School Entry Requirements and Coverage of Nontargeted Adolescent Vaccines

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abstract

BACKGROUND: Low human papillomavirus (HPV) vaccination coverage is an urgent public health problem requiring action. To identify policy remedies to suboptimal HPV vaccination, we assessed the relationship between states' school entry requirements and adolescent vaccination.

METHODS: We gathered data on states' school entry requirements for adolescent vaccination (tetanus, diphtheria, and pertussis [Tdap] booster; meningococcal; and HPV) from 2007 to 2012 from Immunization Action Coalition. The National Immunization Survey–Teen provided medical record–verified vaccination data for 99 921 adolescents. We calculated coverage (among 13- to 17-year-olds) for individual vaccinations and concomitant vaccination. HPV vaccination outcomes were among female adolescents. Analyses used weighted longitudinal multivariable models.

RESULTS: States with requirements for Tdap booster and meningococcal vaccination had 22 and 24 percentage point increases in coverage for these vaccines, respectively, compared with other states (both $P < .05$). States with HPV vaccination requirements had <1 percentage point increase in coverage for this vaccine ($P < .05$). Tdap booster and meningococcal vaccination requirements, respectively, were associated with 8 and 4 percentage point spillover increases for HPV vaccination coverage (both $P < .05$) and with increases for concomitant vaccination (all $P < .05$).

CONCLUSIONS: Ensuring all states have meningococcal vaccination requirements could improve the nation's HPV vaccination coverage, given that many states already require Tdap booster but not meningococcal vaccination for school entry. Vaccination programs and clinicians should capitalize on changes in adolescent vaccination, including concomitant vaccination, that may arise after states adopt vaccination requirements. Additional studies are needed on the effects of HPV vaccination requirements and opt-out provisions.

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DOI: 10.1542/peds.2016-1414

Accepted for publication Sep 9, 2016

WHAT'S KNOWN ON THIS SUBJECT: Uptake of human papillomavirus (HPV) vaccine is suboptimal, leaving many young people at risk for HPV-associated diseases. School entry vaccination requirements have increased coverage of other childhood and adolescent vaccines, but few states have adopted HPV vaccination requirements.

WHAT THIS STUDY ADDS: Requirements for other adolescent vaccines were associated with larger increases in HPV vaccination coverage than were HPV vaccination requirements. Concomitant vaccination may drive these patterns. Permissive opt-out provisions may make HPV vaccination requirements acceptable but may lessen their impact.

To cite: Moss JL, Reiter PL, Truong YK, et al. School Entry Requirements and Coverage of Nontargeted Adolescent Vaccines. *Pediatrics.* 2016;138(6): e20161414

ARTICLE

In 2005, the Advisory Committee on Immunization Practices in the United States began recommending that adolescents routinely receive tetanus, diphtheria, and pertussis (Tdap) booster and meningococcal vaccines.[1] In 2006 and 2011, the recommendations expanded to include 3 doses of human papillomavirus (HPV) vaccine for female and male adolescents, respectively.[1] By 2014, coverage was high for Tdap booster (88%) and meningococcal vaccine (79%).[2] However, HPV vaccination lagged behind (<40% series completion).[2] These estimates mask variation between states; for example, HPV vaccine completion among girls ranged from 20% (Tennessee) to 57% (Washington, DC).[2] In 2014, the President's Cancer Panel emphasized that increasing HPV vaccine completion to 80% nationally would prevent an additional 53 000 cases of cervical cancer in girls currently ≤12 years old.[3] This missed opportunity for cancer prevention has prompted efforts by federal agencies to improve HPV vaccination rates.[3–6]

State school entry requirements[7] for adolescent vaccination may help address persistently suboptimal HPV vaccination rates and explain existing variation in uptake across states. These policies require that adolescents receive vaccines before entering a particular grade, with exemptions allowed for medical and, in most states, religious or philosophical reasons.[7–9] By the 2015 school year, 47 states had adopted requirements for Tdap booster, 25 states for meningococcal vaccine, and 3 states for HPV vaccine completion.[7] The HPV vaccination requirements in Virginia and Washington, DC are remarkably lax, allowing parents to opt out of vaccination for any reason.[10] Furthermore, these requirements target only female adolescents, even though national recommendations have recommended HPV vaccination for all adolescents since 2011.[1]

Vaccination requirements typically increase coverage for vaccines they target[11–15] and can generate smaller spillover increases in coverage for nontargeted vaccines.[16,17] Spillover effects may arise from concomitant vaccination (receipt of multiple vaccines during 1 health care visit).[1,18] Given the backlash against HPV vaccination requirements that has hindered their implementation,[19–22] spillover effects of requirements for other vaccines onto HPV vaccination could be important for public health. However, few studies have investigated the effects of HPV vaccination requirements.[23,24] School entry vaccination requirements may also improve adolescent vaccination timeliness, or uptake at ages 11 or 12, per national recommendations.[1] The vaccines are more effective in younger adolescents,[1,25] but many adolescents receive them when they are ≥13 years old.[4,26]

The objective of our study was to evaluate targeted and spillover effects of school entry requirements on coverage and timeliness of individual and concomitant vaccination, with a special focus on HPV vaccination.

METHODS

Data Sources

Data on school entry vaccination requirements came from the Immunization Action Coalition,[7,12,17] which publishes information on vaccination requirements compiled from health departments in states and Washington, DC (hereafter referred to as "states"). The database indicates whether and when states adopted requirements for Tdap booster, meningococcal, or HPV vaccination.

Data on vaccination outcomes came from the National Immunization Survey–Teen (NIS-Teen), implemented by the Centers for Disease Control and Prevention (CDC).[27] Each year, NIS-Teen interviewers administer telephone surveys to a population-based sample of caregivers of 13- to 17-year-old adolescents. Interviewers asked for consent to contact adolescents' primary health care providers to verify vaccination history by using medical records. Since 2008, NIS-Teen has collected medical record–verified vaccination data for ~20 000 adolescents annually. We examined data from the 2008 to 2012 NIS-Teen, for a total of 99 921 adolescents (an average of 392 adolescents per state, per year).[27]

Data collection for NIS-Teen was approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board. Analysis of deidentified data from the survey is exempt from federal regulations for the protection of human research participants. Analysis of restricted data through the NCHS Research Data Center is also approved by the NCHS Research Ethics Review Board. The University of North Carolina Institutional Review Board exempted this study from review.

Measures

School Entry Vaccination Requirements

For each adolescent vaccine, we coded whether states had adopted school entry vaccination requirements by August 1 of each year (2007–2012).

Vaccination Outcomes

We calculated states' yearly coverage for Tdap booster, meningococcal vaccination, and HPV vaccination (first dose among girls) for 13- to 17-year-olds (2008–2012).[28–32] We also calculated coverage for receipt of 2 vaccines concomitantly (on the same day[18]) for each combination of adolescent vaccines. As a secondary outcome, we measured timeliness,[1] calculated as states' yearly percentage of adolescents who received each vaccine by age 13 (2008–2012).

As a supplementary outcome, we measured summer peaks in adolescent vaccination.[33,34] Health care providers deliver a substantial portion of adolescent vaccinations between June and August,[33] and vaccination requirements may amplify these summer peaks as parents hurry to comply before the school year begins. To measure summer peaks, we coded the month and year adolescents received their vaccinations and calculated the percentage of vaccine doses administered in June, July, and August[33] (2008–2011). Because of small cell sizes, we did not analyze summer peaks for vaccines delivered in 2012.

Data Analysis

First, we estimated the mean of each vaccination outcome for states with and without each school entry requirement (collapsed over study years). We examined these outcomes for all states with a given vaccination requirement, regardless of their other requirements. For example, a state with a Tdap booster requirement may have had only that requirement, or it may have also had meningococcal and HPV vaccination requirements.

Next, we constructed multivariable generalized estimating equations to examine associations between the 3 vaccination requirements and each outcome. Because the effects of vaccination requirements may not have emerged in the same year as policy adoption (because of time needed for effects to spread through the population), we examined effects of vaccination requirements in a given year on outcomes in the next year. Our preliminary analyses found that 1-year lagged models better fit the observed data than nonlagged models (data not shown). Models also controlled for study year and the level of the outcome in previous years.

To examine the variance of requirements' effects over time, we evaluated interaction terms for study year and school entry vaccination requirement. Because Wald tests showed no interactions (all were $P > .05$), we dropped these interactions from the models.

Estimates of vaccination outcomes incorporated NIS-Teen sampling weights to account for nonequal probability of selection.[27] Multivariable analyses were weighted by states' NIS-Teen sample size. We excluded from analysis of vaccination timeliness and summer peaks any adolescent who did not receive the respective vaccines. For all outcomes that included HPV vaccine, we measured initiation of the 3-dose series only among adolescent girls because CDC recommendations for routine administration in boys did not go into effect until 2011.[35] We use the terms *targeted* and *spillover* to refer to associations between school entry vaccination requirements and outcomes for the vaccine named in the requirement versus all other vaccines, respectively. We implemented analyses in SAS version 9.2 (SAS Institute, Inc, Cary, NC). Statistical tests used a 2-tailed *P* value of .05.

RESULTS

Seven states had school entry requirements for Tdap booster in 2007, none for meningococcal vaccination, and none for HPV vaccination (Table 1). By 2012, these figures had increased to 42, 14, and 2 states, respectively. States' vaccination requirements overlapped: In 2012, both states with HPV vaccination requirements also had meningococcal vaccination requirements, and all 14 states with meningococcal vaccination requirements also had Tdap booster requirements.

Vaccination Coverage

Tdap booster requirements had the intended effect: Coverage for the vaccine was 22 percentage points higher (95% confidence interval [CI], 17 to 27) in states with these requirements than in states without them (Table 2) (77% vs 56%; Supplemental Table 4). In terms of spillover effects, HPV vaccination coverage was 8 percentage points higher in states with Tdap booster requirements (Fig 1), and other vaccine coverage outcomes were 4 to 15 percentage points higher. Multivariable analyses confirmed that Tdap booster requirements were associated with higher coverage for all vaccination outcomes (all $P < .05$). Supplemental Table 4 provide additional findings for vaccination coverage, timeliness, and summer peaks.

Meningococcal vaccination requirements also had the intended effect: coverage for the vaccine was 24 percentage points higher (95% CI, 19 to 29) in states with these requirements than in states without them (Table 2) (81% vs 57%; Supplemental Table 4). In terms of spillover effects, HPV vaccination was 4 percentage points higher (Fig 1), and coverage with other vaccines was 3 to 23 percentage points higher. Multivariable analyses confirmed that meningococcal vaccination requirements were associated with higher coverage for all vaccination outcomes (all $P < .05$).

However, HPV vaccination requirements did not act as expected. Coverage for the vaccine was <1 percentage point higher (95% CI, −6 to 7) in states with HPV vaccination requirements than in states without them (Table 2; Fig 1) (47.7% vs 47.3%; Supplemental Table 4). This difference in HPV vaccination coverage was small, but multivariable analyses confirmed that it was statistically significant ($P < .05$). HPV vaccination requirements were also associated with higher coverage for

TABLE 1 Prevalence of School Entry Vaccination Requirements, Vaccination Coverage, and Vaccination Timeliness Across Vaccination Outcomes

Year	Tdap	MCV4	HPV[a]	Tdap and MCV4	Tdap and HPV[a]	MCV4 and HPV[a]
			Number of states with school entry vaccination requirements			
2007	7	0	0	—	—	—
2008	16	3	1	—	—	—
2009	24	8	2	—	—	—
2010	32	10	2	—	—	—
2011	38	13	2	—	—	—
2012	42	14	2	—	—	—
Mean	27	8	2	—	—	—
			Vaccination coverage (% vaccinated)			
2007	—	—	—	—	—	—
2008	40.8	41.8	37.2	13.2	6.6	13.8
2009	55.6	53.6	44.3	19.2	11.4	17.4
2010	68.7	62.7	48.7	27.7	14.6	19.6
2011	78.2	70.5	53.0	36.7	20.2	23.6
2012	84.6	74.0	53.8	42.7	23.8	27.8
Mean	65.5	58.9	47.9	30.3	15.5	21.6
			Vaccination timeliness (% vaccinated by age 13)			
2007	—	—	—	—	—	—
2008	8.7	9.7	11.0	4.1	3.0	4.3
2009	20.8	20.7	19.8	9.8	6.5	8.2
2010	35.8	33.6	28.4	17.9	10.0	11.9
2011	52.6	47.9	38.8	28.2	15.1	16.6
2012	66.6	56.5	41.4	36.3	17.5	19.1
Mean	37.1	35.6	27.1	20.5	10.2	12.5

Columns labeled "Tdap and MCV4," "Tdap and HPV," and "MCV4 and HPV" refer to concomitant (same-day) vaccination outcomes. Data on school entry vaccination requirements came from the Immunization Action Coalition, and data on vaccination outcomes came from the 2008–2012 versions of the NIS-Teen. MCV4, meningococcal vaccine.

[a] Among female adolescents only.

Tdap booster but lower coverage for meningococcal vaccination and other vaccination outcomes in multivariable analyses.

Vaccination Timeliness

States with Tdap booster requirements had timely Tdap booster vaccination rates that were 25 percentage points greater (95% CI, 18 to 32) and timely HPV vaccination rates that were 12 percentage points greater than states without Tdap booster requirements (Table 3). States with meningococcal vaccination requirements had timely meningococcal vaccination rates that were 27 percentage points greater (95% CI, 19 to 34) and timely HPV vaccination rates that were 9 percentage points greater than states without meningococcal vaccination requirements (Table 3). Multivariable analyses confirmed that Tdap booster and meningococcal vaccination requirements were associated with greater timeliness for all vaccination outcomes ($P < .05$).

Finally, states with HPV vaccination requirements had timely HPV vaccination rates that were 4 percentage points greater (95% CI, −3 to 12) than states without the requirements (Table 3). Multivariable analyses confirmed that HPV vaccination requirements were associated with greater timeliness for HPV vaccine, Tdap booster, meningococcal vaccine, and concomitant meningococcal and HPV vaccination, and lower timeliness for remaining outcomes (all $P < .05$).

Summer Peaks in Vaccination

In supplementary analyses, Tdap booster, meningococcal vaccine, and HPV vaccine requirements were associated with increases in summer peaks in all vaccination outcomes ($P < .05$; Supplemental Table 5). For example, summer peaks in HPV vaccination were 8 percentage points larger for states with Tdap booster requirements, 5 percentage points larger for states with meningococcal vaccination requirements, and 25 percentage points larger for states with HPV vaccination requirements than for other states.

DISCUSSION

Adolescent school entry vaccination requirements were associated with improvements in coverage and timeliness in a 5-year, nationally representative study of ~100 000 adolescents. Tdap booster and meningococcal vaccination requirements were effective at increasing coverage for the targeted vaccines and were associated with larger spillover increases in HPV vaccination coverage. In contrast, school entry HPV vaccination requirements for adolescent girls in 2 jurisdictions had minimal impact on HPV vaccination coverage and may have led to poorer coverage for some other vaccination outcomes.

Previous studies have demonstrated similar but smaller increases in coverage with targeted vaccines for Tdap booster[11,12,16] and

TABLE 2 Differences in Adolescent Vaccination Coverage for States With School Entry Vaccination Requirements Versus Without (2008–2012)

	Tdap		MCV4		HPV[a]		Tdap and MCV4		Tdap and HPV[a]		MCV4 and HPV[a]	
	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
States with Tdap booster school entry requirements versus without												
Difference, %	+22	17 to 27	+15	10 to 19	+8	4 to 11	+11	6 to 16	+4	1 to 8	+4	0 to 7
Coefficient	0.462	0.461 to 0.463	0.020	0.019 to 0.021	0.148	0.147 to 0.149	0.196	0.195 to 0.196	0.041	0.040 to 0.042	0.048	0.047 to 0.049
States with meningococcal vaccination school entry requirements versus without												
Difference, %	+17	12 to 22	+24	19 to 29	+4	1 to 8	+23	18 to 28	+3	1 to 6	+4	1 to 6
Coefficient	0.038	0.036 to 0.039	0.800	0.798 to 0.801	0.106	0.105 to 0.107	0.709	0.708 to 0.710	0.082	0.080 to 0.083	0.001	0.000 to 0.002
States with HPV vaccination school entry requirements versus without												
Difference, %	+9	−3 to 20	−3	−9 to 4	+0	−6 to 7	−11	−16 to −7	−5	−8 to −3	−2	−7 to 3
Coefficient	0.174	0.171 to 0.177	−0.233	−0.236 to −0.230	0.192	0.190 to 0.195	−0.664	−0.667 to −0.661	−0.661	−0.665 to −0.656	−0.227	−0.230 to −0.224

In multivariable models assessing the relationship between school entry vaccination requirements and coverage, controlling for year, previous measures of coverage, and other school entry vaccination requirements, with a lag of 1 year, all regression coefficients were $P < .05$. Policies reflect whether a state had the school entry vaccination requirements, although they may have had other requirements as well. Columns labeled "Tdap and MCV4," "Tdap and HPV," and "MCV4 and HPV" refer to concomitant (same-day) vaccination outcomes (not mutually exclusive with "Tdap," "MCV4," and "HPV" columns, ie, nonconcomitant vaccination). Data on vaccination school entry requirements came from the Immunization Action Coalition, and data on coverage came from the 2008–2012 versions of the NIS-Teen. Coefficient, unstandardized regression coefficient; difference, absolute difference in coverage for states with versus without respective requirements; Est., estimate; MCV4, meningococcal vaccine.

[a] Among female adolescents only.

meningococcal vaccination[12,15] requirements. In contrast to those studies, our analyses included a 1-year lag and controlled for previous years' coverage estimates to better establish the size and temporality of the relationships. Recent studies have found negligible or nonexistent differences in coverage from HPV vaccination requirements[23,24]; the statistically significant but very small increase in HPV vaccination coverage demonstrated in our study could have resulted from the large sample size.

Although these findings about HPV vaccination coverage may be counterintuitive, they make sense in the context of the weak HPV vaccination requirements in place at the time of our study. Only Virginia and Washington, DC[10] enacted HPV vaccination requirements during the study period. These requirements covered adolescent girls only and allowed parents to opt out for any reason and with little effort, which has been associated with higher rates of nonmedical exemptions for other vaccination requirements.[36] Adoption of stronger HPV vaccination requirements in other states could have different implications for HPV vaccination coverage. For example, in 2015 Rhode Island adopted an HPV vaccination school entry requirement for all adolescents, with opt-out allowed only for medical or religious reasons.[37] The requirement has faced ongoing public opposition,[37] despite the high rates of HPV vaccination in the state before the requirement went into effect.[2] It will be important to monitor HPV vaccination coverage in Rhode Island among male and female adolescents in the coming years.

School entry vaccination requirements were also associated with spillover increases in HPV vaccination coverage (4–8 percentage points) that were much larger than the modest increase associated with requirements

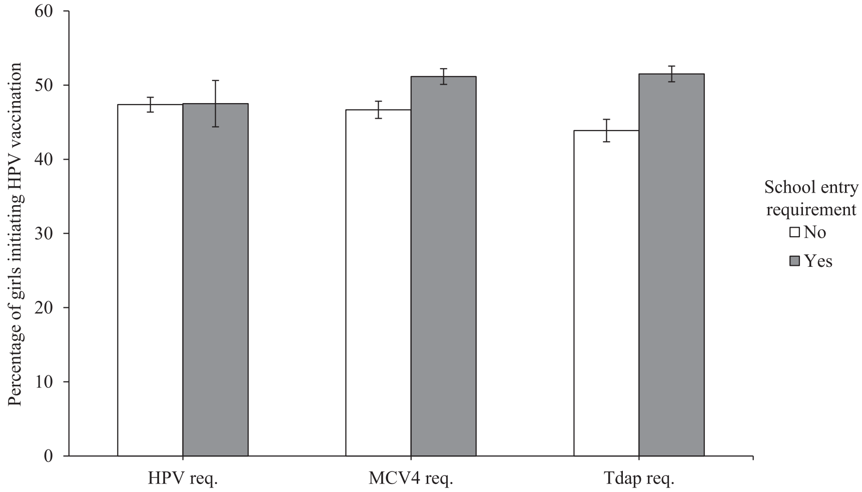

FIGURE 1
HPV vaccine initiation among female adolescents (*n* = 47 742), by state school entry requirements (req.) for HPV vaccination, meningococcal (MCV4) vaccination, and Tdap booster. Error bars show SEs. Requirement data came from Immunization Action Coalition, and vaccination data came from 2008–2012 versions of NIS-Teen.

targeting HPV vaccination (<1 percentage point). HPV vaccination requirements were also associated with spillover decreases in coverage for some of the other outcomes. Future studies should attempt to explain these decreases, but a potential mechanism may be that parents' reactance[38] against HPV vaccination requirements spread to other vaccines. Previous studies have demonstrated the spillover effects of Tdap booster requirements,[11,16,17] but to our knowledge no other studies have investigated spillover effects of meningococcal and HPV vaccination requirements.

Policymakers should consider changing school entry requirements to increase HPV vaccination coverage. First, we believe that states should consider an indirect approach of adopting Tdap booster or meningococcal vaccination requirements. All but 2 states now have Tdap booster vaccination requirements, but many states have not yet adopted meningococcal vaccination requirements.[7] Adoption of the latter requirement may be a promising way to increase HPV vaccination and meningococcal vaccination coverage. Second, states with school entry requirements already in place for Tdap booster and meningococcal vaccination could restrict opt-out provisions. More generous opt-out provisions are associated with higher rates of exemption, lower vaccination coverage, and higher disease incidence.[36,39] Finally, policymakers could try to increase HPV vaccination coverage more directly by adopting HPV vaccination requirements, which may or may not be politically feasible and effective. The impact of HPV vaccination requirements for both boys and girls and with less lenient opt-out provisions remains to be established, but strict requirements for the vaccine are unpalatable to the majority of parents.[40]

In addition, school entry vaccination requirements were associated with more timely adolescent vaccination. Most requirements target students entering the sixth or seventh grade,[7] when adolescents are typically ages 11 or 12, which coincides with national recommendations about age of vaccination.[1] Vaccination requirements may provide an additional incentive for parents to seek timely vaccination for their adolescents. Tdap booster and meningococcal vaccination requirements had larger spillover effects on HPV vaccination timeliness than the targeted association between HPV vaccination requirements and timeliness for that vaccine. Thus, all vaccination requirements improved the rate of timely adolescent vaccination, but Tdap booster and meningococcal vaccination requirements were particularly effective.

Finally, school entry vaccination requirements were associated with larger summer (June to August) peaks in vaccination.[33] This association was particularly striking for the jurisdictions with HPV vaccination requirements. In states without these requirements, health care providers administered 53% of (initial) HPV vaccine doses in the summer, but in states with these requirements, providers administered 78% of HPV vaccine doses in the summer. Thus, interventions that disrupt clinical practice during the summer could be especially problematic for vaccination, but education or promotion campaigns could be especially successful at that time. Providers can prepare for increased summer demand for vaccinations after a state adopts a vaccination requirement through initiatives to increase efficiency, such as adopting standing orders for recommended vaccines[41] and focusing on offering concomitant administration of HPV vaccine during periods when Tdap booster and meningococcal vaccination are at their peak.

Study strengths include a large sample size from a high-quality, national data set.[27] Health care providers verified vaccination status and dates, increasing our confidence in the validity of these measures. Previous studies of school entry vaccination requirements have focused on the associations between Tdap booster requirements and coverage, but we also investigated

TABLE 3 Differences in Adolescent Vaccination Timeliness for States With School Entry Vaccination Requirements Versus Without (2008–2012)

	Tdap		MCV4		HPV[a]		Tdap and MCV4		Tdap and HPV[a]		MCV4 and HPV[a]	
	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI	Est.	95% CI
States with Tdap booster school entry requirements versus without												
Difference,%	+25	18 to 32	+21	14 to 27	+12	8 to 16	+13	8 to 18	+5	2 to 7	+5	2 to 8
Coefficient	0.350	0.350 to 0.351	0.042	0.041 to 0.043	0.118	0.118 to 0.119	0.030	0.029 to 0.031	0.079	0.078 to 0.080	0.047	0.046 to 0.048
States with meningococcal vaccination school entry requirements versus without												
Difference, %	+21	12 to 28	+27	19 to 34	+9	5 to 14	+20	14 to 26	+4	1 to 6	+5	3 to 8
Coefficient	0.052	0.051 to 0.053	0.511	0.510 to 0.511	0.062	0.061 to 0.063	0.065	0.064 to 0.066	0.582	(0.582 to 0.583	0.091	(0.090 to 0.092
States with HPV vaccination school entry requirements versus without												
Difference, %	+6	−14 to 27	+3	−11 to 16	+4	−3 to 12	−7	−14 to 0	−2	−6 to 1	+1	−3 to 5
Coefficient	0.219	0.217 to 0.221	0.108	0.106 to 0.110	0.078	0.076 to 0.080	−0.496	−0.500 to −0.492	−0.601	−0.604 to −0.598	0.158	0.155 to 0.161

In multivariable models assessing the relationship between school entry vaccination requirements and timeliness, controlling for year, previous measures of timeliness, and other school entry vaccination requirements, with a lag of 1 year, all regression coefficients were $P < .05$. Policies reflect whether a state had the school entry vaccination requirements, although they may have had other requirements as well. Columns labeled "Tdap and MCV4," "Tdap and HPV," and "MCV4 and HPV" refer to concomitant (same-day) vaccination outcomes (not mutually exclusive with "Tdap," "MCV4," and "HPV" columns, ie, nonconcomitant vaccination). Data on vaccination school entry requirements came from the Immunization Action Coalition, and data on timeliness came from the 2008–2012 versions of the NIS-Teen. coefficient, unstandardized regression coefficient; difference, absolute difference in timeliness for states with versus without respective requirements; Est., estimate; MCV4, meningococcal vaccine.

[a] Among female adolescents only.

meningococcal and HPV vaccination requirements, other vaccination outcomes (timeliness and summer peaks), spillover effects, and concomitant vaccination. We used a longitudinal design to disentangle the temporal relationships between study variables, and we examined the consistency of these relationships over time.

Study limitations include the observational nature of our study; we could not eliminate all potential confounders. Particularly important is unmeasured confounding by other factors related to vaccination, such as demographics or norms around health care policies. Additionally, vaccination requirements within states were correlated. We addressed this issue by implementing multivariable models controlling for other school entry vaccination requirements. Differences in vaccination outcomes represent population-level averages at the study midpoint (2010); thus, for meningococcal and HPV vaccination school entry requirements (which were uncommon before 2010), the magnitude of the differences may be underestimated. Because of small cell sizes, we could not analyze summer peaks in vaccination for 2012. Similarly, the sample size within a given cell was small, particularly for HPV vaccination, which was measured only among female adolescents. With continuing data collection, future studies can evaluate the relationships described here with more precision. We did not evaluate HPV vaccination among male adolescents, which is an important endpoint for future studies.

CONCLUSIONS

Tdap booster and meningococcal vaccination school entry requirements were consistently associated with higher coverage, greater timeliness, and larger summer peaks for targeted and spillover vaccinations. These findings highlight potential policy interventions to continue improving adolescent vaccination rates. Given the low rates of HPV vaccination and the political difficulties in adopting school entry requirements for this vaccine,[19–22] the associations between Tdap booster and meningococcal vaccination requirements and HPV vaccination outcomes are especially important. Absent strong HPV vaccination school entry requirements, adopting Tdap booster or meningococcal vaccination requirements may lead to the greatest improvements in HPV vaccination among the policy interventions evaluated in the current study. These requirements may be even more influential for HPV vaccination coverage than HPV vaccination requirements with generous opt-out provisions. Because almost all states now have Tdap requirements, more widespread adoption of meningococcal vaccination school entry requirements could have the most positive impact on HPV vaccination. Leveraging school entry requirements to improve vaccination rates can have implications for herd immunity, herd severity,[42] and protecting the population from vaccine-preventable infectious and chronic diseases.

ACKNOWLEDGMENTS

The research was conducted while J.L.M. was a Special Sworn Status researcher of the US Census Bureau at the Center for Economic Studies. All results have been reviewed by the National Center for Health Statistics to ensure that no confidential information is disclosed. This manuscript was prepared by J.L.M. in her personal capacity. The opinions expressed in this article are the authors' own and do not reflect the views of the National Institutes of Health, the Department of Health and Human Services, or the United States government. In addition, the opinions expressed in this article do not reflect the view of the National Center for Health Statistics.

ABBREVIATIONS

CDC: Centers for Disease Control and Prevention
CI: confidence interval
HPV: human papillomavirus
NCHS: National Center for Health Statistics
NIS-Teen: National Immunization Survey–Teen
Tdap: tetanus, diphtheria, and pertussis

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: Supported by National Institutes of Health grant F31 CA189411 (principal investigator: Jennifer L. Moss). Dr Truong was supported by NSF-DMS-1106962. Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: Drs Moss, Truong, and Rimer have indicated they have no potential conflicts of interest to disclose. Dr Reiter has received a research grant from Merck Sharp & Dohme Corp and has also received a research grant from Cervical Cancer–Free America, via an unrestricted educational grant from GlaxoSmithKline. Dr Brewer has served on paid advisory boards or received research grants from Merck, GlaxoSmithKline, the Centers for Disease Control and Prevention (CDC), and the US Food and Drug Administration, and now serves as chair of the CDC-funded National HPV Vaccination Roundtable. None of these entities had any role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript.

COMPANION PAPER: A companion to this article can be found online at www.pediatrics.org/cgi/doi/10.1542/peds.2016-3097.

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