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State Vaccination Policies And Coverage For Adolescent Vaccines In The United States, 2017

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Abstract

Background The wide-ranging nature of state vaccination requirements for school entry allows for suboptimal coverage of adolescent vaccination as well as missed opportunities where some adolescent vaccinations are received but not all of them. Variation exists both in the types of exemptions that are allowed and the process that is required to obtain an exemption. State-level policies have been shown to be associated with childhood vaccination coverage, but far fewer studies have examined adolescent vaccine coverage.

Methods HPV, MenACWY, and Tdap vaccine receipt and demographic data from the 2017 National Immunization Survey-Teen (NIS-Teen) Public Use Dataset were combined with data on school entry requirements and allowable exemptions from the Immunization Action Coalition. Ease of exemption was determined through ranking of exemption criteria collected from state immunization websites. Univariate logistic regressions and multivariable logistic regressions adjusting for demographic variables associated with vaccine outcomes were run to determine the relationship of missed opportunities and vaccine initiation with state vaccine policies.

Results Having a vaccine requirement for a specific adolescent vaccine was associated with higher odds of initiating vaccination for that specific vaccine and lower odds of having a missed opportunity for that vaccine. However, there was no association between requirements for an adolescent vaccine and coverage for other non-targeted vaccines. While there were significant associations between the ease of exemption requirement outcomes and the number of mechanisms to obtain a non-medical exemption with some vaccination outcomes, there was not a consistent trend in the results.

Conclusions The ease of obtaining a vaccine exemption seems to have less of an impact on adolescent vaccination than the presence of a school entry requirement does. Future research that seeks to understand the limited association between exemption policies and adolescent vaccination will be important to determine optimal state policies. School entry requirements still remain the strongest policy means for increasing coverage although their spillover effects are limited.

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Introduction

In additional to annual influenza vaccination, there are three vaccines that are recommended to be given routinely to adolescents: the tetanus, diphtheria, and acellular pertussis vaccine (Tdap), recommended since 2005; the quadrivalent meningococcal vaccine (MenACWY), recommended as one dose since 2005 and recommended with a booster dose since 2010; and the human papillomavirus vaccine (HPV), recommended for females since 2006 and males since 2011.[1,2,3] To decrease incidence of these diseases, a goal was set in the Healthy People 2020 objectives to achieve 80% coverage of these vaccines. Though this goal has been met for the Tdap vaccine, with 88% coverage among 13 to 17-year-olds, and the MenACWY vaccine, with 82.2% of 13 to 17-year-olds having received at least one dose, for the HPV vaccine, up-to-date coverage is only at 43.4% among 13 to 17-year-olds.[4]

HPV coverage has remained lower than the other adolescent vaccines for a number of reasons. One is the widespread lack of school entry requirements for the vaccine. Despite more than 10 years having passed since the initial recommendation of the vaccine, only 3 states and jurisdictions currently have school entry requirements, with some allowing for broad exemptions, and political pushback has prevented requirements being passed in other states.[5] Low HPV vaccination is also associated with provider and parent characteristics. Providers were less likely to perceive HPV vaccination as urgent and were less likely to take time to respond to parental pushback about the HPV vaccine while parents often cited lack of provider recommendations as a reason not to have their children receive the vaccine.[6]

Because of the wide-ranging school entry requirements for adolescent vaccines, missed opportunities can occur where at least one of the three vaccines are administered to an eligible adolescent but the others are not at the same visit. These missed opportunities may be contributing to the lower coverage of HPV vaccination. A recent study in Kansas found of the

sixth and seventh graders who received the Tdap booster between 2013-2015, 53-82% did not receive an HPV vaccine and 36-47% did not receive a MenACWY vaccine at the same time.[7] Another study in Washington observed that 33% of eligible girls and 39% of eligible boys had at least one missed opportunity for HPV vaccine series initiation between 2006 and 2013.[8]

Previous studies have lent some credence to using the expansion of school entry vaccine requirements as a possible strategy for increasing coverage and reducing missed opportunities. This would likely occur through both direct and spillover effects. One study found that states with Tdap booster and meningococcal school entry requirements were associated with larger spillover increases in HPV vaccination coverage while states that did have HPV vaccine school entry requirements saw no higher coverage than states that did not for the other adolescent vaccines.[9] However, there is the possibility that the spillover effects may begin to diminish over time.

Another possible strategy for increasing coverage and reducing missed opportunities is increasing the difficulty of the process of obtaining a non-medical exemption. While states have policies that require certain vaccines for school entry, most states also have policies that allow for non-medical exemptions to these requirements. Policies include both allowable exemption types (religious and/or philosophical) and different procedures for obtaining exemptions that vary in degree of difficulty to obtain. Some possible difficult procedures of obtaining a vaccine exemption include requiring notarization on the exemption form or needing to renew the exemption annually. In some states, it is easier to receive exemptions than meet the vaccine requirement.[10] By assessing the ease of obtaining an exemption, we are able to examine how this may further impact a decision to opt out of HPV and/or MenACWY vaccination.

Studies of the association between exemption policies and their impact on coverage and missed opportunities have largely been focused on childhood vaccines but not adolescent vaccines. While there has been research showing an increased incidence of exemptions and of vaccine-preventable diseases in areas with more expansive exemption policies, they have been focused on vaccines given for kindergarteners, such as the measles vaccine.[11,12] For adolescent vaccines, some research has been done to look at the impact of area-based factors influence HPV vaccination.[13,14,15] One study did look at the impact of state HPV vaccine policies on HPV vaccine coverage, finding completion of HPV vaccine series was associated with having HPV vaccine school entry requirements while there was little variation in non-medical exemption types among the states with the highest and lowest HPV vaccine coverage.[16] Exemption policies have largely not been explored in the realm of adolescent vaccines, though.

This is one of the first studies to explore which components of state vaccine policies, including exemptions, have the greatest impact on increasing coverage and reducing missed opportunities. We hoped to assess what was the association between both overall coverage and missed opportunities for HPV and/or MenACWY vaccination, here defined as receipt of one of the adolescent vaccines, Tdap, MenACWY, or HPV, but not MenACWY or HPV, and various components of state vaccination policies, such as school entry vaccine requirements, allowable non-medical exemption types, and ease of receiving such an exemption.

Our first hypothesis was that those residing in states that have vaccine requirement policies for MenACWY and/or HPV vaccination will be less likely to have a missed opportunity for HPV or MenACWY vaccination and more likely to have higher coverage. Our second hypothesis was that those residing in states that have easier means of getting an exemption for the other adolescent vaccines will be more likely to have lower coverage and have higher odds of

missing an opportunity for HPV or MenACWY vaccination compared to those residing in states with stricter requirements around getting exemptions. By combining these various factors, we hoped to provide a unique perspective to the larger discussion on how state requirements and exemptions could impact adolescent vaccination.

Materials and Methods

Data sources

Immunization, demographic, and geographic data were collected from the public use data for the National Immunization Survey-Teen (NIS-Teen) from 2017, the latest year from which that data was publicly available. NIS-Teen is a cross-sectional population-based national survey. The target population is non-institutionalized adolescents aged 13-17 years living in United States households at the time of the interview. It consisted of two parts: a household telephone survey done through random digit dialing and a mail survey of vaccination providers named and approved to be contacted by those who answered the telephone survey. Each household provided information on a selected member between the ages of 13-17 years. Data were collected from the person deemed most knowledgeable about the selected household member's vaccination history. Data were collected about each selected household member about self-reported vaccination histories, socioeconomic and demographic variables, geographic variables, number and characteristics of providers, and health insurance variables. Respondents were asked for permission to contact named vaccination providers. The public dataset includes 43,591 teens with 20,949 having adequate provider data. Target sample size of completed telephone interviews was chosen to have an equal coefficient of variation of 6.5% for an estimator of vaccination coverage, given a true coverage parameter of 50%. 48.2% were determined to have adequate provider data.[17]

Data about state school entry vaccine requirements and exemptions were publicly available through the Immunization Action Coalition, a non-profit organization that creates and distributes educational materials for both the public and healthcare professionals on immunizations.[18]

Data management and analysis

The dataset was restricted to include those individuals who had adequate provider data. To ensure that this sample would be nationally representative, survey weighting was applied as described in the NIS-Teen User Guide for the 2017 Public Use Dataset.[17]

The two datasets (the 2017 NIS-Teen Public Use Dataset and data from the Immunization Action Coalition) were merged. An individual was listed as living in a state with a vaccine requirement for HPV, MenACWY, or MenACWY booster dose if a requirement was in place in their state of residence for the 2016-2017 school year that applied to students at all schools. A Tdap vaccine requirement was not included as every state had a school entry requirement. Individuals were also classified by the number of mechanisms for obtaining a non-medical exemption (religious and/or philosophical exemptions) in their states of residence that were in place for the 2016-2017 school year.

The ease of exemption variable was created on a 3-point scale (easy, medium, difficult). Criteria for determining the ease of obtaining a vaccine exemption were adapted from the criteria used by Omer *et al* and were collected from state immunization websites and validated through comparison with data collected by the CDC Public Health Law Program.[19,20] Criteria included if a letter needed to be written and submitted (compared to a form), if the form or letter needed to be returned to the health department (compared to the school), if a notarization or a signature from another individual (county official, health professional) is needed (compared to only a parent's signature), and if annual renewal was required (compared to the exemption only needing

to be obtained once). Based on a similar ranking of criteria used to create an ease of exemption variable by Omer *et al*, we created a hierarchy of the criteria.[11] Obtaining a notarization or signature from another individual was deemed the most difficult criteria, and any state with that criteria was classified as difficult. If a state had more than 1 of the remaining criteria, it was also classified as difficult. If a state met only 1 of the remaining criteria, it was classified as medium difficulty. If a state did not meet any of the criteria, it was classified as easy. A correlation test between this variable and the ease of exemption variable created by Omer *et al* found the two measures to be statistically significantly correlated ($p<0.0001$).[11] Those residing in California, West Virginia, and Mississippi were excluded from analysis by this variable as these states do not offer non-medical exemptions.

An individual was defined to have initiated a vaccine (HPV, MenACWY, and Tdap) if they had received at least one provider-confirmed dose. Being up-to-date on HPV was defined as having 3 doses or having 2 doses with the first shot given before age 15 and having an interval between first and second shot of at least 5 months in year 2016 or later.

An individual was defined as having a missed opportunity for MenACWY initiation if they have provider-confirmed receipt of initiation of HPV and/or Tdap vaccination but no provider-confirmed receipt of initiation of MenACWY vaccination. An individual was defined as having a missed opportunity for HPV initiation if they have provider-confirmed receipt of initiation of MenACWY and/or Tdap vaccination but no provider-confirmed receipt of initiation of HPV vaccination.

Bivariate associations were assessed between demographic variables and policy variables with vaccine outcome variables using Wald chi-square tests. The demographic variables were those that have been found to be associated with vaccine initiation and completion in previous

studies (age of teen, mother's age, mother's education level, poverty status, marital status of mother, race/ethnicity, sex, health insurance status, facility type where vaccinations where given, census region, whether the teen had a check-up at 11 or 12, and whether the teen had a doctor's visit in the last 12 months).[15] Policy variables included whether the individual resided in a state with a meningitis vaccine requirement, whether the individual resided in a state with a meningitis booster vaccine requirement, whether the individual resided in a state with a HPV vaccine requirement, the number of mechanisms of obtaining a non-medical exemptions in an individual's state of residence, and the ease of obtaining a vaccine exemption in their state of residence. Vaccine outcome variables included MenACWY vaccine initiation, HPV vaccine initiation, being up-to-date for HPV vaccination, Tdap vaccine initiation, having a missed opportunity for MenACWY vaccination, and having a missed opportunity for HPV vaccination. Missed opportunities for Tdap were not considered as every state has a requirement for this vaccine and less than 3% of the sample had a missed opportunity for Tdap (Results from bivariate analysis included in Supplemental Content).

From there, logistic regression models were created to assess correlates of the vaccine outcome variables. For each outcome variable, a univariate logistic regression model was run using each policy variable as the predictor variable. From there, multivariate logistic regression models were run for each outcome using each policy variable as the predictor variable and adjusting for the demographic variables. The models produced odds ratio estimates (ORs) and 95% confidence intervals (CIs).

All data analysis was performed in SAS 9.4 using SAS survey functions and the sampling weighting for provider-verified data as described in the NIS-Teen User's Guide for the 2017 Public-Use Data File.[17]

Results

Characteristics

Our sample of those with adequate provider-verified data totaled 20,949 individuals. There was a fairly even distribution of age and sex. The majority of the sample was non-Hispanic white (52.3%), had private insurance only (50.5%), received all vaccinations at private facilities (53.4%), received a check-up at age 11 or 12 (95.1%), and had at least one health care visit in the past 12 months (84.2%). About half (55.9%) resided in a state with a MenACWY requirement while the majority resided in a state that did not have a MenACWY booster requirement (84.8%). The majority also resided in a state that did not have an HPV requirement (97.1%). The majority of the sample (52.5%) resided in a state that had one mechanism for non-medical vaccine exemptions (religious or philosophical exemption). Based on our criteria, 27.5% of individuals resided in a state with easy exemption requirements, 15% in a state with medium difficulty exemption requirements, and 57.5% in a state with difficult exemption requirements (**Table 1**).

Coverage

After adjusting for all individual characteristics, it was found that those who resided in states with a MenACWY vaccine requirement was associated with higher odds of initiating MenACWY vaccination (aOR: 1.82, 95% CI: 1.53-2.18). Those residing in a state with an HPV vaccine requirement had higher odds of both initiating HPV vaccination (aOR: 2.43, 95% CI: 1.64-3.61) and being up-to-date on HPV vaccination (aOR: 1.99, 95% CI: 1.04-3.80) compared to those residing in a state without an HPV vaccine requirement. No significant association was observed between residing in a state with a MenACWY booster dose requirement and MenACWY initiation.

When looking at potential spillover effects, residence in a state with a MenACWY was associated with having lower odds of both initiating HPV vaccination and being up-to-date for

HPV vaccination. For the MenACWY booster dose requirement, residence in a state with such a requirement was associated with lower odds of initiating Tdap vaccination and being up-to-date for HPV vaccination compared to residence in a state without one. There was no association between residing in a state with a MenACWY booster dose requirement and HPV initiation as well as no association between residing in a state with an HPV vaccine requirement and MenACWY vaccine initiation or Tdap vaccine initiation.

Individuals residing in a state with 2 mechanisms for obtaining a non-medical exemption had 1.57 times the odds (95% CI: 1.03-2.39) of initiating MenACWY vaccination compared to those who resided in a state with no mechanisms of obtaining a non-medical exemption, but there was no significant association when comparing those residing in a state with 1 mechanism for obtaining a non-medical exemption with those residing in a state with no mechanisms for obtaining a non-medical exemption. Individuals residing in a state with difficult exemption requirements had higher odds of initiating MenACWY vaccination compared to those residing in states with easy exemption requirements (aOR: 1.30, 95% CI: 1.08-1.57) while there was no significant association when comparing those residing in states with exemption requirements of medium difficulty and those residing in states with easy vaccine exemptions.

Those residing in a state with 1 mechanism for obtaining a non-medical exemption had 1.63 times the odds (95% CI: 1.05-2.54) of initiating Tdap vaccination compared to those residing in a state with no mechanism for obtaining a non-medical exemption. There was no significant association when comparing those residing in a state with 2 mechanisms for obtaining non-medical exemptions and those residing in a state with no mechanisms. Compared to residing in a state with easy exemption requirements, residing in a state with exemption requirements of medium difficulty (aOR: 1.35, 95% CI: 1.02-1.78) and residing in a state with difficult

exemption requirements (aOR: 1.48, 95% CI: 1.20-1.82) both had higher odds of initiating Tdap vaccination. There was no association between initiating HPV vaccination and number of mechanisms for obtaining a non-medical exemption or ease of obtaining an exemption. Additionally, there was no association between being up-to-date for HPV vaccination and number of mechanisms for obtaining a non-medical exemption or ease of obtaining a vaccine requirement exemption.

Missed opportunities

After adjusting for all individual characteristics, it was found that those who resided in a state with a MenACWY vaccine requirement had 0.38 times the odds (95% CI: 0.31-0.47) of having a missed opportunity for MenACWY vaccination. A similar relationship held true for the relationship between having a missed opportunity for MenACWY and residence in a state with a MenACWY booster dose requirement (aOR: 0.75, 95% CI: 0.57-0.98).

Additionally, those who resided in a state that had 2 mechanisms for obtaining non-medical exemptions had 0.59 times the odds (95% CI: 0.35-0.99) of having a missed opportunity for MenACWY vaccination compared to those who resided in states that had no mechanisms. There was no significant association when comparing those who lived in a state with 1 mechanism for obtaining non-medical exemptions and those who resided in a state with no mechanisms for obtaining non-medical exemptions.

Adjusting for individual characteristics, those who resided in states with exemption requirements of medium difficulty had 1.32 times the odds (95% CI: 1.01-1.74) of having a missed opportunity for MenACWY compared to those who resided in states in with easy exemption requirements. However, there was not a significant association for the comparison between those who resided in states with difficult exemption requirements and those who resided in states with easy exemption requirements.

For missed opportunities for HPV vaccination, state school entry HPV vaccine requirements appear to having the largest impact on reducing missed those residing in a state that had an HPV vaccination requirement had 0.42 times the odds (95% CI: 0.23-0.62) of having a missed opportunity for HPV vaccination compared to those who resided in a state without such a requirement after adjusting for all individual characteristics. After adjusting for all individual characteristics, there was no association between having a missed opportunity for HPV vaccination and the other policy variables (**Table 2**).

Discussion

For many reasons that may include wide-ranging school entry requirements and exemption polices that vary by state, coverage for adolescent vaccination can be suboptimal and missed opportunities for adolescent vaccination can occur, with individuals receiving a recommended vaccine but not another that is recommended at the same visit. This may be a particular problem for HPV vaccination coverage as it lags behind that of the other adolescent vaccines, the MenACWY vaccine and the Tdap vaccine. To increase coverage, states may consider policy options, such as making obtaining a vaccine exemption more difficult, which may discourage getting one and prevent missed opportunities. However, before this action should be taken, it is important to understand how state vaccine policies may shape receipt of adolescent vaccines to get a sense of how effective of an intervention this may be.

Having school entry requirements for a specific adolescent vaccine is strongly associated with increased odds of initiating that vaccine. In the case of HPV vaccination, it was also strongly associated with completion of the vaccine series. This reflects a body of literature that has found similar results both for HPV and MenACWY vaccination, with the implementation of requirements for a given vaccine contributing to increases in coverage for that vaccine.[21,22] This

is an unsurprising result, but it further validates the importance of school entry requirements serving as a possible means for increasing coverage of adolescent vaccines.

When examining the impact of allowable non-medical exemption types, in general, we found a small yet positive association with higher coverage for states with at least one mechanism for non-medical exemption compared to those with none. However, in most cases, this association was not significant. This trend went in the opposite direction of what we hypothesized and what was observed in the literature around exemptions for childhood vaccines. One study examining exemption rates for kindergarten vaccines found that the non-medical exemption rate in states that allowed both philosophical and religious exemptions was 2.4 times higher than in states that only allowed religious exemptions.[11] In our focus on adolescent vaccines, our results may indicate that the availability of non-medical exemptions may be less important for ensuring coverage for these vaccines compared to childhood vaccines.

When examining the ease of obtaining a non-medical exemption, we saw a similar general trend, a positive association with higher coverage for states with harder exemption criteria. Again, though, most of the results were small but non-significant. This is the opposite of what we expected based on studies examining ease of exemption for childhood vaccines. For childhood vaccines, states with easier exemption requirements had exemption rates more than twice those of states with more difficult exemption requirements.[23] Additionally, states with more difficult vaccine exemption requirements had lower incidences of pertussis compared to those that had less difficult ones.[24]

As our study elucidates, a key piece of the challenge in understanding the link between exemption policies and its impact on coverage for adolescent vaccination is that much of the research, including that described above, has been focused on the impact of vaccine exemptions

on childhood vaccines. There is a dearth in the literature on the relationship between vaccine exemption policy and adolescent vaccination. Because of this, there is not a clear picture of how exemption requirements influence adolescent vaccine coverage. There may be a number of reasons why there may not be a relationship between exemption requirements and adolescent vaccination rates. One may be that school entry vaccination requirements may not be as readily enforced for adolescent vaccines as for childhood vaccines. Previous research suggests that inconsistent school enforcement of state vaccination policies may be contributing to lower vaccine coverage.[25] Another possibility is that as there are fewer vaccines for adolescents who are also seen by health care providers less frequently; therefore, it may be easier to get by without having follow-up about the vaccines. This has also played in the literature, with many adolescents not have primary care visits and fewer than half receiving preventive care.[26] A third possibility is that by adolescence, parents may already be familiar with the process of obtaining an exemption so the difficulty of obtaining one may have less of an impact.

We did not observe any spillover effects in our study, with requirements for the other adolescent vaccines being associated with lower odds of coverage for a particular adolescent vaccine. These effects were small and often non-significant. Previous research has shown a spillover effect wherein having a requirement for one of the adolescent vaccines can result in higher rates of the other adolescent vaccines. A study found that Tdap vaccine and MenACWY vaccine requirements were associated with 8 and 4 percentage point spillover increases in HPV vaccination coverage.[9] It is possible that spillover effects are time-limited. For instance, spillover effects may be more likely when a new adolescent vaccine is recommended as discussion with providers about new vaccines may result in checking if the patient is up-to-date for other

adolescent vaccines. As time goes on, less frequent discussion of the new vaccine may result in less checking of the status of a patient's immunization record.

When examining the outcome of missed opportunities, those residing in a state with a school entry requirement for a given vaccine were less likely to have a missed opportunity for that vaccine. No other policy variable was associated with reducing missed opportunities for adolescent vaccines. This is an important finding to consider when discussing policy measures for lowering rates of missed opportunities. Previous research has focused on the effectiveness of individual- and provider-level means of reducing missed opportunities, such as patient tracking and education and provider prompts.[27] As policy interventions begin to be discussed more as another way of reducing missed opportunities, considering which components of state vaccination policies should be changed becomes an important consideration.

Our study provides some evidence to be considered when making recommendations around state vaccination policies for adolescent vaccines. Further research needs to be done around the relationship between exemption policies and adolescent vaccination. Because of this, school entry requirements appear to be the most effective policy tool for increasing coverage and reducing missed opportunities. States would need to assess the feasibility and readiness for such policy changes on a case-by-case basis. There will likely be some pushback to instituting these requirements, especially for HPV vaccination. However, there is growing evidence that parents may be amenable to these changes with some studies showing increasing support.[28]

Our study had a few limitations that are important to consider along with our results. One limitation is that the provider-verified data were reliant on those taking the survey to be willing and able to recall and name all providers who may have delivered vaccines. While the provider verification ensured that the self-reported number of vaccines received could be validated,

receipt of a vaccine only could be validated in records that were obtainable. This, however, is likely to be non-differential so it is unlikely to have biased the results. Our study was also cross-sectional in nature, only looking at one year of survey data. In order to observe if changes in policies would have an impact on coverage and missed opportunities for adolescent vaccination, longitudinal data would need to be collected and analyzed. This presents an opportunity for further research. A final limitation is that the ease of exemption variable we created could be seen as somewhat subjective based on the criteria we chose to judge the states' exemption processes. To counter some of this perceived subjectivity, we validated the information collected from the state immunization websites against data collected by the CDC Public Health Law Program to ensure accuracy. The hierarchy of criteria was modeled off a study that used a similar variable to judge ease of vaccine exemption to check consistency with similar variables in the literature.

Conclusions

School entry vaccine requirements still remain the strongest policy means for increasing coverage although their spillover effects may be declining. However, in contrast to childhood vaccines, exemption requirements and the ease of obtaining a vaccine exemption may not be significant drivers of the lack of coverage for adolescent vaccination. There is a lack of research on the relationship of vaccine exemption policy and adolescent vaccination to explain why these policies may be less important, such as exploring school enforcement of policies or parent familiarity with these policies. More work needs to be done to look at the feasibility of expanding school entry requirements.

Tables

Table 1. Individual and policy characteristics for included sample who had provider-verified vaccination data

Individual Characteristics (N=20949)			
	N	**Weighted N**	**%**
Age			
13	4283	4176574	20
14	4429	4104984	19.7
15	4212	4370416	21
16	4218	4337415	20.8
17	3807	3844092	18.5
Mother's Age			
<=34 years	1599	1751308	8.4
35 to 44 years	8447	8909298	42.8
>=45 years	10903	10172575	48.8
Census Region			
Northeast	3975	3406885	16.4
Midwest	4485	4447131	21.3
South	8032	8000078	38.4
West	4457	4979087	23.9
Mother's Education Level			
Less than 12 Years	2559	2742980	13.2
12 Years	3139	4610862	22.1
More than 12 Years, Non-College Grad	5173	4963605	23.8
College Graduate	10078	8515734	40.9
Poverty Status			
Above Poverty >$75K	10300	8554815	43.9
Above Poverty <=$75K	6291	6668561	34.2
Below Poverty	3579	4275442	21.9
Marital Status of Mother			
Married	14791	13209334	63.4
Not Currently Married	6158	7623847	36.6
Race/Ethnicity			
Hispanic	3882	4927398	23.7
NH White	13011	10897933	52.3
NH Black	1742	2879031	13.8
NH Other/Mixed Race	2314	2128820	10.2
Sex			
Male	11104	10631199	51
Female	9845	10201982	49

Insurance Status			
Private Insurance Only	11919	10518636	50.5
Any Medicaid	6504	7819181	37.5
Other Insurance	1708	1581348	7.6
Uninsured	818	914017	4.4
Facility Type for Provider			
All Public Facilities	2821	2988083	16
All Hospital Facilities	2270	1831390	9.8
All Private Facilities	9495	9994794	53.4
All STD/School/Teen Clinics or Other Facilities	630	659921	3.5
Mixed	3681	3258077	17.4
Check-Up at 11 or 12			
Yes	16805	16518703	95.1
No	836	848891	4.9
Visits in Past 12 Months			
None	2816	3243992	15.8
At Least 1	17922	17330871	84.2
Policy Characteristics			
	N	**Weighted N**	**%**
Meningitis Requirement			
Yes	11452	11641765	55.9
No	9497	9191416	44.1
Meningitis Booster Requirement			
Yes	3135	3165248	15.2
No	17814	17667933	84.8
HPV Requirement			
Yes	1050	612875	2.9
No	19899	20220306	97.1
Non-medical Exemption			
0 Mechanisms	996	2846172	13.7
1 Mechanism	12269	10934839	52.5
2 Mechanisms	7684	7052170	33.9
Ease of Exemption			
Easy	5410	4937625	27.5
Medium	3490	2698593	15
Difficult	11053	10350791	57.5

Table 2. Crude and adjusted odds ratios for vaccine outcome variables with their 95% confidence intervals as predicted by policy variables. The full model adjusted for the following demographic variables: age of teen, mother's age, mother's education level, poverty status, marital status of mother, race/ethnicity, sex, health insurance status, facility type where vaccinations where given, census region, whether the teen had a check-up at 11 or 12, and whether the teen had a doctor's visit in the last 12 months.

	HPV UTD		HPV Initiation	
	Crude OR (95% CI)	**Adjusted OR (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR (95% CI)**
Meningitis Requirement	1.00 (0.84, 1.21)	0.80 (0.66, 0.98)	0.90 (0.80, 1.00)	0.88 (0.78, 1.00)
Meningitis Booster Requirement	0.90 (0.75, 1.08)	0.75 (0.59, 0.94)	0.91 (0.81, 1.03)	0.92 (0.79, 1.08)
HPV Requirement	1.49 (0.94, 2.37)	1.99 (1.04, 3.80)	1.85 (1.33, 2.58)	2.43 (1.64, 3.61)
Non-medical Exemption				
1 Mechanism	1.19 (0.78, 1.82)	1.39 (0.84, 2.30)	0.81 (0.62, 1.06)	1.21 (0.88, 1.66)
2 Mechanisms	1.06 (0.69, 1.62)	1.13 (0.68, 1.88)	0.77 (0.59, 1.01)	1.09 (0.79, 1.50)
Ease of Exemption				
Medium	0.94 (0.76, 1.16)	1.17 (0.89, 1.53)	0.97 (0.85, 1.11)	1.03 (0.87, 1.22)
Difficult	0.82 (0.69, 0.96)	1.11 (0.91, 1.35)	0.91 (0.82, 1.02)	1.08 (0.95, 1.23)
	MenACWY Initiation		**Tdap Initiation**	
	Crude OR (95% CI)	**Adjusted OR (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR (95% CI)**
Meningitis Requirement	1.92 (1.65, 2.23)	1.82 (1.53, 2.18)	1.16 (0.96, 1.39)	0.90 (0.74, 1.10)
Meningitis Booster Requirement	1.24 (1.05, 1.47)	1.10 (0.89, 1.36)	1.19 (0.99, 1.44)	0.75 (0.59, 0.94)
HPV Requirement	0.86 (0.57, 1.29)	0.82 (0.51, 1.33)	1.11 (0.69, 1.79)	0.88 (0.50, 1.57)
Non-medical Exemption				
1 Mechanism	1.42 (1.01, 2.00)	1.16 (0.77, 1.75)	1.80 (1.23, 2.65)	1.63 (1.05, 2.54)
2 Mechanisms	1.52 (1.08, 2.14)	1.57 (1.03, 2.39)	1.32 (0.90, 1.95)	1.36 (0.87, 2.12)
Ease of Exemption				
Medium	0.81 (0.68, 0.97)	0.97 (0.76, 1.22)	1.07 (0.87, 1.32)	1.35 (1.02, 1.78)
Difficult	0.94 (0.81, 1.09)	1.30 (1.08, 1.57)	1.09 (0.93, 1.27)	1.48 (1.20, 1.82)
	MenACWY Missed Opportunity		**HPV Missed Opportunity**	
	Crude OR (95% CI)	**Adjusted OR (95% CI)**	**Crude OR (95% CI)**	**Adjusted OR (95% CI)**
Meningitis Requirement	0.41 (0.34, 0.49)	0.38 (0.31, 0.47)	1.19 (1.06, 1.33)	1.12 (0.98, 1.27)
Meningitis Booster Requirement	0.76 (0.61, 0.94)	0.75 (0.57, 0.98)	1.13 (1.01, 1.28)	1.03 (0.87, 1.22)
HPV Requirement	1.57 (1.00, 2.49)	1.55 (0.92, 2.62)	0.57 (0.40, 0.80)	0.42 (0.28, 0.62)
Non-medical Exemption				
1 Mechanism	0.83 (0.54, 1.28)	0.99 (0.60, 1.65)	1.49 (1.12, 1.96)	0.90 (0.65, 1.24)
2 Mechanisms	0.57 (0.37, 0.88)	0.59 (0.35, 0.99)	1.44 (1.09, 1.91)	0.99 (0.72, 1.36)
Ease of Exemption				
Medium	1.44 (1.15, 1.81)	1.32 (1.01, 1.74)	1.05 (0.91, 1.21)	1.05 (0.88, 1.25)
Difficult	1.20 (0.99, 1.46)	0.99 (0.79, 1.23)	1.14 (1.02, 1.27)	1.04 (0.91, 1.19)

References

1. Liang, J. L., et al. (2018). "Prevention of Pertussis, Tetanus, and Diphtheria with Vaccines in the United States: Recommendations of the Advisory Committee on Immunization Practices (ACIP)." MMWR. Recommendations and Reports **67**(2): 1-44.
2. Baker, C. J., et al. (2013). "Prevention and Control of Meningococcal Disease: Recommendations of the Advisory Committee on Immunization Practices (ACIP)." MMWR. Recommendation and Reports **62**(RR02): 1-22.
3. Markowitz, L. E., et al. (2014). "Human Papillomavirus Vaccination Recommendations of the Advisory Committee on Immunization Practices (ACIP)." Morbidity and Mortality Weekly Report: Recommendations and Reports **63**(5): 1-30.
4. Walker, T. Y., et al. (2017). "National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years — United States, 2016." MMWR. Morbidity and Mortality Weekly Report **66**(33): 874-882.
5. Schwartz, J. L. and L. A. Easterling (2015). "State Vaccination Requirements for HPV and Other Vaccines for Adolescents, 1990-2015." JAMA **314**(2): 185-186.
6. Holman, D. M., V. Benard, K. B. Roland, M. Watson, N. Liddon and S. Stokley (2014). "Barriers to Human Papillomavirus Vaccination Among US Adolescents: A Systematic Review of the Literature." JAMA Pediatrics **168**(1): 76-82.
7. Doke, K., et al. (2018). "Concomitant HPV and MenACWY Vaccination Among Sixth and Seventh Graders Receiving Tdap." Vaccine **36**(45): 6819-6825.
8. Oltean, H. N., K. H. Lofy, M. J. Goldoft and C. A. DeBolt (2016). "Human Papillomavirus Vaccination in Washington State: Estimated Coverage and Missed

Opportunities, 2006-2013." Public Health Reports (Washington, D.C.: 1974) **131**(3): 474-482.

9. Moss, J. L., et al. (2016). "School Entry Requirements and Coverage of Nontargeted Adolescent Vaccines." Pediatrics **138**(6).
10. Constable, C., et al. (2014). "Rising Rates of Vaccine Exemptions: Problems with Current Policy and More Promising Remedies." Vaccine **32**(16): 1793-1797.
11. Omer, S. B., R. M. Porter, K. Allen, D. A. Salmon and R. A. Bednarczyk (2017). "Trends in Kindergarten Rates of Vaccine Exemption and State-Level Policy, 2011-2016." Open Forum Infectious Diseases **5**(2): ofx244-ofx244.
12. Phadke, V. K., R. A. Bednarczyk, D. A. Salmon and S. B. Omer (2016). "Association Between Vaccine Refusal and Vaccine-Preventable Diseases in the United States: A Review of Measles and Pertussis." JAMA **315**(11): 1149-1158.
13. Henry, K. A., A. L. Swiecki-Sikora, A. M. Stroup, E. L. Warner and D. Kepka (2017). "Area-based Socioeconomic Factors and Human Papillomavirus (HPV) Vaccination Among Teen Boys in the United States." BMC Public Health **18**(1): 19-19.
14. Henry, K. A., A. M. Stroup, E. L. Warner and D. Kepka (2016). "Geographic Factors and Human Papillomavirus (HPV) Vaccination Initiation Among Adolescent Girls in the United States." Cancer Epidemiology, Biomarkers & Prevention **25**(2): 309-317.
15. Swiecki-Sikora, A. L., K. A. Henry and D. Kepka (2019). "HPV Vaccination Coverage Among US Teens Across the Rural-Urban Continuum." The Journal of Rural Health **0**(0).

16. Franco, M., S. Mazzucca, M. Padek and R. C. Brownson (2019). "Going Beyond the Individual: How State-Level Characteristics Relate to HPV Vaccine Rates in the United States." BMC Public Health **19**(1): 246.
17. National Immunization Survey-Teen: A User's Guide for the 2017 Public-Use Data File. Centers for Disease Control and Prevention (2018).
18. "State Laws and Mandates." Immunization Action Coalition. (2018). from http://www.immunize.org/laws/.
19. State School Immunization Requirements and Vaccine Exemption Laws. Public Health Law, Centers for Disease Control and Prevention (2017).
20. Omer, S. B., et al. (2006). "Nonmedical Exemptions to School Immunization Requirements: Secular Trends and Association of State Policies with Pertussis Incidence." JAMA **296**(14): 1757-1763.
21. Simpson, J. E., R. A. Hills, D. Allwes and L. Rasmussen (2013). "Uptake of Meningococcal Vaccine in Arizona Schoolchildren After Implementation of School-Entry Immunization Requirements." Public Health Reports (Washington, D.C.: 1974) **128**(1): 37-45.
22. Thompson, E. L., M. D. L. III, E. M. Daley and G. D. Zimet (2018). "Human Papillomavirus Vaccine Initiation for Adolescents Following Rhode Island's School-Entry Requirement, 2010–2016." American Journal of Public Health **108**(10): 1421-1423.
23. Blank, N. R., A. L. Caplan and C. Constable (2013). "Exempting Schoolchildren from Immunizations: States with Few Barriers Had Highest Rates of Nonmedical Exemptions." Health Affairs **32**(7): 1282-1290.

24. Bradford, W. D. and A. Mandich (2015). "Some State Vaccination Laws Contribute to Greater Exemption Rates and Disease Outbreaks in The United States." Health Affairs **34**(8): 1383-1390.

25. Salmon, D. A., S. B. Omer, L. H. Moulton, S. Stokley, M. P. deHart, S. Lett, B. Norman, S. Teret and N. A. Halsey (2005). "Exemptions to School Immunization Requirements: The Role of School-Level Requirements, Policies, and Procedures." American Journal of Public Health **95**(3): 436-440.

26. Rand, C. M. and N. P. N. Goldstein (2018). "Patterns of Primary Care Physician Visits for US Adolescents in 2014: Implications for Vaccination." Academic Pediatrics **18**(2, Supplement): S72-S78.

27. Jaca, A., L. Mathebula, A. Iweze, E. Pienaar and C. S. Wiysonge (2018). "A Systematic Review of Strategies for Reducing Missed Opportunities for Vaccination." Vaccine **36**(21): 2921-2927.

28. Vercruysse, J., N. L. Chigurupati, L. Fung, G. Apte, N. Pierre-Joseph and R. B. Perkins (2016). "Parents' and Providers' Attitudes Toward School-located Provision and School-entry Requirements for HPV Vaccines." Human Vaccines & Immunotherapeutics **12**(6): 1606-1614.

Supplemental Content

Bivariate Analysis Results

Based on the bivariate analysis, being up-to-date for HPV vaccination was statistically significantly associated with age of teen, mother's age, sex, health insurance status, facility type where vaccinations were given, census region, whether the teen had a check-up at age 11 or 12, and whether the teen had a visit in the last 12 months. Being up-to-date for HPV vaccination was associated with the ease of obtaining a vaccine exemption in their state of residence, with the highest rates of being up-to-date for those residing in states with easy exemption requirements (**Table SC1a**).

MenACWY vaccine initiation was statistically significantly associated with mother's education level, poverty status, facility type where vaccinations were given, census region, whether the teen had a check-up at age 11 or 12, and whether the teen had a visit in the last 12 months. MenACWY vaccine initiation was significantly associated with both residence in a state with a MenACWY vaccine requirement and residence in a state with a MenACWY booster dose requirement (**Table SC1b**).

HPV vaccine initiation was statistically significantly associated with age of teen, mother's age, mother's education level, poverty status, marital status of mother, race/ethnicity, sex, health insurance status, census region, whether the teen had a check-up at age 11 or 12, and whether the teen had a visit in the last 12 months. HPV vaccine initiation was significantly associated with residence in a state with an HPV vaccine requirement (**Table SC1c**).

Tdap vaccine initiation was statistically significantly associated with mother's education level, facility type where the vaccine was given, census region, and whether the teen had a check-up at age 11 or 12. Tdap vaccine initiation was associated with the number of mechanisms

for obtaining a non-medical exemption, with Tdap initiation highest among those residing in states with 1 mechanism for obtaining a non-medical exemption (**Table SC1d**).

Having a missed opportunity for MenACWY vaccination was statistically significantly associated with mother's education level, facility type where vaccines were given, and census region. Having a missed opportunity for MenACWY vaccination was associated with residence in a state with a MenACWY vaccine requirement and residence in a state with a MenACWY booster dose requirement, with a higher percentage of those with a missed opportunity for MenACWY vaccination residing in states without these requirements. Having a missed opportunity for MenACWY vaccination was associated with the numbers of mechanisms a state of residence has for obtaining non-medical exemptions. Having a missed opportunity for MenACWY vaccination was associated with the ease of obtaining a vaccine exemption in their residence, with the highest percentage of having a missed opportunity for MenACWY vaccination was among those who residing in states with easy requirements of obtaining a vaccine exemption (**Table SC1e**).

Having a missed opportunity for HPV vaccination was statistically significantly associated with mother's age, mother's education level, poverty status, marital status of mother, race/ethnicity, sex, health insurance status, census region, and whether the teen had a visit in the last 12 months. It was also found to be associated with residence in a state with an HPV vaccine requirement, with the percentage of those with a missed opportunity for HPV vaccination higher in residents of states without a requirement. It was found to be associated with all other policy variables except with ease of obtaining an exemption (**Table SC1f**).

Table SC1a. Bivariate analysis of up-to-date (UTD) HPV vaccination and individual and policy variables

UTD HPV-Individual			
	UTD HPV	**Not UTD HPV**	
	N (%)	**N (%)**	**P-value**
Age			0.0002
13	1717 (71.5)	616 (28.5)	
14	2111 (80.6)	530 (19.4)	
15	2201 (81.3)	480 (18.7)	
16	2266 (81.8)	453 (18.2)	
17	2038 (79.8)	435 (20.2)	
Mother's Age			0.0001
<=34 years	778 (73.3)	262 (26.7)	
35 to 44 years	4053 (77.0)	1105 (23.0)	
>=45 years	5502 (82.4)	1147 (17.6)	
Mother's Education Level			0.0657
Less than 12 Years	1447 (78.0)	343 (22.0)	
12 Years	1535 (78.9)	401 (21.1)	
More than 12 Years, Non-College Grad	2348 (76.7)	681 (23.3)	
College Graduate	5003 (81.4)	1089 (18.6)	
Poverty Status			0.4123
Above Poverty >$75K	5018 (80.3)	1130 (19.7)	
Above Poverty <=$75K	2923 (78.8)	800 (21.2)	
Below Poverty	1982 (77.8)	507 (22.2)	
Marital Status of Mother			0.1984
Married	7085 (80.0)	1666 (20.0)	
Not Currently Married	3248 (78.0)	848 (22.0)	
Race/Ethnicity			0.2233
Hispanic	2222 (78.8)	523 (21.2)	
NH White	6024 (80.5)	1459 (19.5)	
NH Black	915 (75.9)	262 (24.1)	
NH Other/Mixed Race	1172 (79.2)	270 (20.8)	
Sex			<0.0001
Male	5038 (76.2)	1399 (23.8)	
Female	5295 (82.0)	1115 (18.0)	
Insurance Status			0.0101
Private Insurance Only	5727 (80.8)	1300 (19.2)	
Any Medicaid	3509 (78.7)	862 (21.3)	
Other Insurance	794 (79.7)	228 (20.3)	
Uninsured	303 (63.7)	124 (36.3)	

Facility Type for Provider			0.0158
All Public Facilities	1274 (73.2)	431 (26.8)	
All Hospital Facilities	1248 (82.7)	251 (17.3)	
All Private Facilities	4878 (80.3)	1055 (19.7)	
All STD/School/Teen Clinics or Other Facilities	237 (73.3)	88 (26.7)	
Mixed	1821 (80.8)	439 (19.2)	
Census Region			<0.0001
Northeast	2383 (85.2)	359 (14.8)	
Midwest	2183 (79.5)	544 (20.5)	
South	3660 (76.4)	1037 (23.6)	
West	2107 (79.0)	574 (21.0)	
Check-Up at 11 or 12			0.0016
Yes	8957 (82.0)	1860 (18.0)	
No	259 (62.2)	137 (37.8)	
Visits in Past 12 Months			<0.0001
None	1096 (69.8)	406 (30.2)	
At least 1	9123 (80.8)	2082 (19.2)	
UTD HPV-Policy			
	UTD HPV	**Not UTD HPV**	**P-value**
	N (%)	**N (%)**	
Meningitis Requirement			0.9659
Yes	5737 (79.2)	1384 (20.6)	
No	4596 (79.2)	1130 (20.8)	
Meningitis Booster Requirement			0.2445
Yes	1506 (77.7)	397 (22.3)	
No	8827 (79.5)	2117 (20.5)	
HPV Requirement			0.0559
Yes	706 (84.9)	93 (15.1)	
No	9627 (79.0)	2421 (21.0)	
Non-medical Exemption			0.2223
0 Mechanisms	398 (77.3)	134 (22.7)	
1 Mechanism	6156 (80.3)	1399 (19.7)	
2 Mechanisms	3779 (78.4)	981 (21.6)	
Ease of Exemption			0.0363
Easy	2876 (81.6)	594 (18.4)	
Medium	1714 (80.5)	389 (19.5)	
Difficult	5345 (78.3)	1397 (21.7)	

Table SC1b. Bivariate analysis of MenACWY vaccine initiation and individual and policy variables

MenACWY Initiation-Individual			
	0	>=1	
	N (%)	N (%)	P-value
Age			0.224
13	689 (15.8)	3594 (84.2)	
14	632 (13.3)	3797 (86.7)	
15	602 (14.2)	3610 (85.8)	
16	623 (12.5)	3595 (87.5)	
17	537 (14.8)	3270 (85.2)	
Mother's Age			0.117
<=34 years	280 (17.1)	1319 (82.9)	
35 to 44 years	1310 (14.3)	7137 (85.7)	
>=45 years	1493 (13.4)	9410 (86.6)	
Mother's Education Level			0.0024
Less than 12 Years	366 (12.7)	2193 (83.7)	
12 Years	530 (15.8)	2609 (84.2)	
More than 12 Years, Non-College Grad	893 (16.4)	4280 (83.6)	
College Graduate	1294 (12.3)	8784 (87.7)	
Poverty Status			0.0448
Above Poverty >$75K	1360 (13.4)	8940 (86.6)	
Above Poverty <=$75K	1109 (16.0)	5182 (84.0)	
Below Poverty	504 (13.5)	3075 (86.5)	
Marital Status of Mother			0.6833
Married	2136 (14.0)	12655 (86.0)	
Not Currently Married	947 (14.4)	5211 (85.6)	
Race/Ethnicity			0.7038
Hispanic	489 (13.4)	3393 (86.6)	
NH White	2007 (14.7)	11004 (85.3)	
NH Black	244 (13.2)	1498 (86.8)	
NH Other/Mixed Race	343 (14.1)	1971 (85.9)	
Sex			0.8264
Male	1607 (14.0)	9497 (86.0)	
Female	1476 (14.2)	8369 (85.8)	
Insurance Status			0.0813
Private Insurance Only	1657 (13.7)	10262 (86.3)	
Any Medicaid	960 (14.2)	5544 (85.8)	
Other Insurance	272 (13.7)	1436 (86.3)	
Uninsured	194 (19.0)	624 (81.0)	

Facility Type for Provider			<0.0001
All Public Facilities	581 (17.5)	2240 (82.5)	
All Hospital Facilities	319 (15.3)	1951 (84.7)	
All Private Facilities	996 (11.0)	8499 (89.0)	
All STD/School/Teen Clinics or Other Facilities	171 (23.2)	459 (76.8)	
Mixed	530 (13.0)	3151 (87.0)	
Census Region			<0.0001
Northeast	323 (7.5)	3652 (92.4)	
Midwest	624 (12.5)	3861 (87.5)	
South	1202 (15.7)	6830 (84.3)	
West	934 (17.5)	3523 (82.5)	
Check-Up at 11 or 12			<0.0001
Yes	2113 (12.5)	14692 (87.5)	
No	236 (22.0)	600 (78.0)	
Visits in Past 12 Months			0.0101
None	562 (17.1)	2254 (82.9)	
At least 1	2492 (13.6)	15430 (86.4)	
MenACWY Initiation-Policy			
	0	**>=1**	**P-value**
	N (%)	**N (%)**	
Meningitis Requirement			<0.0001
Yes	1229 (10.6)	10223 (89.4)	
No	1854 (18.5)	7643 (81.4)	
Meningitis Booster Requirement			0.008
Yes	357 (12.0)	2778 (88.0)	
No	2726 (14.5)	15088 (85.5)	
HPV Requirement			0.4858
Yes	117 (16.0)	933 (84.0)	
No	2966 (14.1)	16933 (85.9)	
Non-medical Exemption			0.0864
0 Mechanisms	231 (18.4)	765 (81.6)	
1 Mechanism	1849 (13.7)	10420 (86.3)	
2 Mechanisms	1003 (13.0)	6681 (87.0)	
Ease of Exemption			0.0759
Easy	679 (12.7)	4731 (87.3)	
Medium	639 (15.2)	2851 (84.8)	
Difficult	1534 (13.4)	9519 (86.6)	

Table SC1c. Bivariate analysis of HPV vaccine initiation and individual and policy variables

HPV Initiation-Individual			
	0	>=1	
	N (%)	N (%)	P-value
Age			0.0016
13	1653 (39.3)	2630 (60.7)	
14	1549 (34.9)	2880 (65.1)	
15	1363 (33.5)	2849 (66.5)	
16	1367 (32.7)	2851 (67.3)	
17	1224 (31.9)	2583 (68.1)	
Mother's Age			0.0141
<=34 years	496 (29.8)	1103 (70.2)	
35 to 44 years	2927 (33.8)	5520 (66.2)	
>=45 years	3733 (35.9)	7170 (64.1)	
Mother's Education Level			<0.0001
Less than 12 Years	650 (25.4)	1909 (74.6)	
12 Years	1080 (33.6)	2059 (66.4)	
More than 12 Years, Non-College Grad	1958 (37.0)	3215 (63.0)	
College Graduate	3468 (36.4)	6610 (63.6)	
Poverty Status			<0.0001
Above Poverty >$75K	3640 (37.1)	6660 (62.9)	
Above Poverty <=$75K	2332 (37.4)	3959 (62.6)	
Below Poverty	935 (26.7)	2644 (73.3)	
Marital Status of Mother			<0.0001
Married	5359 (36.8)	9432 (63.2)	
Not Currently Married	1797 (30.4)	4361 (69.6)	
Race/Ethnicity			<0.0001
Hispanic	997 (25.5)	2885 (74.5)	
NH White	4896 (40.0)	8115 (60.0)	
NH Black	491 (30.0)	1251 (70.0)	
NH Other/Mixed Race	772 (33.1)	1542 (66.9)	
Sex			<0.0001
Male	4123 (37.4)	6981 (62.6)	
Female	3033 (31.4)	6812 (68.6)	
Insurance Status			<0.0001
Private Insurance Only	4298 (37.5)	7621 (62.5)	
Any Medicaid	1886 (28.7)	4618 (71.3)	
Other Insurance	622 (38.0)	1086 (62.0)	
Uninsured	350 (42.5)	468 (57.5)	

Facility Type for Provider			0.1967
All Public Facilities	1007 (35.7)	1814 (64.3)	
All Hospital Facilities	642 (30.6)	1628 (69.4)	
All Private Facilities	3114 (33.6)	6381 (66.4)	
All STD/School/Teen Clinics or Other Facilities	277 (38.3)	353 (61.7)	
Mixed	1267 (33.2)	2414 (66.8)	
Census Region			<0.0001
Northeast	1021 (29.7)	2954 (70.3)	
Midwest	1546 (35.3)	2939 (64.7)	
South	2998 (38.6)	5034 (61.4)	
West	1591 (30.5)	2866 (69.5)	
Check-Up at 11 or 12			0.0288
Yes	5234 (32.1)	11571 (67.9)	
No	382 (38.8)	454 (61.2)	
Visits in Past 12 Months			0.0005
None	125 (39.8)	1581 (60.2)	
At least 1	5864 (33.6)	12058 (66.4)	
HPV Initiation-Policy			
	0	**>=1**	**P-value**
	N (%)	**N (%)**	
Meningitis Requirement			0.055
Yes	3813 (35.5)	7639 (64.5)	
No	3343 (33.1)	6154 (66.9)	
Meningitis Booster Requirement			0.124
Yes	1084 (36.2)	2051 (63.8)	
No	6702 (34.2)	11742 (65.8)	
HPV Requirement			<0.0001
Yes	199 (22.4)	851 (77.6)	
No	6957 (34.8)	12942 (65.2)	
Non-medical Exemption			0.1079
0 Mechanisms	422 (30.1)	574 (68.9)	
1 Mechanism	4143 (34.7)	8126 (65.3)	
2 Mechanisms	2591 (35.9)	5093 (64.1)	
Ease of Exemption			0.2147
Easy	1691 (33.9)	3719 (66.1)	
Medium	1235 (34.5)	2255 (65.5)	
Difficult	3808 (35.9)	7245 (64.1)	

Table SC1d. Bivariate analysis of Tdap vaccine initiation and individual and policy variables

Tdap Initiation-Individual			
	0	>=1	
	N (%)	N (%)	P-value
Age			0.0999
13	559 (13.6)	3724 (86.4)	
14	495 (10.1)	3934 (89.9)	
15	439 (10.6)	3773 (89.4)	
16	451 (10.3)	3767 (89.7)	
17	396 (11.9)	3411 (88.1)	
Mother's Age			0.1098
<=34 years	209 (13.1)	1390 (86.9)	
35 to 44 years	1001 (12.0)	7446 (88.0)	
>=45 years	1130 (10.4)	9773 (89.6)	
Mother's Education Level			0.0295
Less than 12 Years	320 (12.1)	2239 (87.9)	
12 Years	399 (12.0)	2740 (88.0)	
More than 12 Years, Non-College Grad	614 (12.7)	4559 (87.3)	
College Graduate	1007 (9.8)	9071 (90.2)	
Poverty Status			0.0721
Above Poverty >$75K	1004 (10.2)	9296 (89.8)	
Above Poverty <=$75K	822 (12.5)	5469 (87.5)	
Below Poverty	417 (11.8)	3162 (88.2)	
Marital Status of Mother			0.2124
Married	1601 (10.8)	13190 (89.2)	
Not Currently Married	739 (12.1)	5419 (87.9)	
Race/Ethnicity			0.0795
Hispanic	469 (13.6)	3413 (86.4)	
NH White	1375 (10.3)	11636 (89.7)	
NH Black	211 (10.3)	1531 (89.7)	
NH Other/Mixed Race	285 (12.2)	2029 (87.8)	
Sex			0.8373
Male	1220 (11.4)	9884 (88.6)	
Female	1120 (11.2)	8725 (88.8)	
Insurance Status			0.1905
Private Insurance Only	1199 (10.5)	10720 (89.5)	
Any Medicaid	793 (12.2)	5711 (87.8)	
Other Insurance	202 (10.3)	1506 (89.7)	
Uninsured	146 (13.4)	672 (86.6)	

Facility Type for Provider			<0.0001
All Public Facilities	390 (12.5)	2431 (87.5)	
All Hospital Facilities	266 (12.6)	2004 (87.4)	
All Private Facilities	846 (9.8)	8649 (90.2)	
All STD/School/Teen Clinics or Other Facilities	145 (17.6)	485 (82.4)	
Mixed	275 (7.8)	3406 (92.2)	
Census Region			<0.0001
Northeast	309 (7.7)	3666 (92.3)	
Midwest	450 (9.4)	4035 (90.6)	
South	967 (11.5)	7065 (88.5)	
West	614 (15.1)	3843 (84.9)	
Check-Up at 11 or 12			0.0153
Yes	1632 (10.2)	15173 (89.8)	
No	164 (16.1)	672 (83.9)	
Visits in Past 12 Months			0.0897
None	427 (13.0)	2389 (87.0)	
At least 1	1885 (11.0)	16037 (89.0)	
Tdap Initiation-Policy			
	0	**>=1**	**P-value**
	N (%)	**N (%)**	
Meningitis Requirement			0.1291
Yes	1271 (10.6)	10181 (89.4)	
No	1069 (12.1)	8428 (87.9)	
Meningitis Booster Requirement			0.0585
Yes	315 (9.9)	2820 (90.1)	
No	2025 (11.5)	15789 (88.5)	
HPV Requirement			0.6514
Yes	110 (10.3)	940 (89.7)	
No	2230 (11.3)	17669 (88.7)	
Non-medical Exemption			<0.0001
0 Mechanisms	124 (15.8)	872 (84.2)	
1 Mechanism	1281 (9.4)	10988 (90.6)	
2 Mechanisms	935 (12.4)	6749 (87.6)	
Ease of Exemption			0.5875
Easy	610 (11.1)	4800 (88.9)	
Medium	395 (10.5)	3095 (89.5)	
Difficult	1211 (10.3)	9842 (89.7)	

Table SC1e. Bivariate analysis of missed opportunities for MenACWY vaccination and individual and policy variables

MenACWY Missed Opportunity-Individual			
	0	**1**	**P-value**
	N (%)	**N (%)**	
Age			0.2691
13	3956 (92.9)	327 (7.1)	
14	4084 (92.2)	345 (7.8)	
15	3841 (90.8)	371 (9.2)	
16	3829 (91.7)	389 (8.3)	
17	3455 (90.6)	352 (9.4)	
Mother's Age			0.6174
<=34 years	1445 (90.6)	154 (9.4)	
35 to 44 years	7696 (91.8)	751 (8.2)	
>=45 years	10024 (91.7)	879 (8.3)	
Mother's Education Level			0.0072
Less than 12 Years	2359 (93.2)	200 (6.8)	
12 Years	2840 (90.3)	299 (9.7)	
More than 12 Years, Non-College Grad	4645 (90.0)	528 (10.0)	
College Graduate	9321 (92.8)	757 (7.2)	
Poverty Status			0.2124
Above Poverty >$75K	9500 (92.3)	800 (7.7)	
Above Poverty <=$75K	5658 (90.9)	633 (9.1)	
Below Poverty	3290 (91.5)	289 (8.5)	
Marital Status of Mother			0.4588
Married	13549 (91.9)	1242 (8.1)	
Not Currently Married	5616 (91.2)	542 (8.8)	
Race/Ethnicity			0.6766
Hispanic	3616 (92.5)	266 (7.5)	
NH White	11824 (91.4)	1187 (8.6)	
NH Black	1593 (90.8)	149 (9.2)	
NH Other/Mixed Race	2132 (92.0)	182 (8.0)	
Sex			0.4801
Male	10194 (91.9)	910 (8.1)	
Female	8971 (91.4)	874 (8.6)	
Insurance Status			0.6818
Private Insurance Only	10918 (91.9)	1001 (8.1)	
Any Medicaid	5952 (91.3)	552 (8.7)	
Other Insurance	1560 (92.4)	148 (7.6)	
Uninsured	735 (90.4)	83 (9.6)	

Facility Type for Provider			0.0376
All Public Facilities	2472 (89.8)	349 (10.2)	
All Hospital Facilities	2094 (91.3)	176 (8.7)	
All Private Facilities	8877 (93.0)	618 (7.0)	
All STD/School/Teen Clinics or Other Facilities	560 (88.3)	70 (11.7)	
Mixed	3301 (91.4)	380 (8.6)	
Census Region			<0.0001
Northeast	3778 (95.1)	197 (4.9)	
Midwest	4131 (92.6)	354 (7.4)	
South	7354 (90.4)	678 (9.6)	
West	3902 (90.4)	555 (9.6)	
Check-Up at 11 or 12			0.0536
Yes	15483 (92.0)	1322 (8.0)	
No	720 (88.1)	116 (11.8)	
Visits in Past 12 Months			0.3639
None	2556 (90.8)	260 (9.2)	
At least 1	16412 (91.8)	1510 (8.2)	
MenACWY Missed Opportunity-Policy			
	0	**1**	**P-value**
	N (%)	**N (%)**	
Meningitis Requirement			<0.0001
Yes	10873 (94.7)	579 (5.3)	
No	8292 (87.8)	1205 (12.2)	
Meningitis Booster Requirement			0.0078
Yes	2955 (93.3)	180 (6.7)	
No	16210 (91.4)	1604 (8.6)	
HPV Requirement			0.0989
Yes	970 (87.6)	80 (12.4)	
No	18195 (91.8)	1704 (8.2)	
Non-medical Exemption			<0.0001
0 Mechanisms	833 (89.3)	163 (10.7)	
1 Mechanism	11126 (91.0)	1143 (9.0)	
2 Mechanisms	7206 (93.7)	478 (6.3)	
Ease of Exemption			0.0071
Easy	5075 (93.1)	335 (6.8)	
Medium	3075 (90.4)	415 (9.6)	
Difficult	10182 (91.9)	871 (8.1)	

Table SC1f. Bivariate analysis of missed opportunities for HPV vaccination and individual and policy variables

HPV Missed Opportunity-Individual			
	0	**1**	**P-value**
	N (%)	**N (%)**	
Age			0.2315
13	2992 (69.5)	1291 (30.5)	
14	3167 (70.6)	1262 (29.4)	
15	3080 (71.5)	1132 (28.5)	
16	3085 (71.6)	1133 (28.4)	
17	2768 (73.5)	1039 (26.5)	
Mother's Age			<0.0001
<=34 years	1229 (77.9)	370 (22.1)	
35 to 44 years	6079 (72.3)	2368 (27.7)	
>=45 years	7784 (69.2)	3119 (30.8)	
Mother's Education Level			<0.0001
Less than 12 Years	2075 (80.4)	484 (19.6)	
12 Years	2290 (72.5)	849 (27.5)	
More than 12 Years, Non-College Grad	3580 (69.4)	1593 (30.6)	
College Graduate	7147 (68.8)	2931 (31.2)	
Poverty Status			<0.0001
Above Poverty >$75K	7220 (68.6)	3080 (31.4)	
Above Poverty <=$75K	4435 (69.5)	1856 (30.5)	
Below Poverty	2859 (78.3)	720 (21.7)	
Marital Status of Mother			<0.0001
Married	10326 (69.0)	4465 (31.0)	
Not Currently Married	4766 (75.2)	1392 (24.8)	
Race/Ethnicity			<0.0001
Hispanic	3108 (80.5)	774 (19.5)	
NH White	8935 (66.1)	4076 (33.9)	
NH Black	1346 (74.0)	396 (26.0)	
NH Other/Mixed Race	1703 (73.0)	611 (27.0)	
Sex			<0.0001
Male	7678 (68.5)	3426 (31.5)	
Female	7414 (74.2)	2431 (25.8)	
Insurance Status			<0.0001
Private Insurance Only	8277 (68.0)	3642 (32.0)	
Any Medicaid	5926 (76.8)	1478 (23.2)	
Other Insurance	1210 (68.1)	498 (31.9)	
Uninsured	579 (66.9)	239 (33.1)	

Facility Type for Provider			0.545
All Public Facilities	2046 (71.6)	775 (28.4)	
All Hospital Facilities	1771 (76.0)	499 (24.0)	
All Private Facilities	6759 (70.4)	2736 (29.6)	
All STD/School/Teen Clinics or Other Facilities	454 (73.2)	176 (26.8)	
Mixed	2564 (71.2)	1117 (28.8)	
Census Region			<0.0001
Northeast	3080 (73.0)	895 (27.0)	
Midwest	3209 (69.8)	1276 (30.2)	
South	5558 (67.6)	2474 (32.4)	
West	3245 (77.4)	1212 (22.6)	
Check-Up at 11 or 12			0.7246
Yes	12362 (72.4)	4443 (27.6)	
No	574 (71.4)	262 (28.6)	
Visits in Past 12 Months			0.0252
None	1883 (68.1)	933 (31.9)	
At least 1	13040 (71.8)	4882 (28.2)	
HPV Missed Opportunity-Policy			
	0	**1**	**P-value**
	N (%)	**N (%)**	
Meningitis Requirement			0.0026
Yes	8289 (69.8)	3163 (30.2)	
No	6803 (73.3)	2694 (26.7)	
Meningitis Booster Requirement			0.0433
Yes	2228 (69.1)	907 (30.9)	
No	12864 (71.7)	4950 (28.3)	
HPV Requirement			0.0003
Yes	888 (81.2)	162 (18.8)	
No	14204 (71.0)	5695 (29.0)	
Non-medical Exemption			0.0123
0 Mechanisms	642 (77.6)	354 (22.4)	
1 Mechanism	8832 (70.0)	3437 (30.0)	
2 Mechanisms	5618 (70.7)	2066 (29.3)	
Ease of Exemption			0.0674
Easy	4063 (72.0)	1347 (28.0)	
Medium	2479 (71.0)	1011 (29.0)	
Difficult	7908 (69.3)	3145 (30.7)	