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State level vaccination systems: Is there a correlation of success for childhood and adolescent immunizations?

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An abstract of
A thesis submitted to the Faculty of the
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Abstract

State level vaccination systems: Is there a correlation of success for childhood and adolescent immunizations?
By Sarah K. McKinstry

Objective: To evaluate whether states' childhood vaccination coverage rates (≥4 doses of DTaP, ≥3 doses of poliovirus vaccine, ≥1 doses of measles vaccine, full series of Hib (depending on product), ≥3 doses of HepB, ≥1 doses of varicella vaccine, and ≥4 doses of PCV) relative to the national average, are associated with adolescent vaccination coverage (≥1 doses of Tdap and ≥1 doses of MenACWY).

Methods: A cross sectional analysis of adolescents, aged 13 to 17 years, with adequate provider verified data from all 50 states and Washington, D.C. (n=19,199) using data from the 2012 National Immunization Survey-Teen. The main outcome measure is individual adolescent vaccination coverage defined as not up-to-date (UTD) for Tdap and MenACWY, UTD for Tdap or MenACWY, or UTD for Tdap and MenACWY.

Results: A state having at or above average childhood vaccination coverage was not significantly more likely to have at or above average adolescent vaccination coverage (PPV: 59.26%, Kappa = 0.217). When comparing adolescents UTD for Tdap and MenACWY to adolescents not UTD for Tdap or MenACWY, the odds of living in a state with at or above average childhood vaccination coverage was 0.87 (95% CI: 0.74, 1.03). The adjusted odds ratio was also not statistically significant (aOR: 0.85; 95% CI: 0.69, 1.04). Comparing adolescents UTD for Tdap or MenACWY to adolescents not UTD for Tdap or MenACWY, the odds of living in a state with at or above average childhood vaccination coverage was 0.94 (95% CI: 0.78, 1.1) and the adjusted odds ratio was 0.89 (95% CI: 0.70, 1.13).

Conclusions: This analysis suggests that there is not a strong correlation of success in achieving high rates of early childhood immunization with achieving high rates of immunization in the adolescent population. Adolescents who live in states with at or above average childhood vaccination coverage do not appear more likely to receive recommended adolescent vaccinations than adolescents who live in states with below average childhood vaccination coverage rates. There is a clear need for policy tailored to meet the specific needs of adolescents, which have proven to be different from that among young children.

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Introduction:

Despite the increasing trend of national adolescent vaccination coverage rates, many states are not meeting Healthy People 2020 (HP2020) targets (1, 2). The Advisory Committee on Immunization Practices (ACIP) recommends adolescents (ages 11-12) receive 1 dose of tetanus, diphtheria, and acellular pertussis vaccine (Tdap), 1 dose of meningococcal conjugate vaccine (MenACWY), 3 doses of human papillomavirus vaccine (HPV), annual seasonal influenza vaccine, and any other overdue vaccines (1). In 2012, the national coverage estimate for Tdap (84.6%) among 13-17 year old adolescents exceeded the HP2020 target (80%), however adolescent vaccination coverage rates were still lower than those achieved for vaccines recommended during the first two years of life, indicating a major gap in vaccine delivery to adolescents versus young children (1, 3). Evaluation of vaccination coverage rates at the state level reveals heterogeneity in protection and identifies a significant proportion of states failing to meet HP2020 targets (80%) for both ≥1 doses of Tdap and ≥1 doses of MenACWY in 2012 (1). Since state legislatures are responsible for vaccination policy, including vaccination mandates and related exemptions, as well as the ease of obtaining exemptions, in this study we evaluated vaccination coverage rates at the state level rather than at the national level (4, 5). Recognizing factors associated with state level adolescent vaccination coverage is important to drive evidence-based policy specifically targeted to improve adolescent coverage rates and to minimize the number of adolescents susceptible to disease (4).

Many factors have been found to impact adolescent vaccination uptake. Studies have investigated middle school vaccination requirements (6), Medicaid reimbursement (7), clinical and demographic factors (8), organization-level correlates (9, 10), attitudes and decision making dynamics (11), and missed opportunities (12, 13) individually. State level vaccination systems need to be considered to better understand, overcome, and reduce the barriers to adolescent vaccination. To our knowledge, no study has investigated correlations between state-level early childhood

vaccination coverage rates and adolescent vaccination coverage. We used state level childhood vaccination coverage as a proxy for a state's ability to overcome barriers to childhood vaccination. We hypothesized that if these vaccination systems were the same for providing vaccines to adolescents, then childhood vaccination coverage rates should also correlate with a state's ability to achieve high vaccination coverage among adolescents.

In this study, we analyzed data from the 2012 National Immunization Survey-Teen (NIS-Teen) to evaluate whether states' childhood vaccination coverage rates, relative to the national average, are associated with adolescent vaccination coverage. We focused on the receipt of Tdap and MenACWY among adolescents.

Methods:

We examined the association between adolescent up-to-date (UTD) status for Tdap and MenACWY and living in a state with at or above average childhood vaccination coverage, using the 2012 NIS-Teen data available from the CDC (14). The methodology of the NIS-Teen has been previously described (14-16). Briefly, random digit dialing was used to identify households with 13-17 year old adolescents, and routine vaccination coverage was measured and verified by the adolescent's healthcare provider. The survey provided a stratified national probability sample of households in the United States. The parent/guardian provided all socio-demographic information. We included 19,199 adolescents (51.2% male) with adequate provider verified data from all 50 states and Washington, D.C.

The main exposure in the study is childhood vaccination coverage in an adolescent's state of residence, classified as a binary variable defined as either living in a state at or above the national average or below the national average for childhood vaccination. Coverage with the combined childhood series (≥4 doses of DTaP, ≥3 doses of poliovirus vaccine, ≥1 doses of measles vaccine, full series of Hib (3 or 4 doses, depending on product), ≥3 doses of HepB, ≥1 doses of varicella vaccine, and ≥4 doses of PCV) was used to provide a strict classification for a state's ability to vaccinate all children. Childhood vaccination coverage was collected from the 2012 CDC report of state level vaccination coverage rates among 19-35 month olds based on results from the 2012 National Immunization Survey (3).

The main outcome in the study is individual adolescent vaccination coverage, a 3-level variable where each adolescent was defined as (a) not UTD for Tdap and MenACWY, (b) UTD for Tdap or MenACWY, or (c) UTD for Tdap and MenACWY. Adolescents' vaccination status was based on the NIS-Teen individual UTD variables for each vaccine classified as 'UTD' or 'Not UTD'. HPV was not included in this analysis due to low state level coverage estimates by sex,

known health disparities, and major differences in reasons against vaccinating for HPV compared to Tdap and MenACWY on the individual level (17-19).

Potential confounding variables that were included (age, sex, provider facility type, race/ethnicity, mother's education status, and poverty status) were categorized by the NIS-teen. Race/ethnicity and poverty status were included because there are known disparities in adolescent vaccination coverage across poverty levels and racial/ethnic groups (1). Unknown, refused and missing data were not included in this analysis. The variable for provider facility type was reclassified due to small numbers. Adolescents who received vaccinations at a hospital were reclassified to the 'other' category, which included all STD/School/Teen Clinics or other facilities.

Geospatial analysis was conducted in ArcMap 10.1 (ESRI, Redlands, California). The 2013 cartographic boundary shapefiles were accessed from the U.S. Census Bureau (20). States were categorized into regions: Northeast, Midwest, South and West as defined by the U.S. Census Bureau. Only geographic regions with vaccination coverage data were shown. The median vaccination coverage rate for adolescent and childhood vaccination coverage (65.1%, 68.4%, respectively) was used from the main exposure and outcome variable (UTD Tdap and MenACWY) to categorize each state as either at or above average or below average. States with at or above average childhood and adolescent vaccination coverage were referred to as 'above', states with below average childhood and adolescent vaccination coverage were referred to as 'below', and states that switched categories between childhood and adolescent vaccination were referred to as 'crossover'. Screening measures (i.e. positive predictive value, kappa, likelihood ratio) were calculated to analyze states with exposure to at or above average childhood vaccination coverage among states with at or above average adolescent vaccination coverage compared to states with below average adolescent vaccination coverage illustrating the crude state level correlation.

Statistical analysis was conducted in SAS 9.4 (SAS Institute, Cary, NC) using survey method specific procedures with weights provided by the NIS-Teen dataset. Rao-Scott Chi-Square tests were performed for categorical variables to account for complex sample design. Crude and adjusted odds ratios were modeled using polytomous logistic regression. A p-value of <0.05 was considered statistically significant.

Because the data used were previously collected and publicly available de-identified data, our research was considered non-human subjects research and did not require Emory IRB approval.

Results:

Nationally, 16 (31.4%) states were classified as 'above' and the Northeast region had the highest proportion of states classified in this category (66.7%) (Figure 1). The Western region had the highest proportion of states classified as 'below' (46.2%), yet 15 (29.4%) states nationally were classified in this category. The 'crossover' category was comprised of 9 (17.6%) states that were classified as below average for childhood vaccination coverage yet at or above average for adolescent vaccination coverage, and 11 (21.6%) states that were classified as at or above average for childhood vaccination coverage but below average for adolescent vaccination coverage. The South had the highest proportion of states classified as 'crossover' (47.1%) of which 6 (75.0%) states were classified as at or above average for childhood vaccination coverage but below average for adolescent vaccination coverage. The Midwest region which had the lowest proportion of states classified as 'crossover' (25.0%), of which 2 (66.7%) states were classified as at or above average for childhood vaccination coverage but below average for adolescent vaccination coverage. Based on these proportions, a state having at or above average childhood vaccination coverage was not significantly more likely to have at or above average adolescent vaccination coverage (PPV: 59.26%, Kappa = 0.217, Positive Likelihood Ratio: 1.51).

Overall, major differences were not observed between vaccination coverage rates for age, sex, or race/ethnicity (Table 1). A greater proportion of adolescents who had a check-up at 11-12 years of age were UTD for Tdap and MenACWY than among adolescents who had not (73.0% and 52.3%, respectively). Only 8.8% of adolescents who had a check-up were not UTD for Tdap or MenACWY, whereas 20.3% of adolescents who had not had a check-up were not UTD for either vaccine. Adolescents categorized with a household poverty status >$75,000 annual income had lower rates of not being UTD for Tdap or MenACWY (7.9%) compared to the group between 'below poverty' and 'above poverty (> $75K)' (12.8%), and those below poverty (11.6%).

Adolescents who used 'All Public' or 'Other' facility types had higher rates of not being UTD for Tdap or MenACWY (17.2, 15.5%, respectively) than adolescents who used private or mixed facilities (8.0%, 9.3%, respectively).

When comparing adolescents UTD for Tdap and MenACWY to adolescents not UTD for Tdap or MenACWY, the odds of living in a state with at or above average childhood vaccination coverage was 0.87 (95% CI: 0.74, 1.03). The adjusted odds ratio was also not statistically significant (aOR: 0.85; 95%CI: 0.69, 1.04). Comparing adolescents UTD for Tdap or MenACWY to not UTD for Tdap or MenACWY, the odds of living in a state with at or above average childhood vaccination coverage was 0.94 (95% CI: 0.78, 1.1) and the adjusted odds ratio was 0.89 (95% CI: 0.70, 1.13).

Discussion:

This analysis suggests that there is not a strong correlation of success in achieving high rates of early childhood immunization with achieving high rates of immunization in the adolescent population. Adolescents who live in states with at or above average childhood vaccination coverage do not appear more likely to receive recommended adolescent vaccinations than adolescents who live in states with below average childhood vaccination coverage rates.

Barriers and solutions to adolescent vaccination have been investigated and proposed according to age (21-23). A study on national health care visit patterns of adolescents concluded that it is better to target younger adolescents, since they still go to the pediatrician for preventive visits and both sexes have a similarly high volume of visits (9, 23). In our results, we saw no difference in adolescent coverage across age and 93% of adolescents received a check-up at 11-12 years of age. However, only 73% of the adolescents who received a check up were UTD for Tdap and MenACWY, indicating potential missed opportunities and possibility for improvement. In 2008, the National Vaccine Advisory Committee (NVAC) suggested investigating additional venues such as pharmacies, family planning and sexually transmitted infection clinics, obstetrician– gynecologist offices, emergency departments, teen clinics and health departments to administer adolescent vaccinations (24). In this study, 23% of teens received vaccinations from 'Mixed' facilities and nearly 10% of teen received vaccinations from 'Other' facilities. Therefore, improving vaccination delivery in these non-traditional venues, outside of the medical home, could catch teens that weren't vaccinated at the 11-12 year old check up or that didn't have one. In future NIS surveys, it may be beneficial to collect the specialty of the adolescent's provider in order to assess if certain specialties are more likely to deliver certain vaccines and how that is associated with state-level policy (21, 23).

States are responsible for managing vaccine delivery, cost, and financing (21). Programs such as Vaccines for Children (VFC) benefit adolescents in the lowest income category, and adolescents

in the highest income category have access to private facilities with more resources, which leaves a gap in access for adolescents in the middle who may have different barriers to access that remain unaddressed (25). In our analysis, the proportion of adolescents categorized in the middle poverty group, 'above poverty level (≤ $75K)', who were not UTD for Tdap or MenACWY was substantially lower than in 'above poverty level (> $75K)' categories. The rate in the middle poverty group was similar to that in the group below poverty. Thus, interventions to address this middle group may require efforts such as mitigating the cost of vaccines since VFC may not cover these adolescents. Considering the high cost of adolescent vaccines (24), future studies should evaluate the impact of expanding state-level programs to improve adolescent vaccination at the recommended 11-12 years of age check-up across poverty levels and to ensure that current efforts to ensure equal access to vaccination aren't leaving adolescents in the middle behind.

One strategy adopted by several states to improve vaccination coverage in response to mandatory reporting of annual vaccination coverage is the implementation of statewide immunization registries (8, 26-28). Findings from a retrospective study of Michigan registry data found higher adolescent vaccination coverage levels among individuals who received childhood immunizations by age 6 and among those who received vaccines at private facilities (8). Based on our null results, this association may not be related to the early childhood immunization systems, and may be more of a function of individual level health care seeking as opposed to policies in place at the state level across the childhood and adolescent period as illustrated by the regional trends we observed. Furthermore, different providers may use registries differently, and as older adolescents transition out of pediatric offices and seek care from other specialties longitudinal follow-up may be lost. The complexity of health care utilization by adolescents must be factored into the implementation of state immunization registries. Future research should investigate which providers outside of the medical home and which providers across different specialties should be given access,

education, and training to best utilize these immunization information systems and how states can improve linked healthcare quality measures and reporting (24).

Another proposed strategy is for states to expand the use of AFIX (Assessment, Feedback, Incentives, and eXchange), a CDC recommended program that has demonstrated success at improving childhood coverage rates, to include adolescent vaccination coverage (29). A study in North Carolina observed a short term gain in coverage among 11-12 year olds (29) and another study observed small increases in delivery of targeted adolescent vaccinations over a one-month period in federally qualified health centers (30). While the observed gains in coverage were modest compared to those seen for childhood vaccination rates, additional studies should evaluate the potential of expanding AFIX for adolescent coverage and the varied use of AFIX for both childhood and adolescent coverage by states.

It is important to note that this study had several limitations. While the NIS-Teen is designed to provide precise national level estimates of 13-17 year old adolescents in the United States, estimates for state and local areas must be interpreted with caution because of their smaller sample sizes (3). Telephone surveys may be biased because of non-response and households without telephones; however, weighting was used to account for this (14). Vaccination coverage rates may have been underestimated because of our exclusive use of provider reported vaccination histories; however, this is preferred over relying on vaccination history based on parental recall, which could be a source of bias (14).

These preliminary findings suggest that future National Immunization Surveys statistically powered to detect state level differences would be useful for states to evaluate policy and compare immunization coverage progress towards HP2020 goals. Since we observed nearly a third of the states with below average coverage for both child and adolescent vaccination coverage, more research in trying to understand the cause of this problem and potential solutions is needed. Future

analysis should consider HPV initiation and completion for both sexes, and examine trends in vaccine related characteristics and uptake over time since 2008, the first year NIS-Teen could be used to make state-specific estimates on vaccination coverage (24). There is a clear need for policy tailored to meet the specific needs of adolescents, which have proven to be different from that among young children. AFIX is a strategy that has demonstrated success and should be carefully adapted to improve adolescent vaccine uptake.

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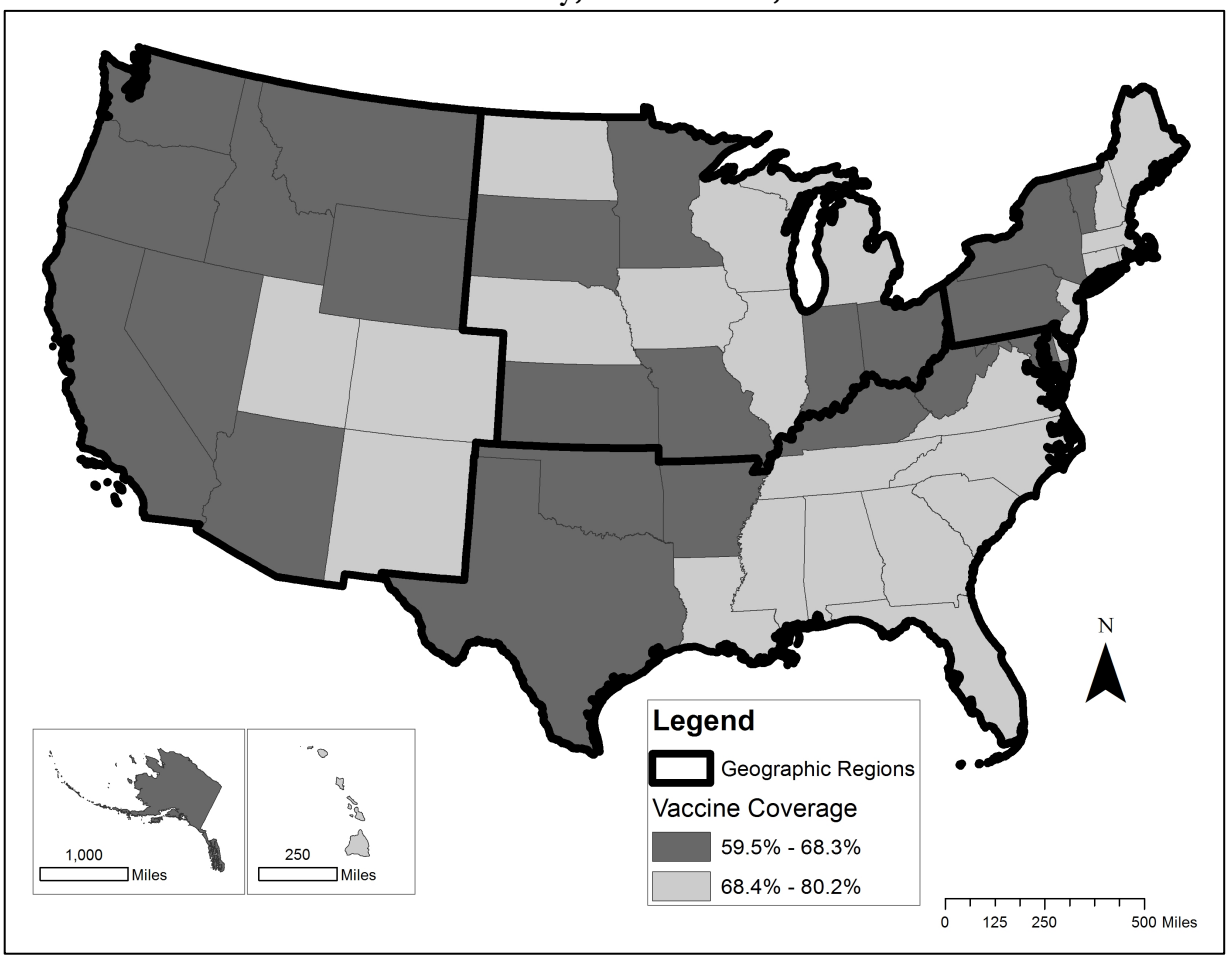
Figure 1a

Estimated vaccination coverage among children aged 19-35 months, by vaccination series and state – National Immunization Survey, United States, 2012

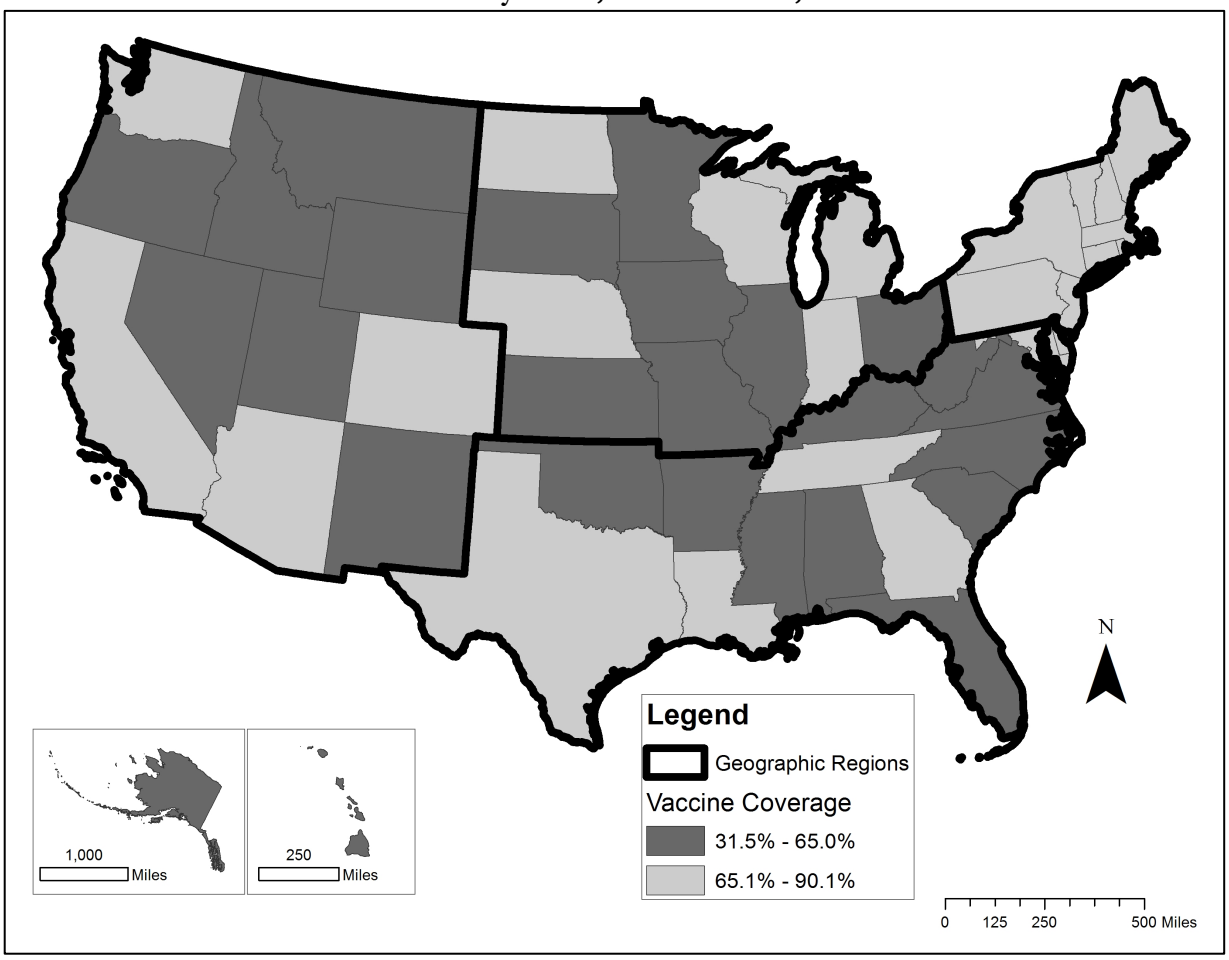


Combined childhood series: ≥4 doses of DTaP, ≥3 doses of poliovirus vaccine, ≥1 doses of measles vaccine, full series of Hib (3 or 4 doses, depending on product), ≥3 doses of HepB, ≥1 doses of varicella vaccine, and ≥4 doses of PCV; Vaccine coverage categorized as below average (59.5%-68.3%) or at or above average (68.4%-80.2%)

States categorized into regions: Northeast, Midwest, South and West (including Alaska and Hawaii) as defined by the U.S. Census Bureau

Figure 1b

Estimated vaccination coverage among teens aged 13-17 years, by vaccination series and state – National Immunization Survey-Teen, United States, 2012



Combined teen series: ≥1 dose of Tdap (on or after age 10 years), ≥1 doses of MenACWY; Vaccine coverage categorized as below average (31.5%-65.0%) or at or above average (65.1%-90.1%)

States categorized into regions: Northeast, Midwest, South and West (including Alaska and Hawaii) as defined by the U.S. Census Bureau

Table 1. Vaccination coverage of teens aged 13-17 years by selected characteristics from the National Immunization Survey-Teen (NIS-Teen), United States, 2012[a]

Characteristics[b]	Not UTD Tdap or MenACWY[d]	UTD Tdap or MenACWY	UTD Tdap and MenACWY	P-values
Childhood vaccination coverage rate in teen's state of residence[c]				0.16
At or above the national average	10.3	19.2	70.5	
Below the national average	11.5	20.2	68.3	
Age				0.91
13	11.6	19.0	69.4	
14	10.4	20.1	69.5	
15	10.2	19.4	70.4	
16	11.3	19.0	69.7	
17	10.9	20.8	68.3	
Sex				0.05
Female	10.4	20.9	68.7	
Male	11.3	18.4	70.2	
Race/Ethnicity				0.01
Hispanic	10.0	17.1	73.0	
NH white	11.4	21.4	67.2	
NH black	11.5	17.5	71.1	
NH other + multiple race	8.8	18.3	72.9	
Had a check-up at 11-12 years of age				<.0001
Yes	8.8	18.3	73.0	
No	20.3	27.5	52.3	
Education level of the mother				<.0001
Less than 12 years	10.9	17.9	71.2	
12 years	13.5	19.9	66.7	
More than 12 years, non college graduate	11.7	21.3	67.1	
College graduate	8.4	18.9	72.7	

Poverty Status				<.0001
Below Poverty level	11.6	19.9	68.4	
Above Poverty level (≤ $75K)	12.8	21.3	65.9	
Above Poverty level (> $75K)	7.9	17.8	74.3	
Provider facility type				<.0001
All Public	17.2	24.6	58.2	
All Private	8.0	16.3	75.7	
Mixed	9.3	23.4	67.3	
Other[e]	15.5	18.1	66.5	

Abbreviations: Tdap, tetanus toxoid, reduced diphtheria toxoid and acellular pertussis vaccine, adult/adolescent formulation; MenACWY, meningococcal conjugate vaccine; HPV, human papillomavirus vaccine; VFC, vaccines for children program; DTaP, diptheria, tetanus toxoid, and acellular pertussis vaccine, child formulation; Hib, Haemophilus influenzae type b; HepB, hepatitis B; PCV, Pneumococcal vaccine; UTD, up to date; NH, non-hispanic; STD, sexually transmitted disease

[a]Teens (N=19,199) in the 2012 NIS-Teen were born during January 6, 1994-February 18, 2000

[b]Categorical variables as percentage; provided by parent/guardian or provider; Rao-Scott Chi-Square test; statistically significant p-values <0.05

[c]Teens living in a state with childhood vaccination coverage at or above the national average or below the national average for the combined childhood series (≥4 doses of DTaP, ≥3 doses of poliovirus vaccine, ≥1 doses of measles vaccine, full series of Hib (3 or 4 doses, depending on product), ≥3 doses of HepB, ≥1 doses of varicella vaccine, and ≥4 doses of PCV)

[d]Referred to as routine for teens: ≥1 doses of Tdap (on or after age 10 years) and ≥1 doses of MenACWY

[e]All STD/School/Teen Clinics, Hospital, or Other Facilities

Table 2. Crude and adjusted odds ratios (OR) and 95% confidence intervals (95% CI) of vaccination coverage of teens aged 13-17 years, by state childhood vaccination coverage from the National Immunization Survey-Teen (NIS-Teen), United States, 2012

	Crude OR (95% CI)				Adjusted OR[a] (95% CI)			
Characteristic	**UTD Tdap and MenACWY /Not UTD Tdap or MenACWY**		**UTD Tdap or MenACWY / Not UTD Tdap or MenACWY**		**UTD Tdap and MenACWY /Not UTD Tdap or MenACWY**		**UTD Tdap or MenACWY / Not UTD Tdap or MenACWY**	
Childhood vaccination coverage rate in teen's state of residence								
At or above the national average	0.87	(0.74, 1.03)	0.94	(0.78, 1.15)	0.85	(0.69, 1.04)	0.89	(0.70, 1.13)
Below the national average	1.00	(Ref)	1.00	(Ref)	1.00	(Ref)	1.00	(Ref)

[a]Adjusted for check-up, mother's education, poverty, provider facility type, race/ethnicity, and sex