8–3.6	144–29	3.4–2.8	357–89
Selected counties[e,f]				
Los Angeles, CA (1, 1)	9.0 (±3.3)	18,610 (±6,824)	5.0 (±2.1)	37,612 (±15,797)
Maricopa, AZ (4, 4)	10.9 (±3.3)	10,263 (±3,107)	7.0 (±2.1)	18,904 (±5,671)
Cook, IL (2, 2)	8.0 (±2.0)	8,834 (±2,209)	4.9 (±1.4)	18,039 (±5,154)
Harris, TX (3, 3)	6.7 (±2.2)	6,744 (±2,215)	7.7 (±2.2)	22,264 (±6,361)
Dallas, TX (7, 9)	9.0 (±2.3)	5,491 (±1,403)	9.1 (±2.7)	15,188 (±4,506)
Kings, NY (8, 7)	9.4 (±3.1)	5,177 (±1,707)	4.2 (±1.6)	7,425 (±2,828)
San Diego, CA (5, 6)	7.4 (±3.9)	4,764 (±2,511)	7.1 (±3.2)	14,999 (±6,760)
Clark, NV (13, 15)	10.9 (±2.9)	4,627 (±1,231)	7.9 (±2.2)	9,658 (±2,690)
San Bernardino, CA (10, 8)	9.4 (±4.6)	4,506 (±2,205)	5.3 (±2.7)	9,103 (±4,638)
Tarrant, TX (12, 14)	8.6 (±3.9)	3,675 (±1,667)	7.7 (±3.3)	9,459 (±4,054)
Broward, FL (19, 17)	10.1 (±5.1)	3,341 (±1,687)	4.4 (±2.4)	5,083 (±2,773)
Dade, FL (11, 11)	6.9 (±3.6)	3,155 (±1,646)	3.0 (±0.2)	4,766 (±318)
Bronx, NY (20, 19)	9.6 (±4.6)	3,050 (±1,461)	5.7 (±2.8)	6,353 (±3,121)
King, WA (18, 20)	9.0 (±3.5)	3,032 (±1,179)	4.6 (±2.0)	5,104 (±2,219)
Wayne, MI (15, 12)	7.7 (±4.0)	3,019 (±1,569)	4.6 (±2.3)	7,093 (±3,547)
Suffolk, NY (25, 22)	9.6 (±4.5)	2,569 (±1,204)	4.2 (±2.1)	4,442 (±2,221)
Salt Lake, UT (26, 33)	9.5 (±3.6)	2,539 (±962)	4.9 (±2.2)	3,662 (±1,644)
Shelby, TN (45, 39)	10.6 (±4.2)	2,176 (±862)	3.9 (±1.9)	2,696 (±1,313)
Bexar, TX (16, 16)	5.5 (±1.6)	2,145 (±624)	6.2 (±1.6)	7,423 (±1,916)
Wake, NC (49, 64)	11.1 (±4.8)	2,135 (±923)	3.6 (±1.7)	2,037 (±962)
El Paso, TX (41, 55)	10.0 (±2.4)	2,090 (±502)	6.7 (±2.5)	4,059 (±1,514)
Philadelphia, PA (21, 21)	6.6 (±2.0)	2,056 (±623)	4.8 (±1.5)	5,174 (±1,617)
Queens, NY (14, 13)	5.0 (±2.4)	2,040 (±979)	4.2 (±1.9)	5,745 (±2,599)
Cuyahoga, OH (32, 27)	8.2 (±4.2)	1,912 (±979)	4.6 (±2.1)	4,135 (±1,888)
Essex, NJ (63, 70)	11.5 (±5.4)	1,908 (±896)	4.1 (±2.1)	2,247 (±1,151)
Utah, UT (65, 99)	10.5 (±3.8)	1,705 (±617)	5.7 (±2.2)	2,378 (±918)
Snohomish, WA (92, 80)	10.5 (±4.9)	1,386 (±647)	4.5 (±2.2)	2,156 (±1,054)
Bernalillo, NM (86, 101)	9.9 (±3.2)	1,358 (±439)	6.5 (±2.4)	2,682 (±990)
Sedgwick, KS (111, 129)	10.5 (±4.4)	1,165 (±488)	6.0 (±2.7)	2,067 (±930)
Hudson, NJ (108, 117)	8.0 (±4.1)	928 (±476)	6.4 (±3.2)	2,292 (±1,146)
Boulder, CO (242, 223)	18.0 (±7.1)	900 (±355)	3.8 (±1.9)	736 (±368)
Kane, IL (97, 105)	6.8 (±3.7)	858 (±467)	7.3 (±3.5)	2,764 (±1,325)
Allen, IN (170, 177)	10.3 (±4.9)	794 (±378)	5.0 (±2.7)	1,270 (±686)
Anchorage, AK (196, 211)	12.1 (±3.7)	761 (±233)	6.2 (±2.2)	1,268 (±450)
Larimer, CO (239, 226)	14.0 (±6.2)	706 (±313)	4.6 (±2.4)	877 (±457)

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Table 1 (continued). Estimated number and percentage of unvaccinated[a] children and adolescents in selected counties in the United States,[b] 2010–2012 NIS and 2010–2012 NIS-Teen

	19- to 35-month-old children unvaccinated against measles		*13- to 17-year-old adolescents unvaccinated against measles*	
U.S. counties	*Estimated percentage unvaccinated against measles (95% CI)*	*Estimated number unvaccinated against measles (95% CI)*	*Estimated percentage unvaccinated against measles (95% CI)*	*Estimated number unvaccinated against measles (95% CI)*
Montgomery, OH (124, 114)	6.7 (±4.0)	678 (±404)	7.3 (±3.4)	2,639 (±1,229)
Polk, IA (131, 161)	6.7 (±3.5)	649 (±339)	6.4 (±2.8)	1,793 (±785)
Clackamas, OR (205, 176)	10.3 (±5.1)	614 (±304)	3.8 (±1.7)	970 (±434)
Hinds, MS (213, 222)	10.5 (±5.4)	613 (±315)	4.0 (±2.0)	783 (±391)
Clark, WA (155, 152)	7.2 (±3.9)	605 (±328)	7.4 (±3.3)	2,200 (±981)
Weber, UT (216, 258)	8.1 (±4.3)	466 (±247)	6.6 (±3.2)	1,110 (±538)
Dona Ana, NM (248, 274)	8.4 (±4.3)	413 (±211)	6.6 (±3.3)	1,027 (±513)
Kanawha, WV (347, 376)	12.1 (±5.6)	406 (±188)	6.6 (±2.8)	728 (±309)
Fairbanks North Star, AK (479, 548)	13.5 (±5.3)	318 (±125)	5.3 (±2.4)	385 (±174)
Sarpy, NE (319, 381)	6.1 (±3.3)	222 (±120)	6.3 (±2.8)	691 (±307)
Matanuska-Susitna, AK (616, 621)	11.9 (±4.7)	205 (±81)	7.3 (±2.9)	449 (±178)
Flathead, MT (631, 669)	12.1 (±5.4)	199 (±89)	7.7 (±3.2)	430 (±179)
Missoula, MT (605, 570)	11.0 (±4.7)	192 (±82)	4.1 (±2.0)	284 (±138)
Kenai Peninsula, AK (963, 873)	9.2 (±4.6)	85 (±42)	8.1 (±3.4)	314 (±132)
Sweetwater, WY (957, 1,109)	8.7 (±4.4)	81 (±41)	7.2 (±3.4)	203 (±96)
Addison, VT (1,452, 1,092)	10.8 (±5.0)	58 (±27)	3.3 (±1.5)	96 (±43)

[a]Unvaccinated against measles refers to those administered no doses of measles-containing vaccine.

[b]Among the 210 counties for which county-level estimates were obtained, selected counties included those that were at least one of the following: (*1*) in the highest decile of the estimated percentage of children unvaccinated against measles, (*2*) in the highest decile of the estimated number of children unvaccinated against measles, (*3*) in the highest decile of the estimated percentage of adolescents who were unvaccinated against measles, or (*4*) in the highest decile of the estimated number of adolescents who were unvaccinated against measles.

[c]National estimates are based on 2013 data from the NIS and NIS-Teen.

[d]Two hundred ten counties had combined sample sizes of ≥35 across 2010–2012 for both the NIS and NIS-Teen.

[e]County population rank of 19- to 35-month-old children among 3,141 counties comprising the United States

[f]County population rank of 13- to 17-year-old adolescents among 3,141 counties comprising the United States

NIS = National Immunization Survey

CI = confidence interval

children in group 3, 77.6% (95% CI 65.6, 89.6) had parents who reported refusing the administration of vaccine doses for their child (data not shown).

For children in group 1, the multivariable analysis found that the independent factors associated with not being vaccinated against measles did not include negative parental beliefs measured by the NIS (Figure 1).

Children in group 2 were 1.9 times more likely (95% CI 1.4, 2.5) to be unvaccinated against measles than children in group 1. Additionally, children in group 2 were 5.7 percentage points (12.3% minus 6.6%) more likely to not be vaccinated against measles than children in group 1. Among children unvaccinated against measles in group 2, the percentage unvaccinated that was attributable to factors other than the negative parental belief factors associated with group 2 was 53.8% (95% CI 40.6, 71.4) (data not shown).

Children in group 3 were 5.1 times more likely (95% CI 3.8, 6.7) to be unvaccinated against measles than children in group 1 (data not shown). Also, children in group 3 were 27.0 percentage points (33.6% minus 6.6%) more likely to not be vaccinated against measles than children in group 1 (Figure 1). Among children unvaccinated against measles in group 3, the percentage unvaccinated that was attributable to factors other than the negative parental belief factors that were associated with group 3 was 19.7% (95% CI 14.9, 26.1) (data not shown).

Among all children unvaccinated against measles in the U.S. population, the percentage unvaccinated that was attributable to factors other than parents' negative beliefs about the necessity of vaccines or vaccine refusal was 74.6% (95% CI 71.3, 77.9). Among children who were unvaccinated against measles, the percentages across the three groups of children who had missed opportunities were 97.3% (95% CI 93.5, 100.0) in group 1, 98.2% (95% CI 96.5, 100.0) in group 2, and 59.6% (95% CI 48.0, 71.2) in group 3. The

Table 2. Bivariable analyses of the percentage of children unvaccinated against measles, by demographic characteristic and age group, in the United States: 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

	Age group					
	19- to 35-month-old children			*13- to 17-year-old adolescents*		
		Number of measles vaccine doses administered			*Number of measles vaccine doses administered*	
	Unweighted sample size	*Unvaccinated*	*≥1 dose*	*Unweighted sample size*	*Unvaccinated*	*≥1 dose*
Demographic characteristics	N	*Percent (95% CI)*	*Percent (95% CI)*	N	*Percent (95% CI)*	*Percent (95% CI)*
Child/adolescent characteristics						
Race/ethnicity						
Hispanic	3,325	25.3 (±4.9)	28.1 (±1.4)	1,076	26.2 (±8.4)	18.9 (±1.8)
Non-Hispanic white	11,812	50.6 (±4.7)	47.7 (±1.4)	5,899	45.0 (±8.8)	60.0 (±1.9)**
Non-Hispanic black	1,909	14.4 (±3.3)	13.0 (±0.9)	982	20.0 (±7.7)	14.3 (±1.3)
Non-Hispanic American Indian/Alaska Native	300	0.6 (±0.6)	1.0 (±0.2)	82	0.1 (±0.1)	0.7 (±0.4)**
Non-Hispanic Asian	679	3.0 (±1.4)	4.3 (±0.6)	19	0.0 (±0.0)	0.1 (±0.1)***
Non-Hispanic other	1,119	6.1 (±2.4)	5.9 (±0.8)	594	8.7 (±4.4)	6.0 (±0.9)
Gender						
Male	9,819	51.5 (±4.7)	51.1 (±1.4)	4,520	55.2 (±8.8)	51.1 (±1.9)
Female	9,325	48.5 (±4.7)	48.9 (±1.4)	4,132	44.8 (±8.8)	48.9 (±1.9)
Foreign-born						
Yes	168	1.6 (±1.2)	1.1 (±0.4)	300	3.6 (±2.7)	4.5 (±1.0)
VFC entitled[a]	7,392	57.2 (±4.7)	53.6 (±1.4)	2,466	35.1 (±8.1)	32.8 (±1.9)
On Medicaid[b]	6,425	43.7 (±4.7)	48.3 (±1.4)	1,832	23.6 (±6.6)	24.7 (±1.7)
Covered by private insurance that covers all of the costs of vaccines[a]	10,121	35.9 (±4.9)	43.2 (±1.4)**	4,358	42.5 (±9.0)	48.8 (±1.9)
Underinsured[c]	2,146	9.2 (±2.1)	7.7 (±0.7)	1,818	19.7 (±7.1)	18.5 (±1.3)
Not covered by health insurance	648	12.7 (±3.0)	4.0 (±0.6)*	371	9.3 (±5.3)	5.4 (±1.0)
American Indian/Alaska Native[d]	699	2.7 (±1.1)	3.6 (±0.5)	244	1.4 (±1.3)	2.7 (±0.7)
Underinsured and vaccinated at a Federally Qualified Health Center[a]	122	0.3 (±0.4)	0.4 (±0.2)	139	0.4 (±0.4)	1.3 (±0.4)**
Parent reported that there was a time when a vaccine dose was delayed	12,259	54.0 (±6.9)	32.3 (±1.8)*	8,652	23.4 (±7.4)	23.1 (±1.5)
Parent reported that there was a time when a vaccine dose was refused	12,259	34.6 (±6.1)	14.7 (±1.3)*	8,652	26.6 (±8.7)	22.4 (±1.5)

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Table 2 (continued). Bivariable analyses of the percentage of children unvaccinated against measles, by demographic characteristic and age group, in the United States: 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

	Age group					
	19- to 35-month-old children			*13- to 17-year-old adolescents*		
		Number of measles vaccine doses administered			*Number of measles vaccine doses administered*	
	Unweighted sample size	*Unvaccinated*	*≥1 dose*	*Unweighted sample size*	*Unvaccinated*	*≥1 dose*
Demographic characteristics	N	*Percent (95% CI)*	*Percent (95% CI)*	N	*Percent (95% CI)*	*Percent (95% CI)*
Maternal characteristics						
Marital status						
Widowed/divorced/separated	1,261	10.4 (±2.7)	8.4 (±0.8)	1,384	16.6 (±6.4)	17.3 (±1.5)
Never married	3,540	26.5 (±4.3)	28.7 (±1.4)	649	7.0 (±4.8)	8.4 (±1.2)
Married	14,325	63.2 (±4.6)	62.7 (±1.4)	6,549	74.5 (±7.8)	73.3 (±1.8)
Deceased	18	0.0 (±0.0)	0.1 (±0.1)**	70	1.9 (±3.1)	1.0 (±0.4)
Maternal age in years (for mothers of 19- to 35-month-old children)						
≤19	322	1.4 (±0.8)	3.0 (±0.6)**			
20–29	5,938	48.8 (±4.7)	43.6 (±1.4)**			
≥30	12,884	49.9 (±4.7)	53.4 (±1.4)			
Maternal age in years (for mothers of 13- to 17-year-old adolescents)						
≤34				616	6.8 (±2.7)	7.6 (±1.0)
35–44				3,498	53.4 (±8.8)	42.6 (±1.9)**
≥45				4,538	39.8 (±8.5)	49.8 (±1.9)**
Preferred language for interview						
English	17,480	88.3 (±3.1)	82.6 (±1.3)*	8,198	88.7 (±5.8)	91.5 (±1.5)
Spanish	1,358	9.1 (±2.8)	14.6 (±1.3)*	380	10.1 (±5.5)	7.4 (±1.4)
Other	306	2.6 (±1.4)	2.7 (±0.6)	74	1.2 (±1.9)	1.1 (±0.4)
Educational attainment						
<12 years	2,021	19.4 (±3.6)	19.8 (±1.3)	721	12.1 (±5.3)	13.9 (±1.7)
12 years	3,326	27.7 (±4.3)	28.1 (±1.4)	1,776	31.0 (±8.9)	26.2 (±1.7)
Some college, non-college graduate	4,937	26.6 (±4.7)	21.1 (±1.1)**	2,526	25.1 (±7.0)	24.5 (±1.5)
College graduate	8,860	26.2 (±3.5)	31.0 (±1.2)**	3,629	31.8 (±8.3)	35.4 (±1.7)

continued on p. 492

Table 2 (continued). Bivariable analyses of the percentage of children unvaccinated against measles, by demographic characteristic and age group, in the United States: 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

	Age group					
	19- to 35-month-old children			*13- to 17-year-old adolescents*		
		Number of measles vaccine doses administered			*Number of measles vaccine doses administered*	
	Unweighted sample size	*Unvaccinated*	*≥1 dose*	*Unweighted sample size*	*Unvaccinated*	*≥1 dose*
Demographic characteristics	N	*Percent (95% CI)*	*Percent (95% CI)*	N	*Percent (95% CI)*	*Percent (95% CI)*
Household characteristics						
Quintile of household income as a percentage of the federal poverty level						
1st quintile (lowest income)	2,302	22.0 (±4.0)	19.8 (±1.3)	1,634	19.3 (±5.8)	20.1 (±1.6)
2nd quintile	2,531	19.4 (±3.6)	20.1 (±1.2)	1,424	23.0 (±8.3)	19.8 (±1.6)
3rd quintile	3,523	23.6 (±4.0)	19.6 (±1.2)	1,664	26.4 (±8.1)	20.2 (±1.6)
4th quintile	5,033	19.5 (±4.1)	20.5 (±1.1)	1,816	15.9 (±6.7)	19.7 (±1.4)
5th quintile (highest income)	5,755	15.5 (±2.8)	20.0 (±1.0)**	2,114	15.4 (±6.2)	20.2 (±1.3)
Number of children ≤18 years of age in the household						
1	4,475	21.2 (±3.8)	27.1 (±1.3)**	3,449	29.2 (±6.8)	32.1 (±1.7)
2–3	11,671	57.1 (±4.8)	57.8 (±1.4)	4,407	51.0 (±9.0)	55.8 (±1.9)
≥4	2,998	21.8 (±4.4)	15.2 (±1.1)**	796	19.8 (±9.0)	12.1 (±1.5)
Location of the household						
MSA—central city	7,814	41.7 (±4.7)	44.0 (±1.4)	3,351	39.3 (±9.0)	37.2 (±1.8)
MSA—non-central city	7,181	42.3 (±4.7)	40.2 (±1.4)	3,171	44.2 (±9.0)	46.3 (±1.9)
Non-MSA	4,149	16.0 (±2.9)	15.8 (±0.9)	1,968	16.4 (±5.0)	16.5 (±1.1)

*Estimated percentage is significantly different from the estimated percentage in the same row among unvaccinated respondents in the selected age group, $p<0.001$.

**Estimated percentage is significantly different from the estimated percentage in the same row among unvaccinated respondents in the selected age group, $0.001 \le p<0.01$.

***Estimated percentage is significantly different from the estimated percentage in the same row among unvaccinated respondents in the selected age group, $0.01 \le p<0.05$.

[a]VFC entitlement status is based on parental report that their child/adolescent is either eligible for Medicaid, not covered by health insurance, American Indian/Alaska Native, or covered by private health insurance that does not cover all of the cost of vaccines and administered doses at a Federally Qualified Health Center or Rural Health Center.

[b]Parental report of health insurance status and health insurance type is among the childhood/adolescent characteristics collected in the telephone interview of the NIS and NIS-Teen.

[c]Underinsured children are reported by their parents to be covered by private health insurance that does not cover all of the cost of all recommended vaccines.

[d]Includes both Hispanic and non-Hispanic American Indian/Alaska Natives

NIS = National Immunization Survey

CI = confidence interval

VFC = Vaccines for Children program

MSA = metropolitan statistical area

Table 3. Percentage of parents agreeing with statements read to them, by Health Belief Model domain,[a] age group, and number of measles vaccine doses administered to their children: United States, 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

		Age group					
		19- to 35-month-old children			13- to 17-year-old adolescents		
			Number of measles vaccine doses administered			Number of measles vaccine doses administered	
			Unvaccinated	≥1 dose		Unvaccinated	≥1 dose
Health Belief Model domain	*Statements read to parents[b]*	*Unweighted sample size N*	*Percent (95% CI)*	*Percent (95% CI)*	*Unweighted sample size N*	*Percent (95% CI)*	*Percent (95% CI)*
Parents' assessment of their child's risk of getting a VPD	Vaccines are necessary to protect the health of children/adolescents.	12,259	79.2 (±65.0)	96.0 (±60.7)*	8,652	87.2 (±64.4)	91.0 (±61.0)
Parents' assessment of whether or not VPDs are a sufficient health concern to make vaccinations relevant	If I vaccinate my child, I worry less about his/her health.	12,259	54.7 (±7.0)	76.2 (±1.6)*	Not read to parents of adolescents		
	Diseases like measles are serious and can hurt children.	12,259	89.8 (±3.0)	94.5 (±0.9)**	Not read to parents of adolescents		
	If I do not vaccinate my child/teen, he/she may get a disease such as measles (children)/meningitis (teens) and cause other children/teens or adults also to get the disease.	12,259	76.5 (±5.2)	84.8 (±1.5)*	8,652	74.7 (±8.5)	81.3 (±1.5)
Parents' assessment of whether or not vaccinating their children can reduce the threat of a VPD	Vaccines do a good job of preventing the diseases they are intended to prevent.	12,259	80.6 (±4.6)	93.6 (±0.9)*	8,652	84.8 (±5.3)	90.8 (±1.2)***
	Children/adolescents receive too many vaccines.	12,259	46.2 (±6.9)	30.4 (±1.8)*	8,652	21.0 (±6.6)	16.2 (±1.5)
Influences							
Provider influences	Health-care workers (e.g., doctor or nurse) influenced parents' decision to vaccinate.	12,259	55.3 (±7.3)	62.1 (±1.8)	Not read to parents of adolescents		
	Practitioner of complementary or alternative medicine influenced parents' decision of whether or not to vaccinate.	12,259	5.3 (±2.3)	1.1 (±0.3)***	Not read to parents of adolescents		
	My child's health-care provider encouraged me to vaccinate my child.	12,259	86.3 (±4.2)	91.5 (±1.2)***	Not read to parents of adolescents		
	At the visits to my child's doctor for vaccinations, I was given enough time with my child's doctor to discuss issues that concerned me about the vaccinations.	12,259	83.2 (±4.9)	89.9 (±1.3)**	Not read to parents of adolescents		
	I was satisfied with the information I received about vaccines at the visits I made to my child's doctor for vaccinations.	12,259	82.4 (±4.5)	91.6 (±1.3)*	Not read to parents of adolescents		
	I have a good relationship with my child's health-care provider.	12,259	87.9 (±4.3)	94.4 (±1.0)**	8,652	93.5 (±3.0)	94.3 (±0.9)
	In general, medical professionals in charge of vaccinations have my child's best interest at heart.	12,259	84.3 (±4.7)	95.0 (±0.9)***	8,652	89.2 (±4.5)	91.8 (±1.0)

continued on p. 494

Table 3 (continued). Percentage of parents agreeing with statements read to them, by Health Belief Model domain,[a] age group, and number of measles vaccine doses administered to their children: United States, 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

		Age group					
		19- to 35-month-old children			13- to 17-year-old adolescents		
			Number of measles vaccine doses administered			Number of measles vaccine doses administered	
			Unvaccinated	≥1 dose		Unvaccinated	≥1 dose
Health Belief Model domain	*Statements read to parents[b]*	*Unweighted sample size N*	*Percent (95% CI)*	*Percent (95% CI)*	*Unweighted sample size N*	*Percent (95% CI)*	*Percent (95% CI)*
Influences (continued)							
Other influences	My teenager helps to make the decision about whether or not he or she will receive a vaccine.	Not read to parents of children			8,652	37.0 (±8.8)	29.3 (±1.8)
	The decision to be vaccinated was influenced by school or daycare vaccination requirements.	12,259	24.6 (±5.6)	26.6 (±1.6)	Not read to parents of adolescents		
Safety concerns	Vaccines are safe.	12,259	63.0 (±6.4)	82.8 (±1.4)*	8,652	73.0 (±6.9)	77.8 (±1.5)
	If I vaccinate my child, he/she may get autism.	12,259	21.4 (±4.9)	9.9 (±1.2)*			
	If I vaccinate my child, he/she may have serious side effects.	12,259	39.7 (±6.7)	26.0 (±1.8)*	8,652	27.3 (±7.8)	26.5 (±1.8)
	Too many vaccines can overwhelm a child's immune system.	12,259	47.3 (±7.1)	34.2 (±1.9)*	Not read to parents of adolescents		
	Vaccination should be delayed if a child/adolescent has a minor illness.	12,259	72.1 (±7.7)	62.0 (±1.9)***	8,652	60.4 (±9.0)	61.9 (±1.9)

*Estimated percentage is significantly different from the estimated percentage in the same row among unvaccinated respondents in the selected age group, $p<0.001$.

**Estimated percentage is significantly different from the estimated percentage in the same row among unvaccinated respondents in the selected age group, $0.001 \leq p<0.01$.

***Estimated percentage is significantly different from the estimated percentage in the same row among unvaccinated respondents in the selected age group, $0.01 \leq p<0.05$.

NIS = National Immunization Survey

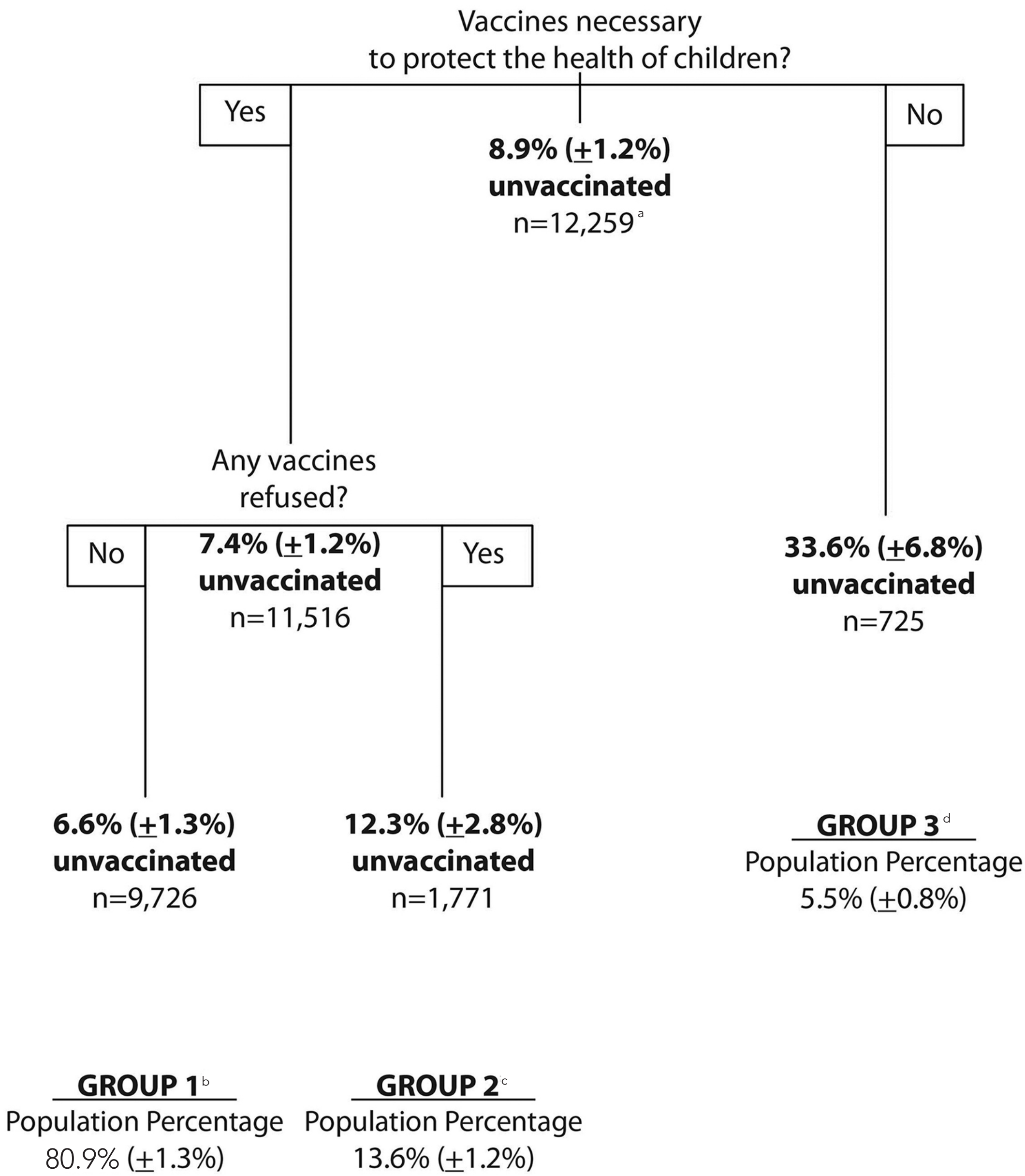
[a]Rosenstock IM, Derryberry M, Carriger BK. Why people fail to seek poliomyelitis vaccination. Public Health Rep 1959;74:98-104.

[b]Parents were read the listed statements and asked about their level of agreement on a scale from 0 to 10. Responses of ≥7 were interpreted as agreement.

CI = confidence interval

VPD = vaccine-preventable disease

Figure 1. Percentage of 19- to 35-month-old children unvaccinated against measles, by vaccine-related parental beliefs found to be the independent factors associated with being unvaccinated, 2011 National Immunization Survey



[a]*n* = unweighted sample size associated with the listed percentage. Sample sizes at daughter nodes may not add to the sample size at the parent node because of missing values in the variable defining splits at the daughter node.

[b]Group 1 consists of children whose parents believed that vaccines are necessary to protect the health of children and did not report refusing the administration of any vaccines.

[c]Group 2 consists of children whose parents believed that vaccines are necessary to protect the health of children and reported refusing the administration of ≥1 vaccine dose of any vaccine type.

[d]Group 3 consists of children whose parents did not believe that vaccines are necessary to protect the health of children.

Table 4. Percentage of parents agreeing with statements read to them, by Health Belief Model[a] domain, age group, and group defined by recursive partioning:[b] 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

		19- to 35-month-old children			*13- to 17-year-old adolescents*		
Unweighted sample size		*Group 1[c]* *9,726*	*Group 2[d]* *1,771*	*Group 3[e]* *725*	*Group 1[f]* *6,000*	*Group 2[g]* *1,735*	*Group 3[h]* *917*
Health Belief Model domain	*Statements read to parents[i]*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*
Parents' assessment of their children's risk of getting a VPD	Vaccines are necessary to protect the health of children/adolescents.	100.0 (±0.0)	100.0 (±0.0)	0.0 (±0.0)**	89.6 (±1.2)	93.2 (±2.3)	91.8 (±2.5)
Parents' assessment of whether or not VPDs are a sufficient health concern to make vaccinations relevant	If I vaccinate my child, I worry less about his/her health.	28.2 (±8.9)	47.6 (±12.0)**	12.7 (±7.4)**	Not read to parents of adolescents		
	Diseases like measles are serious and can hurt children.	97.2 (±1.9)	92.3 (±7.2)	66.3 (±10.6)***	Not read to parents of adolescents		
	If I do not vaccinate my child/teen, he/she may get a disease such as measles (children)/meningitis (teens) and cause other children/teens or adults also to get the disease.	88.6 (±4.6)	78.6 (±11.0)	39.2 (±12.5)*	80.4 (±1.7)	85.2 (±2.9)	77.4 (±5.2)
Parents' assessment of whether vaccinating their child can reduce the threat of a VPD	Vaccines do a good job of preventing the diseases they are intended to prevent.	95.6 (±2.6)	88.2 (±7.7)*	31.4 (±12.4)*	91.6 (±1.0)	88.7 (±2.9)	89.3 (±4.1)
	Children/adolescents receive too many vaccines.	28.8 (±8.2)	59.4 (±11.3)*	84.4 (±7.3)*	10.8 (±1.3)	28.4 (±4.2)*	19.8 (±4.7)*

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Table 4 (continued). Percentage of parents agreeing with statements read to them, by Health Belief Model[a] domain, age group, and group defined by recursive partioning:[b] 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

		19- to 35-month-old children			13- to 17-year-old adolescents		
Unweighted sample size		*Group 1[c]* 9,726	*Group 2[d]* 1,771	*Group 3[e]* 725	*Group 1[f]* 6,000	*Group 2[g]* 1,735	*Group 3[h]* 917
Health Belief Model domain	*Statements read to parents[i]*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*
Influences							
Provider influences	Health-care worker (e.g., doctor or nurse) influenced parents' decision to vaccinate.	54.6 (±10.5)	57.4 (±12.2)	55.0 (±12.8)	Not read to parents of adolescents		
	Practitioner of complementary or alternative medicine influenced parents' decision of whether or not to vaccinate.	1.2 (±1.3)	5.1 (±5.6)	17.6 (±8.3)*	Not read to parents of adolescents		
	My child's health-care provider encouraged me to vaccinate my child.	93.8 (±4.2)	79.4 (±12.1)***	70.9 (±10.4)*	Not read to parents of adolescents		
	At the visits to my child's doctor for vaccinations, I was given enough time with my child's doctor to discuss issues that concerned me about the vaccinations.	86.9 (±6.3)	79.7 (±11.3)	75.0 (±9.8)***	Not read to parents of adolescents		
	I was satisfied with the information I received about vaccines at the visits I made to my child's doctor for vaccinations.	92.7 (±3.9)	79.2 (±10.3)***	54.3 (±12.6)*	Not read to parents of adolescents		
	I have a good relationship with my child's health-care provider.	93.5 (±2.9)	86.8 (±9.0)	72.7 (±13.9)**	95.1 (±0.9)	93.8 (±1.7)	91.9 (±3.7)
	In general, medical professionals in charge of vaccinations have my child's best interest at heart.	95.1 (±3.5)	85.9 (±9.2)	50.7 (±12.7)**	92.4 (±1.1)	91.2 (±2.0)	89.9 (±3.3)

continued on p. 498

Table 4 (continued). Percentage of parents agreeing with statements read to them, by Health Belief Model[a] domain, age group, and group defined by recursive partioning:[b] 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

		19- to 35-month-old children			*13- to 17-year-old adolescents*		
Unweighted sample size		*Group 1[c]* *9,726*	*Group 2[d]* *1,771*	*Group 3[e]* *725*	*Group 1[f]* *6,000*	*Group 2[g]* *1,735*	*Group 3[h]* *917*
Health Belief Model domain	*Statements read to parents[i]*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*	*Percent (95% CI)*
Influences (continued)							
Other influences	My teenager helps to make the decision about whether or not he/she will receive a vaccine.	Not read to parents of children			27.0 (±1.8)	36.7 (±4.3)*	29.4 (±5.2)
	The decision to be vaccinated was influenced by school or daycare vaccination requirements.	26.7 (±8.0)	20.5 (±8.9)	22.1 (±11.2)	Not read to parents of adolescents		
Safety concerns	Vaccines are safe.	80.5 (±7.3)	60.3 (±11.7)**	15.1 (±9.7)*	76.3 (±1.7)	80.8 (±3.2)	77.6 (±4.6)
	If I vaccinate my child, he/she may get autism.	8.7 (±3.7)	26.0 (±10.5)**	54.3 (±12.6)*	Not read to parents of adolescents		
	If I vaccinate my child, he/she may have serious side effects.	25.1 (±8.2)	46.7 (±12.3)**	74.7 (±9.1)*	23.5 (±1.7)	34.2 (±4.4)*	26.9 (±5.3)
	Too many vaccines can overwhelm a child's immune system.	31.0 (±8.5)	63.0 (±11.6)*	79.3 (±11.8)*	Not read to parents of adolescents		
	Vaccination should be delayed if a child/adolescent has a minor illness.	63.0 (±11.1)	84.6 (±9.4)**	87.5 (±6.0)*	61.4 (±2.1)	62.3 (±4.3)	62.8 (±5.8)

continued on p. 499

Table 4 (continued). Percentage of parents agreeing with statements read to them, by Health Belief Model[a] domain, age group, and group defined by recursive partioning:[b] 2011 NIS (quarters 1–4) and 2010 NIS-Teen (quarters 3–4)

*Estimated percentage is significantly different from the estimated percentage in the same row among respondents in Group 1 and in the selected age group, $p<0.001$.

**Estimated percentage is significantly different from the estimated percentage in the same row among respondents in Group 1 and in the selected age group, $0.001 \leq p<0.01$.

***Estimated percentage is significantly different from the estimated percentage in the same row among respondents in Group 1 and in the selected age group, $0.01 \leq p<0.05$.

[a]Rosenstock IM, Derryberry M, Carriger BK. Why people fail to seek poliomyelitis vaccination. Public Health Rep 1959;74:98-104.

[b]Recursive partitioning is a multivariable statistical method that creates a decision tree that attempts to classify members of the population based on several independent variables.

[c]For 19- to 35-month-old children, Group 1 consists of children whose parents believe that vaccines are necessary to protect the health of children and did not report refusing the administration of any vaccines.

[d]For 19- to 35-month-old children, Group 2 consists of children whose parents believe that vaccines are necessary to protect the health of children and reported refusing the administration of ≥1 vaccine dose of any vaccine type.

[e]For 19- to 35-month-old children, Group 3 consists of children whose parents did not believe that vaccines are necessary to protect the health of children.

[f]For 13- to 17-year-old adolescents, Group 1 consists of non-Hispanic white, American Indian/Alaska Native, and non-Hispanic Asian adolescents.

[g]For 13- to 17-year-old adolescents, Group 2 consists of Hispanic, non-Hispanic black, and people of other races/ethnicities who live in a household with an annual income in either the lower quintile or upper two quintiles of the distribution of household income, adjusted for household composition.

[h]For 13- to 17-year-old adolescents, Group 3 consists of Hispanic, non-Hispanic black, and people of other races/ethnicities who live in a household with an annual income in either the second or third quintiles of the distribution of household income, adjusted for household composition.

[i]Parents were read the listed statements and asked about their level of agreement on a scale from 0 to 10. Responses of ≥7 were interpreted as agreement.

NIS = National Immunization Survey

CI = confidence interval

VPD = vaccine-preventable disease

overall percentage was 89.6% (95% CI 86.1, 93.1). Also, among all 19- to 35-month-old children unvaccinated against measles, only 34.6% (95% CI 28.5, 40.7) had a parent who reported refusing the administration of any vaccine doses (data not shown).

Adolescents unvaccinated against measles (unvaccinated adolescents)

In 2013, the estimated number and percentage of unvaccinated 13- to 17-year-old adolescents was 941,134 (95% CI 796,832, 1,085,436) and 4.5% (95% CI 3.8, 5.2) (Table 1). The number and percentage of adolescents not administered two doses of measles-containing vaccine were 1,642,293 (95% CI 1,472,783, 1,811,803) and 7.9% (95% CI 7.1, 8.7). Among the 3,141 counties that the United States comprised in 2013, approximately 80.0% of unvaccinated adolescents lived in counties containing 30.4% of the national population of adolescents (data not shown).

In 2013, children living in the 210 counties comprised 53.5% of all adolescents nationally. The upper decile of the number of adolescents unvaccinated against measles ranged from 37,612 in Los Angeles County, California, to 4,135 in Cuyahoga County, Ohio. The upper decile of the percentage of unvaccinated adolescents ranged from 9.1% in Dallas County, Texas, to 6.4% in Hudson County, New Jersey, and Polk County, Iowa (Table 1).

Bivariable analyses found that compared with adolescents vaccinated against measles, unvaccinated adolescents (*1*) were significantly more likely to be Hispanic, non-Hispanic American Indian/Alaska Native, or non-Hispanic Asian; (*2*) were more likely to have other statistically significant differences with respect to maternal characteristics, insurance status, and the likelihood of having a parent who reported ever refusing vaccines (Table 2); but (*3*) were not statistically significantly different with respect to any of the 10 vaccine-related factors measured (Table 3).

Multivariable analyses found that among the 19 demographic and 10 vaccine-related belief factors measured on parents of adolescents, no vaccine-related parental belief factors and only two demographic factors (i.e., race/ethnicity and household income) were independently associated with vaccination of adolescents (Figure 2). In particular, compared with non-Hispanic white, American Indian/Alaska Native, and non-Hispanic Asian adolescents, Hispanic and non-Hispanic black adolescents were significantly less likely to be vaccinated against measles by 2.9 (95% CI 1.1, 4.7) percentage points. The multivariable analysis segmented the population of adolescents into three groups. However, few significant differences in vaccine-related parental beliefs and no increasing pattern of negative parental beliefs were found across these groups (Table 4).

DISCUSSION

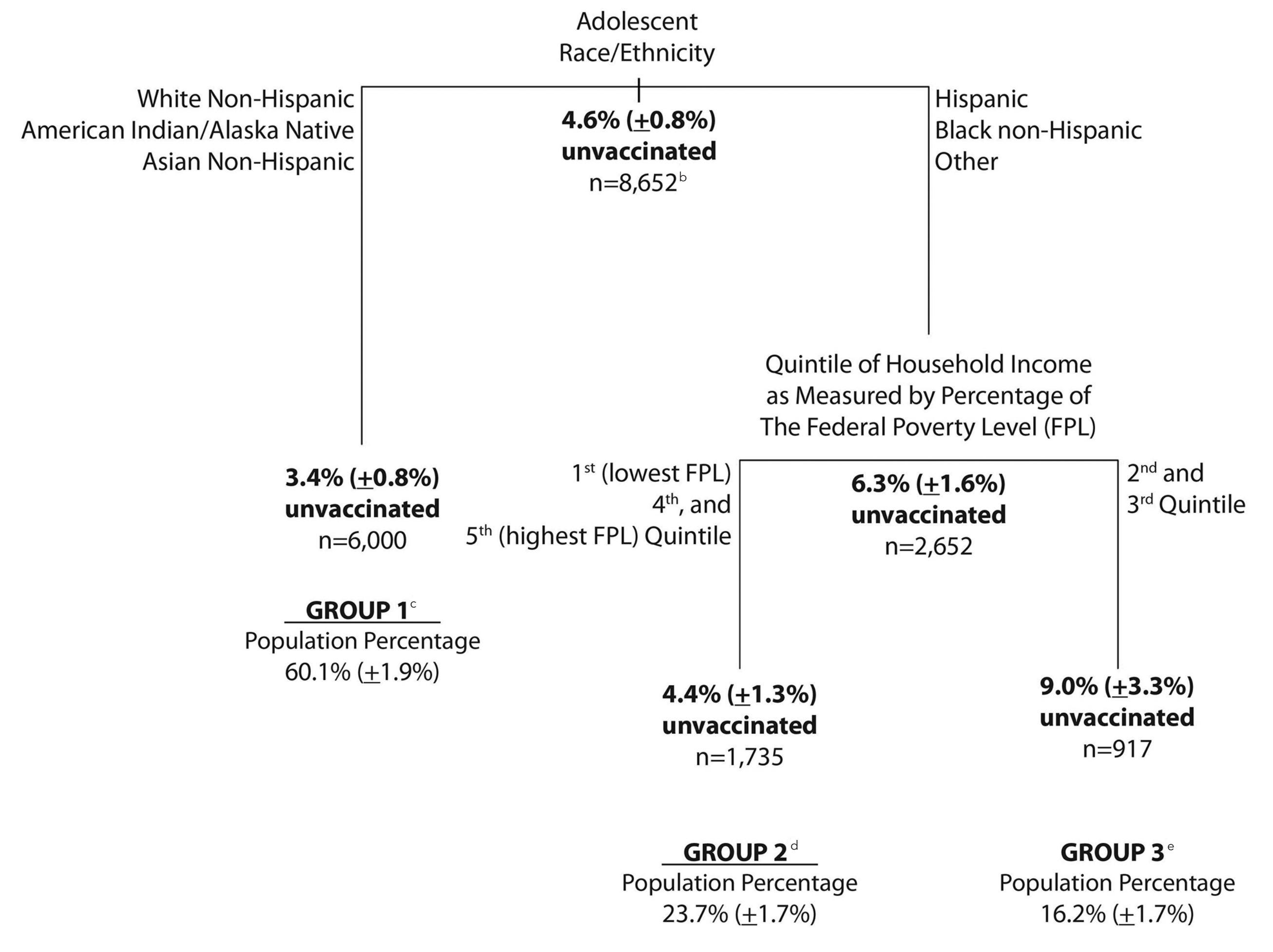
In the United States in 2013, 7.5% of 19- to 35-month-old children and 4.5% of 13- to 17-year-old adolescents were unvaccinated against measles. Our analyses found that unvaccinated children and adolescents clustered within certain U.S. counties disproportionately with respect to the fraction of the national populations of children and adolescents that those counties represent. Among 210 selected counties representing more than a majority of the U.S. population of children and adolescents, the percentage of children and adolescents unvaccinated against measles was as high as 18.0% and 9.1%, respectively. Additionally, the upper decile of the number of children and adolescents unvaccinated against measles ranged from several tens of thousands to several thousands. Our data and other data[45] highlight appreciable levels of measles susceptibility despite high levels of population immunity to measles nationally,[37,38] and suggest a substantial risk of large measles outbreaks with the potential for reestablishment of sustained measles transmission in these communities if measles is introduced.

Although the popular media[20,21] have suggested that parents' decision not to vaccinate their children against measles is a manifestation of the influence from the anti-vaccine movement, our analyses found that (*1*) the percentage of children who were unvaccinated that was attributable to factors other than parents' negative beliefs about the necessity of vaccines or vaccine refusal was 74.6% and (*2*) among all children unvaccinated against measles, 89.6% were deemed to have had missed opportunities because they were administered at least one dose of another recommended childhood vaccine after 12 months of age. Also, our study found that among all 19- to 35-month-old children unvaccinated against measles, only 34.6% had a parent who reported refusing vaccine doses. These findings suggest that missed opportunities to vaccinate are the main factor associated with not being vaccinated against measles and support the use of standards of care for pediatric immunization practices recommending that providers review children's vaccination records at every visit to assess the need for catch-up doses of measles and other vaccines.[46] Client reminder and recall systems[47,48] have been shown to be effective as part of a strategy to administer missed doses of all recommended vaccines.

Children affected by the measles resurgence of the late 1980s and early 1990s were often unvaccinated against measles because of financial or other barriers.[49] Similarly, our data suggest that compared with children who are vaccinated against measles, children who are unvaccinated against measles are significantly less likely to be covered by health insurance. Although children who are not covered by health insurance are entitled to publicly purchased vaccines at no cost from providers enrolled in their state's Vaccines for Children Program (VFC), VFC-entitled children and adolescents are known to live in lower socioeconomic conditions[50,51] and other barriers to vaccination may remain.[52]

Also, we found that a relatively small percentage (5.5%) of children had parents who believed that vaccines are not necessary to protect the health of children. Among those children, a relatively high percentage (33.6%) were unvaccinated against measles, and more than a majority (77.6%) had parents who deliberately refused the administration of vaccine doses for their children and held many unfavorable vaccine-related beliefs. Special advice is available to vaccination providers for communicating with parents who have unfavorable vaccine-related beliefs.[53,54] That advice

Figure 2. Percentage of 13- to 17-year-old unvaccinated adolescents, by independent factors associated with being unvaccinated determined from the multivariable recursive partitioning[a] analysis, 2010 NIS-Teen



[a]Recursive partitioning is a multivariable statistical method that creates a decision tree that attempts to classify members of the population based on several independent variables.

[b]*n* = unweighted sample size associated with the listed percentage

[c]Group 1 consists of adolescents who were either non-Hispanic white, American Indian/Alaska Native, or non-Hispanic Asian.

[d]Group 2 consists of adolescents who were either Hispanic, non-Hispanic black, or of another race/ethnicity and lived in a household with an annual income in the first, fourth, or fifth income quintile.

[e]Group 3 consists of adolescents who were either Hispanic, non-Hispanic black, or of another race/ethnicity and lived in a household with an annual income in the second or third income quintile.

includes listening to parents to understand and address their concerns and making a clear, strong, and unambiguous recommendation to vaccinate. It is especially important to keep the lines of communication open with those parents and to revisit the conversation on subsequent visits, because the majority of children who acquire measles in the United States have parents with unfavorable vaccine-related beliefs.[4,14,19] The higher risk may be due to (*1*) their traveling internationally or having international visitors from countries where measles continues to be endemic and/or (*2*) their clustering to a greater degree because of shared interests that may include participating in educational, social, and religious events with other children whose parents are like-minded.

Among adolescents, multivariable analysis found that vaccine-related parental beliefs were not independently associated with being unvaccinated, but that being Hispanic or non-Hispanic black was associated with a higher rate of being unvaccinated. These findings support the use of standards of care for pediatric immunization practices[46] recommending that providers review vaccination records at every adolescent visit and provide catch-up doses of measles and other vaccines for the purposes of increasing measles vaccination coverage among adolescents and for decreasing the racial/ethnic disparity our analysis identified.

Limitations

This study was subject to several limitations. First, while all of the annual surveys of the NIS and NIS-Teen used in our study collected data from households with a landline telephone, the 2011–2013 surveys also collected data from households with cell phones. Although the response rates of the telephone portions of the NIS and NIS-Teen can be low, the analysis described in the Appendix shows that NIS and NIS-Teen estimates compare favorably with vaccination coverage estimates from the National Health Interview Survey, which has a response rate of approximately 90%.[55] A further limitation was that some states with large populations (e.g., California) were allocated a disproportionately small percentage of the national NIS and NIS-Teen sample, thereby limiting our ability to obtain precise estimates among some counties where the population is large. A final limitation was that the NIS and NIS-Teen record dates on visits to primary HCPs only for dates on which vaccinations are administered. Other visit dates may have existed for a purpose other than vaccine administration. Because children and adolescents may have been eligible but were not administered routinely recommended vaccine doses at those visits, our estimates of the percentage who had a missed opportunity may be underestimated. However, as our point estimate for that percentage (89.6%) and the upper bound of its 95% CI (93.1%) were very high, the degree to which our statistics underestimated the percentage of children who had a missed opportunity could not be appreciable.

CONCLUSION

Through a successful measles vaccination program, the United States has eliminated year-round endemic measles transmission and the accompanying heavy annual health burden from measles and its complications.[56] However, sustaining elimination requires maintaining high measles vaccine coverage rates, particularly among preschool and school-aged children and among adolescents, to provide sufficiently high population immunity (>93%) to result in herd immunity,[3,57] which would decrease the risk of measles exposure and afford protection to those who cannot be vaccinated. In 2013, 17 states had <90% coverage for ≥1 measles-mumps-rubella dose for 19- to 35-month-old children.[37] Achieving and maintaining very high vaccination coverage for measles in all communities is the most effective strategy to reduce the risk of measles outbreaks and reestablish endemic disease transmission. Approaches to achieving higher vaccine coverage should account for our findings that (*1*) unvaccinated children and adolescents cluster within certain counties, (*2*) reasons other than parents' negative vaccine-related beliefs account for the majority of children and adolescents unvaccinated against measles, and (*3*) most children unvaccinated against measles have been administered doses of other recommended vaccines after 12 months of age. Strategies to address missed opportunities should be addressed.

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The NIS and NIS-Teen have been approved annually by the Ethics and Research Review Board of the National Center for Health Statistics.

The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

REFERENCES

1. Orenstein WA, Papania MJ, Wharton ME. Measles elimination in the United States. J Infect Dis 2004;189(Suppl 1):S1-3.
2. Black CL, Yankey D, Kolasa M. National, state, and local area vaccination coverage among children aged 19–35 months—United States, 2011. MMWR Morb Mortal Wkly Rep 2012;61(35):689-96.
3. Gay NJ. The theory of measles elimination: implications for the design of elimination strategies. J Infect Dis 2004;189(Suppl 1):S27-35.
4. Gastanaduy PA, Redd SB, Parker Fiebelkorn A, Rota JS, Rota PA, Bellini WJ, et al. Measles—United States, January 1–May 23, 2014. MMWR Morb Mortal Wkly Rep 2014;63(22):496-9.
5. Parker Fiebelkorn A, Redd SB, Gallagher K, Rota PA, Rota J, Bellini W, et al. Measles in the United States during the postelimination era. J Infect Dis 2010;202:1520-8.
6. Green M, Levin J, Michaels M, Vasbinder S, Voorhees R, Lute J, et al. Hospital-associated measles outbreak—Pennsylvania, March–April 2009. MMWR Morb Mortal Wkly Rep 2012;61(02):30-2.
7. Grigg MA, Brzezny AL, Dawson J, Rietberg K, DeBolt C, Linchangco P, et al. Update: measles—United States, January–July 2008. MMWR Morb Mortal Wkly Rep 2008;57(33):893-6.
8. Hassidim A, Waters-Montijo K, Wooten W, Sawyer M, Sidelinger D, Harriman K, et al. Outbreak of measles—San Diego, California, January–February 2008. MMWR Morb Mortal Wkly Rep 2008;57(08):203-6.
9. Sugerman DE, Barskey AE, Delea MG, Ortega-Sanchez IR, Bi D, Ralston KJ, et al. Measles outbreak in a highly vaccinated population, San Diego, 2008: role of the intentionally undervaccinated. Pediatrics 2010;125:747-55.
10. Cocoros N, Hernandez R, Harrington N, Rausch-Phung E, Schulte CR, Blog D, et al. Notes from the field: measles transmission associated with international air travel—Massachusetts and New York, July–August 2010. MMWR Morb Mortal Wkly Rep 2010;59(33):1073.
11. Notes from the field: measles outbreak—Hennepin County, Minnesota, February–March 2011. MMWR Morb Mortal Wkly Rep 2011;60(13):421.
12. Notes from the field: measles outbreak—Indiana, June–July 2011. MMWR Morb Mortal Wkly Rep 2011;60(34):1169.
13. Notes from the field: measles among U.S.-bound refugees from Malaysia—California, Maryland, North Carolina, and Wisconsin, August–September 2011. MMWR Morb Mortal Wkly Rep 2011;60(37):1281-2.
14. Kodagoda D, El Amin NA, Nguyen V, Holguin J, Zipprich J, Harriman K, et al. Measles outbreak associated with an arriving refugee—Los Angeles County, California, August–September 2011. MMWR Morb Mortal Wkly Rep 2012;61(21):385-9.
15. Measles—United States, 2011. MMWR Morb Mortal Wkly Rep 2012;61(15):253-7.
16. Notices to readers: final 2011 reports of nationally notifiable infectious diseases [published erratum appears in MMWR Morb Mortal Wkly Rep 2012;61(46):954]. MMWR Morb Mortal Wkly Rep 2012;61(32):624-37.
17. Gahr P, DeVries AS, Wallace G, Miller C, Kenyon C, Sweet K, et al. An outbreak of measles in an undervaccinated community. Pediatrics 2014;134:e229-39.
18. Smith PJ, Singleton JA. County-level trends in vaccination coverage among children aged 19–35 months—United States, 1995–2008. MMWR Surveill Summ 2011;60(4):1-92.
19. Centers for Disease Control and Prevention (US), National Center for Immunization and Respiratory Diseases, Division of Viral Diseases. Documentation and verification of measles, rubella and congenital rubella syndrome elimination in the Region of the Americas: United States national report. 2012 Mar 28 [cited 2014 Dec 10]. Available from: URL: http://www.cdc.gov/measles/downloads/report-elimination-measles-rubella-crs.pdf
20. Chen PW. Putting us all at risk for measles. New York Times 2014 Jun 26 [cited 2014 Dec 8]. Available from: URL: http://well.blogs.nytimes.com/2014/06/26/putting-us-all-at-risk-for-measles/?module=Search&mabReward=relbias%3As%2C%7B%222%22%22%3A%22RI%3A18%22%7D&_r=0
21. Public Broadcasting Service (PBS). The vaccine war. Frontline 2015 Mar 24 [cited 2015 Apr 6]. Available from: URL: http://www.pbs.org/wgbh/pages/frontline/the-vaccine-war
22. Smith PJ, Humiston SG, Marcuse EK, Zhao Z, Dorell CG, Howes C, et al. Parental delay or refusal of vaccine doses, childhood vaccination coverage at 24 months of age, and the Health Belief Model. Public Health Rep 2011;126 Suppl 2:135-46.
23. Gust DA, Strine TW, Maurice E, Smith P, Yusuf H, Wilkinson M, et al. Underimmunization among children: effects of vaccine safety concerns on immunization status. Pediatrics 2004;114:e16-22.
24. Salmon DA Moulton LH, Omer SB, DeHart MP, Stokley S, Halsey NA. Factors associated with refusal of childhood vaccines among parents of school-aged children: a case-control study. Arch Pediatr Adolesc Med 2005;59:470-6.
25. Smith PJ, Kennedy AM, Wooten K, Gust DA, Pickering LK. Association between health care providers' influence on parents who have concerns about vaccine safety and vaccination coverage. Pediatrics 2006;118:e1287-92.
26. Salmon DA, Sotir MJ, Pan WK, Berg JL, Omer SB, Stokley S, et al. Parental vaccine refusal in Wisconsin: a case-control study. WMJ 2009;108:17-23.
27. Freed GL, Clark SJ, Butchart AT, Singer DC, Davis MM. Parental vaccine safety concerns in 2009. Pediatrics 2010;125:654-9.
28. Szilagyi PG, Rodewald LE. Missed opportunities for immunizations: a review of the evidence. J Public Health Manag Pract 1996;2:18-25.
29. Smith PJ, Battaglia MP, Huggins VJ, Hoaglin DC, Roden A, Khare M, et al. Overview of the sampling design and statistical methods used in the National Immunization Survey. Am J Prev Med 2001;20(4 Suppl):17-24.
30. Jain N, Singleton JA, Montgomery M, Skalland B. Determining accurate vaccination coverage rates for adolescents: the National Immunization Survey-Teen 2006. Public Health Rep 2009;124:642-51.
31. Black CL, Wooten KG, Yankey D, Kolasa M. National and state vaccination coverage among children aged 19–35 months—United States, 2010. MMWR Morb Mortal Wkly Rep 2011;60(34):1157-63.
32. Black CL, Yankey D, Kolasa M. National, state, and local area vaccination coverage among children aged 19–35 months—United States, 2012. MMWR Morb Mortal Wkly Rep 2013;62(36):733-40.
33. Black CL, Yankey D, Kolasa M. National, state, and local area vaccination coverage among children aged 19–35 months—United States, 2012. MMWR Morb Mortal Wkly Rep 2013;62(36):733-40.
34. Dorell C, Stokley S, Yankey D, Liang JL, Markowitz L. National and state vaccination coverage among adolescents aged 13 through 17 years—United States, 2010. MMWR Morb Mortal Wkly Rep 2011;60(33):1117-23.
35. Dorell C, Stokley S, Yankey D, Jeyarajah J, MacNeil J, Markowitz L. National and state vaccination coverage among adolescents aged 13–17 years—United States, 2011 [published erratum appears in MMWR Morb Mortal Wkly Rep 2012;61(41):844]. MMWR Morb Mortal Wkly Rep 2012;61(34):671-7.
36. Robinette Curtis C, Yankey D, Jeyarajah J, Stokley S, MacNeil J, Hariri S. National and state vaccination coverage among adolescents aged 13–17 years—United States, 2012. MMWR Morb Mortal Wkly Rep 2013;62(34):685-93.
37. Elam-Evans LD, Yankey D, Singleton JA, Kolasa M. National, state, and selected local area vaccination coverage among children aged 19–35 months—United States, 2013. MMWR Morb Mortal Wkly Rep 2014;63(34):741-8.
38. Elam-Evans LD, Yankey D, Jeyarajah J, Singleton JA, Robinette Curis C, MacNeil J, et al. National, state, and selected local area vaccination coverage among adolescents aged 13–17 years—United States, 2013. MMWR Morb Mortal Wkly Rep 2014;63(29):625-33.
39. Smith PJ, Singleton JA. Vaccination coverage for selected counties: attainment of Healthy People 2010 goals and association with indices of access to care, economic conditions, and demographic composition. Public Health Rep 2008;123:155-72.
40. Rosenstock IM, Derryberry M, Carriger BK. Why people fail to seek poliomyelitis vaccination. Public Health Rep 1959;74:98-104.
41. Breiman L, Friedman J, Stone CJ, Olshen RA. Classification and regression trees. Boca Raton (FL): Chapman & Hall/CRC; 1984.
42. Zhang H, Singer B. Recursive partitioning in the health sciences. 2nd ed. New York: Springer; 1999.
43. Cole P, MacMahon B. Attributable risk percent in case-control studies. Brit J Prev Soc Med 1971;25:242-4.
44. Lumley T. Analysis of complex survey samples. J Stat Software 2004;9:1-19.

45. Lieu TA, Ray GT, Klein NP, Chung C, Kulldorff M. Geographic clusters in underimmunization and vaccine refusal. Pediatrics 2015;135:280-9.
46. National Vaccine Advisory Committee. Standards for pediatric immunization practices. MMWR Recomm Rep 1993;42(RR-5):001.
47. Szilagyi PG, Bordley C, Vann JC, Chelminski A, Kraus RM, Margolis PA, et al. Effect of patient reminder/recall interventions on immunization rates: a review. JAMA 2000;284:1820-7.
48. Saville AW, Beaty B, Dickinson LM, Lockhart S, Kempe A. Novel immunization reminder/recall approaches: rural and urban differences in parent perceptions. Acad Pediatr 2014;14:249-55.
49. Orenstein WA, Atkinson W, Mason D, Bernier RH. Barriers to vaccinating preschool children. J Health Care Poor Underserved 1990;1:315-30.
50. Smith PJ, Lindley MC, Rodewald LE. Vaccination coverage among U.S. children aged 19–35 months entitled by the Vaccines for Children Program, 2009. Public Health Rep 2011;126 Suppl 2:109-23.
51. Lindley MC, Smith PJ, Rodewald LE. Vaccination coverage among U.S. adolescents aged 13–17 years entitled by the Vaccines for Children Program, 2009. Public Health Rep 2011;126 Suppl 2:124-34.
52. Lannon C, Brack V, Stuart J, Caplow M, McNeill A, Bordley WC, et al. What mothers say about why poor children fall behind on immunizations. Arch Pediatr Adolesc Med 1995;149:1070-5.
53. Diekema DS; American Academy of Pediatrics Committee on Bioethics. Responding to parental refusals of immunization of children. Pediatrics 2005;115:1428-31.
54. Diekema DS. Improving childhood vaccination rates. N Engl J Med 2012;366:391-3.
55. Centers for Disease Control and Prevention (US). About the National Health Interview Survey [cited 2015 Apr 6]. Available from: URL: http://www.cdc.gov/nchs/nhis/about_nhis.htm
56. Bloch AB, Orenstein WA, Stetler HC, Wassilak SG, Amler RW, Bart KJ, et al. Health impact of measles vaccination in the United States. Pediatrics 1985;76:524-32.
57. Fine P, Eames, Heymann DL. "Herd immunity": a rough guide. Clin Infect Dis 2011;52:911-6.

Appendix. Comparisons of vaccination coverage estimates from the NIS and NIS-Teen with estimates from the National Health Interview Survey, 2012

From 2010 to 2013, ranges of response rates of the National Immunization Survey (NIS)[a] and NIS-Teen[b] landline telephone surveys were 62%–65% and 51%–58%, respectively, and 25%–31% and 22%–24%, respectively, for the 2011–2013 NIS and NIS-Teen cell phone surveys. The ranges of the percentages of interviews providing consent and adequate provider-reported vaccination histories were 63%–72% and 55%–59%, respectively, for the NIS and NIS-Teen landline surveys, and 60%–66% and 54%–56%, respectively, for the NIS and NIS-Teen cell phone surveys.

In 2012 and 2013, approximately 80% of the NIS and NIS-Teen samples were obtained from a sampling frame of cell phone numbers, and approximately 20% of the samples were obtained from a sampling frame of landline telephone numbers. Because of the lower response rate that was anticipated for the portion of the samples obtained from the cell phone sampling frame, in 2012, the Centers for Disease Control and Prevention (CDC) conducted a study to compare vaccination coverage rates estimated from the 2012 NIS with vaccination coverage rates estimated from the National Health Interview Survey (NHIS), which was augmented to obtain provider-reported vaccination coverage of 19- to 35-month-old children and 13- to 17-year-old adolescents sampled by the NHIS in 2012. The response rate for the NHIS is typically about 90%.[c]

Results from the study showed that among 19- to 35-month-old children in 2012, the estimated percentage of children administered zero doses of the measles-mumps-rubella (MMR) vaccine was 1.6 (95% CI 0.0, 3.9) percentage points higher (9.2% vs. 7.6%) as estimated by the NIS, but that difference was not significantly different from zero ($p=0.42$). Also, among 13- to 17-year-old adolescents in 2012, the estimated percentage of teens administered zero doses of the MMR vaccine was 2.6 (95% CI 1.4, 3.8) percentage points lower (4.7% vs. 7.3%) as estimated by the NIS-Teen, and it was statistically significant ($p<0.05$) primarily because of the large sample sizes of both the NIS-Teen ($n=19,199$) and NHIS ($n=3,070$) samples. These results were typical of the results observed in the CDC study and suggest that although the response rates of the NIS and NIS-Teen may seem low, national estimates of vaccination coverage are very comparable with those obtained from the NHIS, a survey based on sampling households that has a very high response rate.

[a]Smith PJ, Battaglia MP, Huggins VJ, Hoaglin DC, Roden A, Khare M, et al. Overview of the sampling design and statistical methods used in the National Immunization Survey. Am J Prev Med 2001;20(4 Suppl):17-24.

[b]Jain N, Singleton JA, Montgomery M, Skalland B. Determining accurate vaccination coverage rates for adolescents: the National Immunization Survey-Teen 2006. Public Health Rep 2009;124:642-51.

[c]Centers for Disease Control and Prevention (US). About the National Health Interview Survey [cited 2015 Apr 6]. Available from: URL: http://www.cdc.gov/nchs/nhis/about_nhis.htm

NIS = National Immunization Survey