Policy Approaches for Increasing Adolescent HPV Vaccination Coverage: A Systematic Review

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abstract

CONTEXT: US jurisdictions have enacted a wide range of policies to address low human papillomavirus (HPV) vaccination coverage among adolescents, but it is unclear which policies are effective.

OBJECTIVE: To systematically review the impact of governmental policies on adolescent HPV vaccination coverage.

DATA SOURCES: PubMed, Embase, and Scopus databases.

STUDY SELECTION: Eligible studies, published from 2009 to 2022, evaluated the impact of governmental policies on HPV vaccination coverage among adolescents ages 9 to 18.

DATA EXTRACTION: Two investigators independently extracted data on study sample, study design and quality, policy characteristics, and HPV vaccination outcomes. We summarized findings by policy type: school-entry requirements (SERs), federally-funded policies related to the Vaccines for Children program and Medicaid, educational requirements, and others.

RESULTS: Our search yielded 36 eligible studies. A majority of studies evaluating HPV vaccine SERs found positive associations between SERs and HPV vaccination coverage (8 of 14), particularly for SERs in Rhode Island and Washington, DC. All studies evaluating SERs for other adolescent vaccines observed positive spillover effects for HPV vaccination (7 of 7). Federally-funded policies related to Vaccines for Children and Medicaid were consistently associated with higher HPV vaccination coverage (7 of 9). Relatively few studies found associations between educational requirements and HPV vaccination coverage (2 of 8).

LIMITATIONS: Studies used limited vaccination data sources and non- or quasi-experimental designs. Some studies had no or poorly matched comparison groups.

CONCLUSIONS: Our findings suggest promise for SERs and federally-funded policies, but not educational requirements, for increasing HPV vaccination coverage among adolescents.

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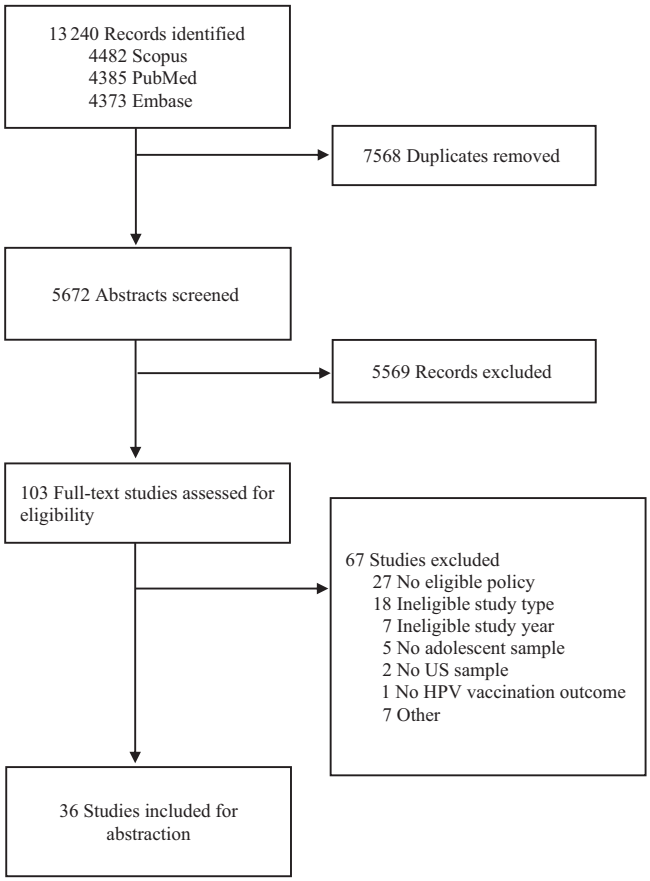

FIGURE 1
Flow diagram.

States and other area-level jurisdictions have adopted a wide variety of policies to improve persistently lackluster human papillomavirus (HPV) vaccination coverage in the United States, where only half (50.0%) of 13-year-old adolescents were up-to-date on the multidose series by 2022.[1] Most notably, 5 jurisdictions, Hawaii, Puerto Rico, Rhode Island, Virginia, and Washington, DC, have enacted school-entry requirements (SERs) that require families to vaccinate their adolescents against HPV or receive an exemption before starting a particular grade.[2] Furthermore, all jurisdictions have enacted SERs for other adolescent vaccines, which may have positive spillover effects on HPV vaccination coverage.[3,4] In addition to SERs, 13 jurisdictions have implemented educational requirements, which require schools or other entities to distribute information to parents or students to increase awareness of the benefits of HPV vaccination.[5,6] Finally, still other policies attempt to improve HPV vaccination coverage by increasing access. These include federally-funded policies implemented at the jurisdiction level, such as the Vaccines for Children (VFC) program that funds vaccines for families with limited ability to pay,[7] as well as Medicaid expansion and financing.[8,9] By targeting "upstream" and population-level factors that affect large numbers of families, policy interventions like these have the potential to bring about population-level increases in HPV vaccination and a reduction in HPV-associated disease burden.

Despite their promise, little consensus exists about which types of policies are effective for increasing HPV vaccination coverage. Understanding policy effectiveness is critical for guiding policymakers in considering whether future policies are worth the financial and political costs of implementation. Thus, we sought to systematically review the impact of governmental policies on adolescent HPV vaccination coverage.

METHODS

We systematically reviewed studies from 2009 to 2022 assessing the association between policies and HPV vaccination coverage among US adolescents. We defined policies as legislation, rules, or requirements passed by a governmental policymaking body at the district or state, municipality, or national level. We excluded policies enacted by clinics, health systems, or school districts. Eligible studies evaluated policies' influence on HPV vaccination coverage, or the proportion of adolescents who initiated (≥1 dose) or completed (2–3 doses) the multidose HPV vaccine series, as defined by guidelines for administration at the time of the study. We defined adolescents as children aged 9 to 18 and excluded studies with study populations beyond that age range. Studies that had populations consisting of adolescents and other individuals (eg, young adults) were deemed eligible if the study reported adolescent outcomes separately. All included studies used US data from 2009 to 2022; we chose to focus on this period to allow time for policy enactment and evaluation after HPV vaccination was approved for girls in 2006. We excluded non-peer-reviewed articles, commentaries, conference abstracts and proceedings, guidelines for vaccine administration, and other reviews.

A medical librarian (R.C.) developed search strings for the concepts of HPV, vaccines, and policies, using a combination of subject headings and keywords (Supplemental Table 2). Using these search strings, we searched PubMed, Embase, and Scopus for papers published from January 1, 2009 to February 11, 2022 (the search date), using database filters to specify study period and exclude nonhuman studies. We excluded non-US studies for a more consistent jurisdictional policy environment. A custom publication type filter was used to exclude reviews and conference literature from the search. We exported citations, removed duplicates, and then imported studies using Covidence software (Covidence, Melbourne, Australia).

A team of 7 investigators (B.K.G., M.C.M., M.B.G., J.H.M., W.Y.K., N.L.O., G.J.) assessed each record to determine eligibility and used Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines for reporting results.[10] First, 2 team members reviewed each record independently, comparing titles and abstracts against eligibility criteria to

TABLE 1 Summary of Adolescent HPV Vaccine Policy Studies (36 studies)

First Author, Year	Study Population	Data Source, Study Period, and Design	Policies	Main Result	Types of Policies Considered			
					SERs[a]	Education[b]	Federally-funded	Other[c]
Bugenske, 2012[5]	37 901 adolescents aged 13–17 in national sample (females only for HPV vaccine analysis)	NIS-Teen, 2008–2009; cross-sectional study	(1) TdaP and/or MenACWY vaccine SER (spillover effects on HPV vaccine); (2) parental education requirements for HPV vaccination[d]	(1) States with at least 1 adolescent vaccine SER had higher initiation for all 3 vaccines combined (42.2%; 95% CI: 40.7% to 43.7%) than states with educational requirements only (35.4%; 95% CI: 32.9% to 37.9%), but did not differ from states with no SER or educational requirements (42.1%; 95% CI: 38.4% to 45.9%); (2) parental education requirements not associated with HPV vaccine initiation	X	X	—	—
Carpenter, 2019[3]	57 133 adolescents aged 10–13[e] in a national sample	NIS-Teen, 2008–2013; pooled cross-sectional study with pre-post analysis	Tdap vaccine SER (spillover effects on HPV vaccine)	SERs associated with increased HPV vaccine initiation by 4.2–4.9 percentage points (SE: 0.0151 and 0.0152, respectively) and completion by 2.5–3.3 percentage points (SE: 0.00863 and 0.0107, respectively)	X	—	—	—
Chen, 2020[23]	7 837 480 adolescents aged 9–17 in a national sample	Market-scan claims data, 2003–2017; retrospective cohort study	(1) HPV vaccine SER; (2) personal belief exemption to SER for HPV; (3) HPV vaccine education requirements for parents or adolescents by HCPs; (4) state-purchased HPV vaccinations	(1) SERs not associated with HPV vaccination coverage (≥2 doses); (2) Not allowing personal belief exemptions not associated with HPV vaccination coverage; (3) Educational requirements associated with coverage increase of 8.8% (95% CI: 3.3% to 14.2%) for girls and an 8.7% (95% CI: 3.2% to 14.2%) for boys; (4) State-purchased vaccines not associated with increased HPV vaccination coverage	X	X	—	X
Churchill, 2021a[13]	172 891 adolescents aged 13–17 in a national sample	NIS-Teen, 2010–2018; pooled cross-sectional study	Medicaid expansion as part of the ACA	Medicaid expansion associated with a 4-percentage point increase in the probability that an adolescent had initiated HPV vaccination ($P < .01$).	—	—	X	—
Churchill, 2021b[35]	200 894 adolescents aged 13–17 in Washington, DC	NIS-Teen, 2008–2018; pooled cross-sectional with pre-post analysis and synthetic control	(1) HPV vaccine SER for boys; (2) HPV vaccine SER opt-out structure (one-time versus annually)	(1) SER for boys associated with increase in likelihood of initiation (26 percentage points) and completion (23 percentage points); (2) Change from one-time opt-out provision to an annual requirement associated with an 11-percentage point increase in the probability of initiating HPV vaccination ($P < .05$) for teen girls (age 14–17), and 20-percentage point increase in probability of vaccination completion ($P < .01$)	X	—	—	—

TABLE 1 Continued

First Author, Year	Study Population	Data Source, Study Period, and Design	Policies	Main Result	Types of Policies Considered			
					SERs[a]	Education[b]	Federally-funded	Other[c]
Cuff, 2016[24]	908 female adolescents aged 11–12 in Virginia	Electronic medical records, 2014; prospective cohort study; pre-post comparison with an earlier study	HPV vaccine SER	SERs not associated with HPV vaccine initiation.	X	—	—	—
Dempsey, 2011[17]	Female adolescents aged 13–17 in a national sample[f]	NIS-Teen, 2009; population-based cross-sectional study	Td or Tdap vaccine SER (spillover effects on HPV vaccine)	SERs associated with higher coverage for HPV vaccine initiation (47.3%) among adolescent females in comparison with states without SERs (42.9%; $P = .004$).	X	—	—	—
Fagan, 2020[34]	Adolescents aged 13–17 in a national sample[f]	NIS-Teen, 2016; population-based cross-sectional study	State requirements for abstinence-based sex education	Degree to which sex education policies emphasize abstinence not associated with HPV vaccination initiation or completion in adjusted analyses.	—	X	—	—
Falik, 2018[14]	Adolescents aged 13–17 in Pennsylvania, Rhode Island, Virginia, and Washington, DC[f]	NIS-Teen, 2016; descriptive comparison	HPV vaccine SER	HPV vaccine SERs for boys and girls associated with higher HPV vaccination completion (DC: 62% and RI: 70.8%) than a state without (PA: 51%, $P < .01$). HPV vaccine SER for girls only associated with lower HPV vaccine initiation and completion (VA: 50.7% and 41.4%, respectively) compared with a state without (PA: 72% and 58%, $P < .01$).	X	—	—	—
Franco, 2019[15]	20 495 adolescents aged 13–17 in a national sample	NIS-Teen, 2016; population-based cross-sectional study	(1) HPV vaccine SER; (2) state requirements for sex education; (3) level of centralization of state public health department; (4) CDC funding available to be used for HPV vaccine promotion per capita	(1) HPV vaccine SERs associated with higher HPV vaccination completion at the state-level (OR: 1.71, 95% CI: 1.19 to 2.45); (2) Comprehensive sex education policies and abstinence-only education policies not associated with HPV vaccination completion in adjusted analyses; (3) Level of centralization not associated with HPV vaccine completion; (4) CDC funding per capita not associated with HPV vaccine completion	X	X	—	X
Garcia-Huidobro, 2016[43]	21 704 adolescents aged 10–24 in Minnesota	Electronic medical records, 2010–2014; retrospective cohort study	Patient-centered medical home enrollment	Enrollment in patient-centered medical homes associated with increased likelihood of initiating HPV vaccination compared with those not enrolled in these programs (OR: 2.06, 95% CI: 1.75 to 2.43)	—	—	—	X

TABLE 1 Continued

First Author, Year	Study Population	Data Source, Study Period, and Design	Policies	Main Result	Types of Policies Considered			
					SERs[a]	Education[b]	Federally-funded	Other[c]
Gowda, 2012[36]	Adolescents aged 13–17 in a national sample[f]	NIS-Teen, 2009; population-based cross-sectional study	(1) Medicaid reimbursement; (2) scope of VFC program	(1) Medicaid reimbursement not associated with vaccine completion; (2) Participation in a more expansive VFC program (universal or universal-select) associated with higher HPV vaccine completion by 8.16 percentage points (95% CI: 3.21 to 13.1) in states with ≥1 Td or Tdap or MenACWY vaccine mandate	—	—	X	—
Hoff, 2020[37]	145 153 adolescents aged 13–17 in national sample	NIS-Teen, 2011–2017; pooled cross-sectional study with pre-post analysis	Medicaid expansion as part of the ACA	Medicaid expansion associated with increased HPV vaccine initiation (36%) compared with states that did not expand Medicaid (32%); (difference in differences model adjusted effect: β = 0.031, 95% CI: 0.016 to 0.046)	—	—	X	—
Inguva, 2020[38]	36 296 adolescents aged 9–26 in Mississippi	Claims data, 2013–2018; retrospective cohort study	State Medicaid provider payment plans (fee-for-service versus managed care)	Enrollment in managed care at initiation associated with lower odds of completion of HPV vaccine series than those in fee-for-service (females aOR: 0.92, 95% CI: 0.85 to 0.98; males aOR: 0.81, 95% CI: 0.76 to 0.87).	—	—	X	—
Johnson, 2016[39]	18 264 adolescents aged 13–17 in a national sample	NIS-Teen, 2013; population-based cross-sectional study	VFC program eligibility	Ineligibility for VFC associated with lower odds (0.67; 95% CI: 0.48 to 0.96) of initiating vaccination among boys. No association for vaccine completion for boys and no association for initiation or completion for girls.	—	—	X	—
Kashani, 2019[40]	684 509 adolescents aged 9–18 in Michigan	State immunization registry, 2006–2015; pooled cross-sectional study	Number of VFC providers by zip code	Adolescents that lived in a zip code with a greater number of VFC providers had higher odds of completing vaccination than those with just 1 VFC provider (2–4 providers aOR: 1.05 (95% CI: 1.02 to 1.07); ≥5 providers aOR: 1.07 (95% CI:1.04 to 1.10). No consistent pattern for association with vaccine initiation.	—	—	X	—

TABLE 1 Continued

First Author, Year	Study Population	Data Source, Study Period, and Design	Policies	Main Result	Types of Policies Considered			
					SERs[a]	Education[b]	Federally-funded	Other[c]
Ko, 2020[16]	4784 adolescents aged 13–17 in Rhode Island, Virginia, and Washington, DC	NIS-Teen, 2008–2017; population-based cross-sectional study	HPV vaccine SER	SERs in RI and DC associated with greater odds of HPV vaccination initiation compared with regional nonpolicy jurisdictions (RI aOR: 4.34, 95% CI: 2.16 to 10.00; DC aOR: 2.35, 95% CI: 1.39 to 4.19). RI and DC SERs associated with increased initiation post policy (RI boys aOR: 5.84, 95% CI: 3.92 to 8.69; RI girls aOR 3.12, 95% CI: 1.92 to 5.07) (DC boys aOR: 6.36, 95% CI: 4.27 to 9.46; DC girls aOR: 2.13, 95% CI: 1.31 to 3.45). VA SER was not associated with vaccine initiation compared with regional nonpolicy jurisdictions. VA SER associated with increased initiation in girls 16–17 post policy (aOR: 3.23, 95% CI: 1.17 to 8.90), but not significant for all ages.	—	—	X	—
La, 2021[22]	Adolescents aged 17 in a national sample[f]	NIS-Teen, 2015–2018; pooled cross-sectional study	MenACWY vaccine SER (spillover effects on HPV vaccine)	MenACWY SERs associated with higher odds of completion of recommended vaccinations (HPV, Tdap, MenACWY) (OR: 1.64; 95% CI: 1.16 to 2.33)	—	—	X	—
Lindley, 2011[42]	20 066 adolescents aged 13–17 in a national sample	NIS-Teen, 2009; population-based cross-sectional study	Adolescent VFC eligibility	VFC eligibility not associated with initiation or completion of HPV vaccine	—	—	X	—
Moghtaderi, 2016[26]	65 415 female adolescents aged 13–17 in a national sample	NIS-Teen, 2008–2011; pooled cross-sectional study	(1) HPV vaccine SER; (2) education for parents or students	(1) SERs not associated with HPV vaccine initiation or completion; (2) Educational requirements not associated with HPV vaccine initiation or completion	X	X	—	—
Moss, 2016[4]	99 921 (47 742 female) adolescents aged 13–17 in a national sample	NIS-Teen, 2007–2012; pooled cross-sectional study	(1) Tdap and MenACWY SER (spillover effects on HPV vaccine); (2) HPV vaccine SER	(1) Tdap booster and meningococcal vaccination requirements, respectively, associated with 8-percentage point (95% CI: 4 to 11) and 4-percentage point (95% CI: 1 to 8) spillover increases for HPV vaccination initiation (both $P < .05$); (2) HPV vaccine SERs associated with a<1-percentage point increase in initiation (95% CI: −6 to 7; $P < .05$)	X	—	—	—

TABLE 1 Continued

First Author, Year	Study Population	Data Source, Study Period, and Design	Policies	Main Result	Types of Policies Considered			
					SERs[a]	Education[b]	Federally-funded	Other[c]
Perkins, 2016[28]	47 845 female adolescents aged 13–17 in a national sample	NIS-Teen, 2009–2013; pooled cross-sectional study	(1) HPV vaccine SER; (2) HPV vaccine education for parents and/or students	(1) SERs not associated with higher HPV vaccine initiation or completion; (2) Education requirements not associated with higher HPV vaccine initiation or completion	X	X	—	—
Pierre-Victor, 2017a[29]	3203 female adolescents aged 13–17 in South Carolina, Tennessee, and Virginia	NIS-Teen, 2008–2012; pre-post design with natural experiment control	HPV vaccine SER	SER not associated with an increase in HPV vaccine initiation among adolescent females compared with adolescent females in nonpolicy jurisdictions. HPV vaccine initiation increased in all 3 states from the pre-policy to the post-policy period.	X	—	—	—
Pierre-Victor, 2017b[33]	3317 female adolescents aged 13–17 in Alabama, Louisiana, and Mississippi	NIS-Teen, 2008–2012; pre-post design with natural experiment control	HPV vaccine education materials for parents distributed by schools	Parental education requirement implementation in Louisiana not associated with increased HPV vaccine initiation in adolescent females compared with Alabama or Mississippi.	—	X	—	—
Polonijo, 2020[18]	4579 female adolescents aged 13–14 in Virginia, Washington, DC, and 7 other surrounding states	NIS-Teen, 2008–2009, 2011–2013; pre-post design with natural experiment control	HPV vaccine SER	SERs associated with an increase in HPV vaccine initiation for middle-income girls and girls with mothers who had no more than high school education, 30 percentage points and 13 percentage points respectively (both $P < .05$). No association between SERs and vaccine series completion.	X	—	—	—
Potter, 2014[25]	264 789 adolescents aged 11–15 in Michigan (females only for HPV vaccine analysis)	State immunization registry, 2009–2013; retrospective cohort study	Tdap, MenACWY, and varicella catch-up dose vaccine SER (spillover effects on HPV vaccine)	SERs associated with increased HPV vaccine initiation in girls compared with those enrolled before requirements enacted (HR:1.180; 95% CI:1.160 to 1.200)	X	—	—	—
Roberts, 2018[30]	Adolescents aged 13–17 in a national sample[f]	NIS-Teen, 2015; qualitative comparative analysis	(1) Medicaid expansion; (2) policies permitting HPV vaccination in pharmacies; (3) HPV vaccine SER; (4/5) classroom sex education mandates and parental education mandates	No single policy was necessary or sufficient for high HPV vaccine initiation. States with (1) Medicaid expansion, (2) policies permitting HPV vaccination in pharmacies, (3) SERs for HPV vaccine, and (4/5) classroom sex education mandates had consistently high initiation of HPV vaccine	X	X	X	X

TABLE 1 Continued

First Author, Year	Study Population	Data Source, Study Period, and Design	Policies	Main Result	Types of Policies Considered			
					SERs[a]	Education[b]	Federally-funded	Other[c]
Srivastava, 2020[27]	Adolescents aged 12–18 in New Jersey and Pennsylvania[f]	Electronic medical records, 2016–2017; pooled cross-sectional design with pre-post analysis	Tdap vaccine SER and new MenACWY vaccine SER provisional period reduced to 5 days (spillover effects on HPV vaccine)	Policy enactment associated with increased HPV vaccination initiation among 12–13-year-old adolescents (50.3% to 59.6%) and initiation and completion in 17–18-year-old adolescents (76.5% to 79.5% and 64.0% and 69.2%, respectively) in Philadelphia and surrounding counties; though in a simple descriptive comparison, similar increases were found in a nearby jurisdiction without shortened provisional period policy enactment (NJ)	X	—	—	—
Thompson, 2018[21]	Adolescents aged 13–17 in a national sample[f]	NIS-Teen, 2010–2016; pre-post design with natural experiment control	HPV vaccine SER	SER associated with 11% increased probability (b = 0.11; 95% CI: 0.05 to 0.18) in HPV vaccination initiation for boys in Rhode Island in comparison with boys in other states. No differences observed comparing girls in Rhode Island with girls in other states.	X	—	—	—
Thompson, 2020[19]	145 153 adolescents aged 13–17 in a national sample	NIS-Teen, 2011–2017; pre-post design with natural experiment control	HPV vaccine SER	SER associated with increased probability of HPV vaccination initiation by age 13 years by nearly 14 percentage points for boys in Rhode Island in comparison with boys in other states (b = 0.139; 95% CI: 0.073 to 0.205); no differences observed comparing girls in Rhode Island with girls in other states	X	—	—	—
Thompson, 2021[20]	Adolescents aged 12–14 in Rhode Island[f]	State immunization registry, 2015–2019; pooled cross-sectional study with pre-post analysis	HPV vaccine SER	SER associated with increased HPV vaccination completion for all adolescents (from 57% before policy enactment to 82.9% after); pairwise comparisons by school year were statistically significant for frequency of HPV vaccination comparing the pre-policy period to post-policy periods, for the full sample, males, and females, respectively (P values $< .0001$)	X	—	—	—

TABLE 1 Continued

First Author, Year	Study Population	Data Source, Study Period, and Design	Policies	Main Result	Types of Policies Considered			
					SERs[a]	Education[b]	Federally-funded	Other[c]
Torres, 2022[44]	81 999 adolescents aged 13–17 in a national sample	NIS-Teen, 2015–2018; pooled cross-sectional study	Adolescent consent to HPV vaccination	Adolescents permitted to consent were more likely to initiate HPV vaccination than those that were not (aOR: 1.16; 95% CI: 1.01 to 1.34)	—	—	—	X
Trogdon, 2016[45]	80 556 adolescents aged 13–17 in a national sample (males included after 2010)	NIS-Teen, 2008–2014; pre-post design with natural experiment control	Policies permitting HPV vaccination in pharmacies	Pharmacist authority laws not associated with increased HPV vaccine initiation or completion	—	—	—	X
Vadaparampil, 2012[41]	Female adolescents aged 9–17 in Florida[f]	Claims data, NIS-Teen, 2009; cohort study with physician survey	VFC provider status	Provider participation in VFC associated with higher HPV vaccine initiation compared with providers who did not participate in VFC or those who did not know their status ($F = 27.73$, $P < .0001$)	—	—	X	—
Vielot, 2020[32]	205 356 adolescents age 11 in Missouri, Kentucky[g], Indiana, and Oregon	Claims data, 2009–2017; retrospective cohort study	(1) Educational campaigns; (2) permitting HPV vaccination in pharmacies	(1) Educational campaigns not associated with an increase in HPV vaccine initiation rate with the exception of males in Missouri postlegislation ($\beta = 0.16\%$, $P < .05$); (2) pharmacist authority laws not associated with increases in HPV initiation vaccination rate in adolescents.	—	X	—	X
Wood, 2021[31]	Adolescents aged 13–17 in a national sample[f]	NIS-Teen, 2019; population-level cross-sectional design	Provisional attendance periods for vaccine SER including Tdap, MenACWY, and HPV	Length of provisional attendance periods for SERs not associated with HPV vaccine initiation.	X	—	—	—

—, Policy type not considered. ACA, Affordable Care Act; aOR, adjusted odds ratio; CDC, Centers for Disease Control and Prevention; CI, confidence interval; DC, Washington, DC; HR, hazard ratio; NJ, New Jersey; OR, odds ratio; PA, Pennsylvania; RI, Rhode Island.

[a] Includes HPV SERs, other adolescent vaccine SERs with spillover effects on HPV vaccination, and specific HPV vaccine SER-related policy provisions (eg, opt-out provisions).

[b] Includes parental education policies (materials mailed to parents, sent home with adolescents, or included on vaccination reporting forms) or student sex education policies (school-based comprehensive sex education or abstinence-only education).

[c] Includes all other policies examined for association with HPV vaccination (eg, permitting HPV vaccination in pharmacies).

[d] Because of sample size (only 1 state with HPV vaccine SER at time of study), HPV education requirement group included the 1 state with HPV SER and HPV SER was not assessed separately.

[e] Sample for vaccination outcomes is individuals who were age 13 between 2004 and 2013 (who received doses between 10 and 13); NIS-Teen includes age at which child received vaccine, even if before the phone interview.

[f] Sample size not specified.

[g] Kentucky's HR 80 was a resolution advising HPV vaccination for those eligible but had no specific policy provisions and is not included in this table as a "relevant policy."

make an initial determination. For abstracts that passed the initial review, 2 team members independently reviewed each full text to confirm eligibility. In both steps, team members resolved disagreements through discussion.

For each eligible study, 2 team members independently abstracted information using a standardized form. Abstracted information included sample and policy characteristics, results, data sources, study design and methods, and sample size. We also evaluated study quality using an adapted quality assessment tool.[11] The tool consisted of 12 items: 1 binary item assessing the inclusion of a comparison group (0, 1), and 11 items that scored studies on characteristics such as study sample, data collection, and statistical analysis, using a 4-point response scale ranging from 0 to 3. For each study, we totaled scores to produce an overall quality score with the possible range of 0 to 34. We resolved disagreements on both abstracted information and quality assessment scores through discussion.

We qualitatively summarized variation in study quality primarily by study design. We considered strong, well-designed studies to be those that used multiple years of data and pre-post policy implementation comparisons, among other characteristics. We prospectively registered our study protocol with the Carolina Digital Repository on January 15, 2022.[12]

RESULTS

The literature searches yielded a total of 13 240 citations, with 5672 unique records after the removal of duplicates (Fig 1). Title and abstract screening yielded 103 records for full-text review, which resulted in final inclusion of 36 studies. These studies examined policies aimed at increasing HPV vaccination, including SERs, educational requirements, and federally-funded policies related to the VFC program and Medicaid (Table 1). The mean quality score was 25.5 of 34 (SD: 4.2; range: 13–32). We summarize study findings by policy category below.

School Entry Requirements

Studies that evaluated the impact of SERs on HPV vaccination included those that examined adoption of HPV vaccine-specific SERs, characteristics of HPV vaccine SERs, and spillover effects of SERs for other adolescent vaccines on HPV vaccination.[3–5,13–31] At the time of this review, evaluations of HPV vaccine SERs had been conducted for 3 of the 5 jurisdictions with legislation: Rhode Island, Virginia, and Washington, DC. Legislation varied by jurisdiction, including by year of enactment, vaccine exemption requirements, and exemption process.

Adoption of HPV Vaccine SERs

Eight of 14 studies found positive associations between the adoption of HPV vaccine SERs and HPV vaccination coverage.[4,13,15,16,18–21] Among the subset of studies that evaluated the impact of SERs in single jurisdictions, 4 of 6 found a positive association with HPV vaccination coverage (1 of 1 study of DC,[13] 3 of 3 studies of Rhode Island,[19–21] and 0 of 2 studies of Virginia).[24,29] One particularly well-designed study assessed Washington, DC's 2014 policy change to include boys in that jurisdiction's SER, using econometric methods to conduct a causal analysis.[13] This study found that the SER for boys was associated with a 26-percentage-point increase in likelihood of HPV vaccine initiation and a 23-percentage-point increase in likelihood of vaccine completion, compared with the prepolicy time period.[13] Also of note were 3 high-quality pre-post studies that examined Rhode Island's SER. Two of these studies used National Immunization Survey-Teen (NIS-Teen) data to identify a >10% increase in the probability of initiation for boys aged 13 to 17.[19,21] The third study used the state's immunization registry data and found a statistically significant increase in HPV vaccination coverage for both boys and girls aged 12 to 14, from 57% vaccine series completion before policy enactment to 83% after.[20] In contrast, neither study examining SERs in Virginia found an association with increased HPV vaccination coverage,[24,29] although 1 study used a comparatively weak design with a small sample size and a pre-post comparison with an earlier study.[24]

Four studies evaluated SERs using pooled data from Washington, DC and Virginia, with 2 of the 4 finding a positive association between SERs and HPV vaccination coverage.[4,18,26,28] One well-designed study employed a pre-post analysis with a comparison group of 7 surrounding states and found that SERs were associated with a 30-percentage-point increase in HPV vaccine initiation among girls from middle-income households and a 13-percentage-point increase among girls whose mothers had a high school degree or less education, but found no association with vaccine series completion.[18] The remaining 3 studies used less robust study designs with mixed results: 1 study found that SERs were associated with an increase in HPV vaccine initiation, albeit a small magnitude,[4] whereas the other 2 studies found that SERs were not associated with higher HPV vaccine initiation or completion.[26,28]

Four studies evaluated SERs using pooled data from all 3 jurisdictions (DC, Rhode Island, and Virginia), with 3 of 4 finding positive associations between SERs and at least 1 HPV vaccination outcome.[14–16,23] Notably, 1 study used a pre-post study design to demonstrate increases in HPV vaccine initiation in girls aged 16 to 17 postpolicy implementation (adjusted odds ratio [aOR] 3.23; 95% confidence interval [CI]: 1.17–8.90); however, the change was not significant for other ages.[16] In contrast, another relatively strong study used a retrospective cohort design with 14 years of claims data to find no association between SERs and HPV vaccination coverage (≥2 doses).[23] The remaining 2 studies were less robust and had positive[15] and a mix of positive and null findings.[14]

Characteristics of HPV Vaccine SERs

Three studies assessed the impact of characteristics of HPV vaccine SERs on HPV vaccination coverage, with mixed findings.[13,23,31] One well-designed, difference-in-differences study evaluated the impact of DC's SER exemption structure among girls, who had been subject to an HPV vaccine SER since 2009.[13] In 2014, this SER changed from a 1-time, multiyear exemption from vaccination requirements to a structure requiring an annual request for exemption. This study found that requiring annual exemption was associated with an 11-percentage-point increase in the likelihood that girls aged 14 to 17 initiated HPV vaccination and a 20-percentage-point increase in the likelihood of vaccine series completion. In contrast, the second study, using a strong retrospective cohort design with 14 years of claims data from Washington, DC and Rhode Island, found no association between restricting

personal belief exemptions to HPV vaccine SERs and HPV vaccination.[23] The third study used a less robust cross-sectional design with 1 year of NIS-Teen data and found that reducing provisional attendance periods for SERs in Washington, DC, Rhode Island, and Virginia was not associated with increased HPV vaccination coverage.[31]

Spillover Effects of Other Adolescent Vaccine SERs

Seven studies examined SERs for other adolescent vaccines, mainly tetanus, diphtheria, and acellular pertussis vaccine (Td or Tdap); and/or meningococcal conjugate (MenACWY) vaccines, with all 7 studies finding spillover effects for HPV vaccination coverage.[3–5,17,22,25,27] Three of these studies used relatively strong study designs with multiple years of data.[3,25,27] The first study, using Philadelphia-area electronic medical record vaccination data, found that Pennsylvania's combined Tdap and MenACWY SER shortened provisional policy was associated with increased HPV vaccine initiation among 12 to 13-year-olds (9 percentage points), as well as vaccine initiation (3 percentage points) and completion (5 percentage points) among 17 to 18-year-olds.[27] The second study used 5 years of pooled cross-sectional data and found that Tdap SERs were associated with significant increases in HPV vaccine initiation (4 percentage points) and completion (3 percentage points) in adolescents by age 13.[3] The third study used a retrospective cohort design and 4 years of state immunization registry data to find a small association between Michigan's combined Tdap, MenACWY, and varicella SER policy and HPV vaccine initiation among girls (hazard ratio: 1.180, 95% CI: 1.160–1.200).[25] The other 4 studies assessing spillover effects used less robust cross-sectional study designs with pooled multiyear national samples.[4,5,17,22] These studies generally observed positive associations between other adolescent vaccine SERs and HPV vaccination coverage,[4] although findings were small in magnitude[17,22] or mixed[5] in some cases.

Education Requirements

Two of 8 studies that evaluated educational requirements found a positive association with HPV vaccination coverage.[23,32] A subset of 6 of these 8 studies focused on educational requirements for parents that involved the distribution of HPV vaccine information through schools, health care providers, or health departments.[5,23,26,28,32,33] Only 2 of these 6 studies of parental education requirements found an association with HPV vaccination coverage.[23,32] Both of these studies were relatively strong, retrospective cohort studies using claims data. One found that state-level policies to improve vaccination education were associated with a 9% increase in HPV vaccination coverage (≥2 doses) for girls and boys.[23] The other study examined parental education policies across multiple states, but only found a positive association with the HPV vaccine initiation rate for males in Missouri.[32] Of the 4 remaining studies, 1 had a particularly strong pre-post design using natural experiment controls and found no association between education requirements and HPV vaccination coverage in Louisiana (compared with Alabama and Mississippi).[33] The last 3 studies found no association between education requirements and HPV vaccination coverage using fairly strong cross-sectional study designs,[26,28] although 1 study only included 1 year of data.[5]

The remaining 2 of 8 studies focused on educational requirements for students. These studies assessed the impact of requiring comprehensive sex education, as well as restriction to abstinence-based education, and found no association between either type of policy with HPV vaccination coverage in adjusted analyses.[15,34] Both studies used national data and a cross-sectional design, but only from a single year.

Federally-funded Policies

Seven of 9 studies that evaluated federally-funded policies related to VFC and Medicaid found a positive association with HPV vaccination coverage.[35–41] Among the subset of 5 studies that evaluated state-level variations in VFC participation, 4 found a positive association with HPV vaccination coverage.[36,39–42] One relatively strong cross-sectional study, using 9 years of immunization registry data, found that adolescents in Michigan aged 9 to 18 living in a zip code with a greater number of VFC providers had higher odds of completing vaccination (2–4 vs 1 provider aOR: 1.05; ≥5 vs 1 provider aOR: 1.07).[40] The other 3 studies all used 1 year of cross-sectional data and reported that policies governing more expansive participation in VFC were associated with an 8-percentage-point increase in HPV vaccination coverage for adolescents aged 13 to 17 (in states with either a Td or Tdap or MenACWY mandate)[36]; provider participation in VFC was associated with higher HPV vaccine initiation, compared with providers who did not participate in VFC or those who did not know their status[41]; and ineligibility for VFC was associated with lower odds of HPV vaccine initiation among boys, but that association did not persist for vaccine completion or for girls.[39] Lastly, 1 study that found no association between VFC eligibility and HPV vaccination coverage among adolescent girls used a cross-sectional design with a single year of national data.[42]

The remaining 4 of 9 studies examined Medicaid-related policies,[35–38] with 3 of 4 finding an association with HPV vaccination coverage.[35,37,38] Two well-designed studies used a pooled cross-sectional design with multiple years of data and focused on Medicaid expansion.[35,37] One of these 2 studies found that Medicaid expansion was associated with a 4-percentage-point increase in probability of HPV vaccine initiation for adolescents aged 13 to 17.[35] The other study found that Medicaid expansion was associated with about a 4% increase in vaccination coverage, compared with states that did not expand Medicaid.[37] The remaining 2 of 4 studies assessed state-level financing aspects of Medicaid.[36,38] Of

these, 1 retrospective cohort study found that enrollment in managed care plans was associated with lower odds of HPV vaccine series completion, compared with fee-for-service plans for both boys and girls (aOR: 0.81 and 0.92, respectively).[38] The other study, using 1 year of national data, did not find an association between Medicaid reimbursement levels and HPV vaccination coverage.[36]

Other Policies

Seven studies evaluated other policies.[15,23,30,32,43–45] Two studies examined policies related to adolescent consent (1 study)[44] and patient-centered medical home enrollment (1 study)[43] and both studies observed a positive association with HPV vaccination. Four studies examined policies related to allowing HPV vaccination in pharmacies (2 studies), state-purchased vaccinations (1 study), and state health department structure and funding (1 study).[15,23,32,43–45] None of these studies found any observed association with HPV vaccination. Interestingly, 1 study used qualitative comparative analysis to assess layered policies, including HPV vaccine SERs, Medicaid expansion, permitting HPV vaccination in pharmacies, classroom sex education mandates, and parental education mandates.[30] Results from this study indicated that no single policy was sufficient for high HPV vaccine initiation, but that the 2 jurisdictions with all policies (Washington, DC and Rhode Island) had consistently high HPV vaccine initiation.

DISCUSSION

Jurisdictions in the US have enacted a wide variety of policies aimed at increasing adolescent HPV vaccination coverage since the Advisory Committee on Immunization Practices first recommended the vaccine for routine administration in 2006. We systematically reviewed studies that assessed the effectiveness of these policies and summarized findings by policy type to synthesize the available evidence for researchers and policymakers. We found that SERs showed promise with more than half of studies on HPV vaccine-specific SERs finding a positive association with HPV vaccination coverage. Furthermore, SERs for other adolescent vaccinations consistently showed positive spillover effects for HPV vaccination. Federally-funded policies related to VFC and Medicaid also demonstrated consistent effectiveness, suggesting that improving access to care is important for increasing HPV vaccination coverage. In contrast, relatively few studies on policies of educational requirements for parents or adolescents observed an association with HPV vaccination.

Our review suggests that HPV-specific SERs may vary in effectiveness by jurisdiction. For example, all 3 studies that examined Rhode Island's SER specifically found positive associations with HPV vaccination coverage.[19–21] These findings may reflect the strength of Rhode Island's policy, which allows for religious or medical exemptions but not philosophical exemptions. A study that examined Washington, DC's SER specifically also found positive associations with HPV vaccination coverage.[13] Although the Washington, DC policy allows for philosophical exemption, it requires that parents submit exemption forms annually from grades 6 through 12, which 1 study on SER characteristics found to be associated with large increases in coverage.[46] In contrast, neither of the 2 studies that examined Virginia's SER specifically found an association with HPV vaccination,[24,29] possibly reflecting the policy's generous exemption structure that includes philosophical exemptions and does not require annual renewal. Virginia's weaker performance in HPV vaccination coverage may also explain the mixed findings among studies that used pooled data, all of which included vaccination data from Virginia. Taken together, our findings suggest that it is not enough that a jurisdiction adopt an HPV vaccine SER; rather, the ways that SERs are implemented may be critical to their success.

This "ease of exemption" effect has been demonstrated in other research and with other vaccines, although with caveats. SERs that offer philosophical exemptions or an easier exemption process for school-aged children are associated with higher rates of nonmedical exemptions and, in turn, increased risk of disease outbreaks, compared with SERs without these provisions.[47–51] However, the interplay among SER characteristics is unclear, given that simply removing nonmedical philosophical exemptions without increasing the difficulty of the exemption process can have the unintended consequence of increasing medical exemptions.[23,47,48,52–57] Little is known about the mechanism for this replacement effect. Nonetheless, this strategy might be effective in increasing vaccination coverage in some contexts, such as for high-incidence diseases or "high risk" regions with low vaccination coverage.[58,59] Thus, policymakers must carefully consider context when enacting policies to improve HPV vaccination to avoid implementing policies that are either too weak to have an effect or are so controversial that they cannot be implemented.

Given the delicate balance, policymakers could consider requiring SERs for other adolescent vaccinations as a way to increase HPV vaccination coverage. All studies in our review that examined associations between SERs for other adolescent vaccines (primarily Tdap and MenACWY) and spillover to HPV vaccination outcomes had positive findings. SERs for other adolescent vaccines have the advantage of positive spillover effects without risking debate in contexts where implementing an HPV vaccine SER would be less feasible. We note that all 50 states,[60] Washington, DC,[61] and Puerto Rico[62] already have SERs for adolescent Tdap vaccination, but only 36 states, DC, and Puerto Rico have MenACWY SERs.[61–63] In the remaining jurisdictions, a MenACWY SER may be an acceptable alternative to an HPV vaccine SER, should the latter prove to be politically or administratively infeasible.

Beyond state-level policies, federally-funded policies related to VFC and Medicaid were also consistently associated with increased HPV vaccination coverage. Previous studies have found

that components of the VFC program were associated with improved vaccination coverage for other adolescent and childhood vaccines.[64–67] Positive associations between Medicaid expansion and HPV vaccination have similarly been found in other studies among adults ages 19 to 25[68] and among women ages 15 to 25 in low-income contexts.[69] With respect to financing in Medicaid, a fee-for-service insurance structure in Medicaid was associated with increased HPV vaccination coverage,[38] although Medicaid reimbursement level for HPV vaccination was not.[36] The success of these policies could be due in part to the federal financing that is part of VFC and Medicaid, which helps reduce the cost of vaccination for states and increase access to low-income patient populations.

In contrast to SERs and federally-funded policies, educational requirements about HPV vaccine were largely not associated with HPV vaccination coverage. Although educational requirements might seem like a Goldilocks policy option – directly targeted to HPV vaccination while allowing for greater personal choice and avoiding controversy – these policies likely lacked the "teeth" necessary to be effective on their own. In some particularly polarized contexts, educational policies may even cause harm by fueling disinformation campaigns from antivaccine groups.[70–72] Education campaigns alone have been shown to be ineffective for behavior change in many contexts, including adolescent HPV vaccination.[70,73,74] If jurisdictions wish to improve adolescent HPV vaccination coverage, mandating vaccine education on its own is unlikely to be successful and education would need to be accompanied by other HPV vaccination interventions. Indeed, the potential for success by bundling multiple policies was noted in 3 of our included studies: both Roberts and Chen observed that jurisdictions with a greater number of policies aimed at improving HPV vaccination had higher vaccination coverage,[23,30] and Franco noted that states with both comprehensive sex education policies and an HPV vaccine SER had higher HPV vaccination completion.[15]

This review has several implications for future research. Our findings underscore the importance of state-specific analyses with respect to HPV vaccine SERs, given the differences in SER implementation and with so few jurisdictions enacting HPV vaccine SERs. We note that research evaluating the recent implementation of HPV vaccine SERs in Hawaii and Puerto Rico will be important to further our understanding of how SER implementation can impact adolescent HPV vaccination coverage. Additionally, most included studies used NIS-Teen data, but other data sources, including state immunization information systems, may also have an important role in state-level policy evaluation. State immunization information systems can provide a more complete picture of immunization for a particular state, in contrast to national surveys that rely on sampling frames that may be less accurate for state-level and within-state evaluations.[67,75] Lastly, we note that the most persuasive evidence for policy-generated change came from studies that used pre-post designs, such that comparisons within jurisdictions before and after policy enactment yielded more compelling evidence than comparisons between jurisdictions. It is challenging to make comparisons between states with different policy environments, even if investigators attempt to control for baseline characteristics in the absence of randomized designs that are typically infeasible in policy evaluation. Considering these challenges, we recommend pre-post designs with multiple years of data in future evaluations.

This review presents a comprehensive overview of the extant literature on governmental policies aimed at improving HPV vaccination among US adolescents and provides insight into the types of policies that are associated with improved vaccination coverage, with some strengths and limitations. With a focus on a specific vaccine and age group, this review may be less generalizable to other vaccines or populations, including children or young adults outside of the age group or living in other countries. We excluded policies implemented in school districts, health care systems, and clinics; policies at these more granular levels may have varying levels of success and can be targeted to specific contexts but do not have the wide scope of higher-level policies this review aimed to examine. Studies included in our review present a wide range of policies and study designs to test the effectiveness of those policies. Although the diversity of the policies included here is a strength for our review, not all included studies used strong evaluation designs.

Jurisdictions in the US have implemented policies to improve HPV vaccination coverage with mixed success. Findings of our systematic review suggest that SERs for HPV and other adolescent vaccines, along with federally-funded policies related to VFC and Medicaid, are promising and warrant further consideration in public health practice and research as strategies for increasing HPV vaccination coverage among adolescents. In contrast, educational mandates alone have shown relatively little success and may not warrant the administrative and political costs of implementation. Policy interventions to increase HPV vaccination coverage among adolescents have the potential to improve population health through widespread reduction of HPV related cancers and disease, provided that policymakers select evidence-based policies and consider jurisdictional context.

ABBREVIATIONS

HPV: human papillomavirus
MenACWY: meningococcal conjugate vaccine
SERs: school-entry requirements
Td: tetanus and diphtheria vaccine
Tdap: tetanus, diphtheria, and pertussis vaccine
VFC: Vaccines for Children

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