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Polonijo, Andrea N

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The impact of school-entry mandates on social inequalities in human papillomavirus vaccination

Andrea N. Polonijo

Department of Social Medicine, Population, and Public Health, University of California, Riverside, School of Medicine, Riverside, CA, USA

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ABSTRACT

Fundamental cause theory (FCT) is influential for explaining the enduring relationship between social position and health, yet few empirical studies test FCT's contention that policy supporting the equal distribution of interventions across populations can help reduce health inequalities. Following human papillomavirus (HPV) vaccine approval, complex socioeconomic and racial-ethnic inequalities emerged in distinct stages of the diffusion of this health innovation. Virginia and the District of Columbia were the first U.S. jurisdictions to implement school-entry HPV vaccination mandates for sixth-grade girls, offering an opportunity to test whether inequalities in HPV vaccination are mitigated by policy that seeks to standardize the age of vaccine administration and remove barriers to knowledge about the vaccine. Using data from the 2008, 2009, 2011, 2012, and 2013 National Immunization Survey–Teen ($N = 4579$) and a triple-difference approach, this study tests whether vaccine mandates are associated with smaller socioeconomic and racial-ethnic inequalities in health provider recommendation and vaccine uptake. It finds mandates were associated with improvements in provider recommendation and vaccine uptake for some socioeconomic and racial-ethnic groups. However, mandates also likely led to a decline in HPV vaccine series completion overall. Implications of these findings for informing FCT and vaccination policy are discussed.

Fundamental cause theory (FCT) contends that as health-related situations change, individuals with the most resources are best able to take advantage of new health-promoting innovations to avoid diseases and their negative consequences (Link & Phelan, 1995). FCT also suggests health inequalities will be reduced when policy supports the equal distribution of health-promoting innovations across populations (Link, 2008). Empirical tests have found support for FCT across various health outcomes (Phelan et al., 2010), yet policy's role in mediating the relationship between social position and health remains underexplored.

Following human papillomavirus (HPV) vaccine availability in 2006, social scientists documented complex socioeconomic and racial-ethnic inequalities in distinct stages of uptake—from vaccine-related knowledge through to vaccine series completion (Burdette et al., 2017; Polonijo & Carpiano, 2013). In 2007, Virginia and the District of Columbia (DC) became the first U.S. jurisdictions to issue school-entry HPV vaccination mandates for sixth-grade girls, requiring parents to review information about HPV vaccination before opting their daughters out (Pitts & Tufts, 2013). These mandates offer an opportunity to test whether policy that aims to increase parental knowledge and standardize the age of vaccine administration can facilitate the equal

diffusion of this innovation across social groups. Using five waves of National Immunization Survey (NIS)–Teen data, this study analyzes the impact of school-entry HPV vaccine mandates on socioeconomic and racial-ethnic inequalities in health provider recommendations to vaccinate and HPV vaccine series initiation and completion. In doing so, it provides a theoretically informed test of the role mandates played in shaping the fundamental cause relationship between social position and inequalities in the diffusion of this health-promoting innovation.

Background

Fundamental cause theory

FCT suggests health inequalities emerge and persist due to the unequal distribution of resources in society; persons who are more advantaged in terms of knowledge, money, power, prestige, and beneficial social connections are better positioned to avail themselves of health-promoting resources to avoid diseases and their negative consequences at any given time (Link & Phelan, 1995). The theory articulates fundamental causes become apparent under conditions of change—such

E-mail address: apolonijo@ucmerced.edu.

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as changes in diseases, treatments, and risk knowledge—because the resources fundamental causes embody can be transported across situations to benefit health (Phelan et al., 2004).

FCT literature offers concrete examples of how human action shapes social patterns of morbidity and mortality and exemplifies how well-intentioned interventions can increase health disparities. Consistent with FCT, empirical tests demonstrate: (a) more pronounced inequalities in relatively preventable versus less preventable diseases (e.g., heart disease vs. brain cancer; Phelan et al., 2004), (b) the emergence of inequalities in preventive screening after the implementation of new diagnostic tools (e.g., mammography, Pap smear, and colorectal cancer screening; Link et al., 1998; Saldana-Ruiz et al., 2013), and (c) the exacerbation of inequalities in disease and mortality following the introduction of new medical interventions (e.g., highly active antiretroviral therapy for HIV/AIDS, statins for high cholesterol; Rubin et al., 2010; Chang & Lauderdale, 2009). A test of FCT in relation to adolescent HPV vaccination found socioeconomic and racial-ethnic inequalities persisted across distinct stages of uptake, which could shape future patterns of HPV-related cancer morbidity and mortality (Polonijo & Carpiano, 2013). Together, this literature suggests health inequalities are (a) most pronounced for diseases that are amenable to prevention and (b) shaped by differences in health behaviors and/or uptake, following the introduction of new knowledge, treatments, or screening tools.

FCT conjectures health and social policy are closely linked to health inequalities, and the relationship between social position and health can be weakened by implementing policies that distribute health enhancing knowledge, resources, and/or interventions equally across populations (Link, 2008; Phelan et al., 2010). Studies examining policies in relation to social inequalities in the United States have found: mandatory seat-belt laws lessened the socioeconomic gap in seatbelt use (Harper et al., 2014); smoking bans reduced young adult smoking regardless of race or parental socioeconomic status (SES; Vuolo et al., 2016) and were especially effective for those with low individual and/or parental education (Hernandez et al., 2019); and folic acid fortification decreased absolute disparities in low folate status by race-ethnicity and income—yet concentrated the prevalence of low folate status within the most disadvantaged groups (Dowd & Aiello, 2008). Cross-nationally, a comparative study of the United States and Canada suggests social policy buffers the SES–health relationship for highly preventable disease (Willson, 2009). However, persistent SES-based health inequalities in Western European countries with highly developed welfare states suggest policy impacts are limited because higher-SES people can make better use of social resources, allowing new disparity-generating mechanisms to emerge (Mackenbach, 2012; Mackenbach et al., 2008). Further examination of the conditions under which policy shapes the fundamental cause relationship between social position and health is needed.

Social inequalities in HPV vaccination

The U.S. Advisory Committee on Immunization Practices recommends HPV vaccination for all 11–12-year-olds to protect against HPV-related cancers and genital warts (Walker et al., 2017). Initially administered as a three-shot series, two shots are now recommended for most adolescents (Centers for Disease Control and Prevention, 2019). Most private health insurance and the Vaccines for Children Program (VFC; for uninsured, underinsured, Medicaid-eligible, and American Indian and Alaska Natives) cover HPV vaccination costs, and the vaccine is available in safety-net clinics serving predominantly low-income and racial-ethnic minority adolescents (Tsui et al., 2013). Nevertheless, only about half of U.S. adolescents are fully vaccinated against HPV (Walker et al., 2017).

Parents are the primary HPV vaccination decision-makers for younger adolescents (Gilkey & McRee, 2016), while health provider recommendation is the strongest correlate of HPV vaccine uptake

(Holman et al., 2014). Research documenting HPV vaccination inequalities suggests low (vs. high) SES and Black (vs. White) girls are less likely to receive a health provider recommendation (Polonijo & Carpiano, 2013) and the racial gap in recommendations has waned, but not disappeared, over time (Burdette et al., 2017). Inequalities in HPV vaccine uptake have also evolved over time (Burdette et al., 2017); recent estimates suggest lower (vs. higher) income and Black and Hispanic (vs. non-Hispanic White) adolescents are more likely to initiate vaccination, however lower SES and Black girls are less likely to complete the vaccine series and be fully protected (Reagan-Steiner et al., 2016; Walker et al., 2017). Hispanic adolescents—initially less likely to complete the HPV vaccine series—now have the highest completion rates (Reagan-Steiner et al., 2016).

Several factors may drive the complex inequalities in HPV vaccination. Disadvantaged adolescents may be less likely to visit a health provider at the optimal time to receive an HPV vaccine recommendation or to follow-up for repeat HPV shots due to noninsurance, limited healthcare access, time constraints, lack of knowledge, or—particularly for racial-ethnic minorities—mistrust in the medical system (Alsan et al., 2019; Holman et al., 2014; Polonijo & Carpiano, 2013). Social position also shapes patients' cultural health capital—the skills and resources, such as medical knowledge and the ability to communicate effectively, that individuals bring into clinical encounters and influence their interactions with providers (Shim, 2010). Studies of HPV vaccination practices in clinical encounters show low-SES and racial-ethnic minority parents are less likely to be engaged by providers yet more likely to defer to provider advice, when compared to more socially advantaged parents (Gilkey & McRee, 2016). Differences in cultural health capital may also influence provider perceptions about patients' HPV risk factors and likelihood of vaccine acceptance, which may lead to stronger recommendations to initiate vaccination for more disadvantaged groups (Gilkey & McRee, 2016). Finally, personal experience shapes lay understandings of risk (Brown, 1992) and greater perceived risk is associated with HPV vaccine uptake (Holman et al., 2014). Given socially disadvantaged populations have higher rates of HPV-related cancers, they may be more likely to conceptualize HPV as a high-risk infection that is worth preventing via vaccination (Polonijo et al., 2016).

Vaccine mandates as a test of fundamental cause theory

In 2007, Virginia and DC implemented school-entry HPV vaccination mandates for sixth-grade girls (National Conference of State Legislatures, 2018). While girls must still access HPV vaccines via a health provider, these mandates encourage a standardized age of vaccine administration and require schools to distribute information about the benefits of HPV vaccination to all parents (which they are expected to review before opting their daughters out; Pitts & Tufts, 2013). Consequently, mandates may be expected to facilitate the equal diffusion of basic knowledge about HPV vaccines across social groups, promote uniformity in health provider recommendations, and—as a result—lessen social inequalities in uptake. Hence, school-entry HPV vaccine mandates offer an opportunity to explore one context in which, consistent with FCT-based predictions, policy can facilitate the equal diffusion of health-promoting innovations across populations. Three hypotheses are tested regarding the association between school-entry mandates and social inequalities in HPV vaccination:

Relative to the pre-mandate period, in jurisdictions with mandates (vs. those without), there will be smaller observed SES and racial-ethnic inequalities in:

- Hypothesis 1.** receipt of a provider recommendation to vaccinate,
- Hypothesis 2.** initiation of the vaccine series, and
- Hypothesis 3.** completion of the vaccine series.

Data and methods

Survey data

Data came from the 2008, 2009, 2011, 2012, and 2013 waves of the NIS-Teen, a nationally representative cross-sectional survey that aims to identify adolescent vaccination coverage. Random-digit-dialing was used to identify households with adolescent's aged 13–17; response rates ranged from 51 to 59% for landline and 22–24% for cell-phone samples (Centers for Disease Control and Prevention et al., 2014). NIS-Teen interviewed the parent most knowledgeable about their adolescent's vaccination history, and immunization providers were contacted to verify responses. Given limited cases had provider-verified data and NIS-Teen analyses have found substantial to near-perfect agreement between parent- and provider-reported HPV vaccination (Dorell et al., 2011), I restricted analyses to parent-reported data.

Analytic sample to evaluate the policy change

NIS-Teen first collected HPV vaccination data in 2008. Virginia and DC passed school-entry HPV vaccination mandates for sixth-grade girls in April 2007, however, implementation was delayed until August–September 2009 (see Virginia Code, 2007). As annual NIS-Teen data collection begins in January and captures teens aged 13 and older (typically eighth grade or above), the impact of mandates would first be observable among 13- and 14-year-old girls in the 2011 survey wave.

Given regional variation in physicians' HPV vaccination practices (Daley et al., 2010), I limited analyses to 13- and 14-year-old girls (primarily affected by mandates as of 2011) living in the South Atlantic census region (including Virginia and DC, where HPV vaccination is mandated for school-entry, and Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, and West Virginia, where school-entry mandates were not in place). Yearly data from the time periods before (2008–2009) and after (2011–2013) school-entry HPV vaccination mandates would have affected the sample were pooled to achieve sufficient power for analyses (using non-pooled years yielded similar yet underpowered findings). I excluded 2010 data because only some of the sample were affected by the policy change that year.

The final analytic sample included 4579 girls with complete data for all study variables (87% of the total sample). Missing data were due to non-response on three variables: income, provider recommendation, and vaccine uptake (each 5% missingness). Data were more likely to be missing from low-income and non-White respondents, and respondents surveyed in the post-mandate period; estimates may thus be less precise for these groups.

Variables

Provider recommendation. Recommendation was measured dichotomously (no = 0; yes = 1), based on whether a doctor or health-care professional ever recommended the adolescent receive an HPV vaccine.

Vaccine uptake. Respondents reported the number of times the adolescent received HPV shots—as recorded on the adolescent's immunization record and recalled from memory. This was recoded into two variables: (1) “vaccine initiation,” for teens who received at least one shot (zero shots = 0; one or more shots = 1) and (2) “vaccine completion,” for teens who received three shots (zero/one/two shots = 0; three shots = 1)—corresponding with the recommended number of shots for all adolescents in 2008–2013.

Independent variables. A variable for *jurisdiction* compared respondents living in states where HPV vaccination was not mandated for school-entry (hereafter “non-mandated jurisdiction”; 0), with DC and Virginia (hereafter “mandated jurisdiction”; 1).

A dichotomous variable for *period* compared combined 2008–2009 survey years (“pre-mandate” period; 0) with combined 2011–2013

survey years (“post-mandate” period; 1).

SES was measured using household income and mother's education, modeled separately. *Income* was based on the poverty threshold for the given year and recorded categorically as: “above poverty and >\$75,000” (hereafter “high income”; referent), “above poverty but ≤\$75,000” (hereafter “middle income”), and “below poverty” (hereafter “low income”). *Mother's education* was coded categorically as “high school or less,” “some college,” and “college/university degree.”

Adolescent's *race-ethnicity* was recorded as “non-Hispanic White” (hereafter, “White”), “non-Hispanic Black” (hereafter, “Black”), “Hispanic,” or “other/mixed race-ethnicity.” Hispanic ($n = 77$) and other/mixed race-ethnicity ($n = 84$) categories were combined for sufficient power (hereafter “other race-ethnicity”). Black was retained as a distinct category given this group faces unique HPV vaccination disparities (Reagan-Steiner et al., 2016).

Controls. Demographic controls relevant to vaccination included: mother's age (under 45 = 0; 45 or older = 1), mother's marital status (married = 0; single/divorced/separated/widowed = 1), number of children in the household (two or more = 0; only one = 1), and the respondent's relationship to the teen (mother/female guardian = 0; other guardian = 1).

Statistical analyses

I used a difference-in-difference-in-difference—or “triple-difference” approach (see Berck & Villas-Boas, 2016; Raifman et al., 2018)—to evaluate the impact of mandates on social inequalities in provider recommendation and vaccine uptake. This enabled the examination of socioeconomic and racial-ethnic inequalities in outcomes across jurisdictions and time periods, while (a) controlling for omitted factors influencing vaccination differently for girls in mandated and non-mandated jurisdictions that were constant across time and (b) removing omitted factors influencing vaccination differently across time periods for girls in both mandated and non-mandated jurisdictions. In applying this approach, I specified a series of linear probability models (LPMs) and then computed and graphed marginal effects to interpret the models' interaction terms (further discussed below). LPMs are an acceptable—and easier to interpret—alternative to logistic regression models for analyzing binary outcomes (Mood, 2010) and preliminary logistic regression analyses yielded nearly identical findings (results not shown). Due to NIS-Teen's complex sampling design, all analyses were conducted using Stata/SE 13's survey design (svyset) feature (Stata-Corp, 2013)—based on guidelines regarding sampling weights and variance estimation for analyses within and across years (see Centers for Disease Control and Prevention et al., 2014). Analyses were considered significant at $p < 0.05$.

Procedures for analyzing inequalities in provider recommendation. The impact of mandates on inequalities in provider recommendation were analyzed using three steps. First, I examined overall inequalities in provider recommendation by regressing recommendation on SES, race-ethnicity, and all control variables.

Second, I used three triple-difference models (see Berck & Villas-Boas, 2016; Raifman et al., 2018) to assess the impact of mandate implementation on inequalities in provider recommendation. In the first model, I analyzed the effect of mandates on income-based inequalities by regressing provider recommendation on (a) the three-way interaction term $income \times jurisdiction \times period$, (b) two-way interactions for $income \times jurisdiction$, $income \times period$, and $jurisdiction \times period$, and (c) main effects for *income*, *jurisdiction*, and *period*, as well as *education*, *race-ethnicity*, and all control variables. In this model, the coefficients for low- and middle-income groups derived from the three-way interaction represent the effects for girls subject to mandated vaccination in the post-mandate period and therefore whose outcomes capture the impact of mandates. The two-way interaction $income \times jurisdiction$ controls for factors affecting recommendation differently for income groups within mandated jurisdictions that are constant across time periods.

Income × period controls for factors affecting recommendation differently across time for different income groups that are constant across jurisdictions. *Jurisdiction × period* controls for factors affecting recommendation similarly over time for all individuals in mandated jurisdictions. *Income*, *jurisdiction*, and *period* control for factors, respectively, affecting provider recommendation: (a) differently for income groups, regardless of jurisdiction and consistently across time, (b) differently within a mandated jurisdiction, constantly across time periods, and (c) constantly across time periods within a mandated jurisdiction. To evaluate the effect of the mandates on educational and racial-ethnic inequalities in provider recommendation, the above triple-difference model was repeated—substituting *education* and then *race-ethnicity* for *income* in the two- and three-way interactions.

Third, to interpret three-way interaction results, I used Stata’s margins command (StataCorp, 2013) to calculate and graph marginal effects at representative values (MERs), holding all other variables constant at their respective modes (see Williams, 2012). The MERs can be interpreted as the discrete change in predicted probabilities for the dependent variable (recommendation, initiation, or completion) for each category of an independent variable (education, income, or race-ethnicity) relative to its referent group—at each time period and within each jurisdiction—for individuals with modal values on all other variables.

Procedures for analyzing inequalities in vaccine uptake. To examine the impact of mandates on inequalities in vaccine uptake, I repeated the three steps described above, replacing *vaccine initiation* and then *vaccine completion* as the dependent variables in each model. Given provider recommendation predicts HPV vaccine uptake (Holman et al., 2014), I added *provider recommendation* as an independent variable in all uptake models (analyses excluding provider recommendation were similar; results not shown).

Results

Descriptive statistics

Table 1 reports descriptive statistics for all variables. The weighted

Table 1
Descriptive statistics for study variables by time period and mandate jurisdiction (NIS-Teen 2008–2009 and 2011–2013).

	Total Sample (N = 4579)		Pre-Mandate Period (2008–2009)				Post-Mandate Period (2011–2013)			
			Non-Mandated Jurisdiction (n = 1417)		Mandated Jurisdiction (n = 442)		Non-Mandated Jurisdiction (n = 2127)		Mandated Jurisdiction (n = 593)	
	N	% ^a	n	% ^a	n	% ^a	n	% ^a	n	% ^a
Dependent Variables										
Received (vs. did not receive) recommendation	2660	54.71	726	49.61	226	45.86	1321	58.44	387	59.50
Initiated (vs. did not initiate) vaccine series	1761	36.74	466	30.11	163	34.09	862	41.47	270	37.15
Completed (vs. did not complete) vaccine series	919	18.62	250	16.18	92	21.51	450	20.12	127	17.39
Independent Variables										
<i>Income</i>										
High income	2179	38.13	623	38.40	221	52.79	995	33.93	340	52.18
Middle income	1734	41.90	621	46.27	155	37.00	802	41.20	156	31.58
Low income	666	19.97	173	15.53	66	10.21	330	24.87	97	16.24
<i>Mother’s education</i>										
College degree	2132	37.45	614	36.17	212	41.44	973	36.31	333	46.95
Some college	1178	26.41	401	26.48	111	27.40	552	27.08	114	21.18
High school	1269	36.15	402	37.35	119	31.17	602	36.62	146	31.87
<i>Race-ethnicity</i>										
White	2863	54.89	963	55.93	211	57.77	1376	52.71	313	61.88
Black	941	24.32	236	25.37	163	25.63	355	23.79	197	22.26
Other	775	20.79	218	18.70	68	16.59	396	23.49	93	15.86
Control Variables										
Mother <45 years old (vs. ≥ 45 years old)	2695	63.04	890	63.46	237	62.28	1267	62.84	301	63.14
Mother married (vs. other)	3270	66.44	1058	71.70	279	72.06	1512	59.98	421	80.40
≥2 children in household (vs. only 1)	3161	75.11	970	76.07	284	70.38	1485	74.22	422	80.09
Mother respondent (vs. other adult)	3594	78.93	1152	81.13	353	81.02	1646	77.83	443	75.00

^a Weighted percentages.

sample from mandated (vs. non-mandated) jurisdictions was of higher SES, consistent with regional demographics (Glassman, 2016; Ryan & Siebens, 2012). Before mandate implementation: (a) nearly half all girls (46–50%) received a recommendation to vaccinate, regardless of jurisdiction, (b) 30% initiated and 16% completed the vaccine series in non-mandated jurisdictions, and (c) 34% initiated and 22% completed the vaccine series in mandated jurisdictions. After mandate implementation: (a) provider recommendations increased in both non-mandated and mandated jurisdictions (58–60%), (b) vaccine initiation rates increased in both non-mandated and mandated jurisdictions (37–41%), and (c) vaccine completion rates increased in non-mandated jurisdictions (20%) but decreased in mandated jurisdictions (17%). Analyses (not shown) of 2008, 2009, and 2011 data indicate 93–97% of respondents had heard about HPV vaccines across jurisdictions and years.

Hypothesis 1: Health provider recommendation

Results of the LPM regressing health provider recommendation on income, education, race-ethnicity, and all control variables, without any interaction terms (see Supplementary Table 1, Model 1), revealed the probability of receiving a recommendation was 7–15 percentage points (pps) lower for girls who lived in middle- or low- (vs. high-) income households, had parents with no more than high school education (vs. a college degree), or were Black (vs. White), net of time period and jurisdiction. The probability of receiving a provider recommendation increased by 11 pps in the post- (vs. pre-) mandate period, net of SES, race-ethnicity, and jurisdiction.

Table 2 provides a high-level summary of the remaining results for recommendation, which are described in detail below.

Income inequalities in recommendation. Three-way interactions estimating the impact of mandates on inequalities in recommendation for middle- and low- (vs. high-) income girls were non-significant, suggesting mandates did not improve provider recommendations for these groups (see Supplementary Table 1, Model 2). Fig. 1 shows marginal effects of this interaction indicating, in mandated jurisdictions, disparities for middle- (vs. high-) income girls were not observed, while

Table 2
Summary of key results from linear probability models and marginal effects.

Sig. 3-Way Interaction? ^a		Mandated Jurisdiction ^{b,c}		Non-Mandated Jurisdiction ^{b,c}	
		Pre-Mandate Period	Post-Mandate Period	Pre-Mandate Period	Post-Mandate Period
Hypothesis 1: Provider Recommendation					
<i>Income</i> (ref = high)					
Low	No	Disparity	–	–	Disparity
Middle	No	–	–	Disparity	–
<i>Education</i> (ref = college degree)					
High school	No	–	–	Disparity	Disparity
Some college	No	–	–	Disparity	–
<i>Race-ethnicity</i> (ref = White)					
Black	No	Disparity	–	–	Disparity
Other	Yes	–	–	–	Disparity
Hypothesis 2: Vaccine Series Initiation					
<i>Income</i> (ref = high)					
Low	No	–	Reverse disparity	–	Reverse disparity
Middle	Yes	–	–	–	–
<i>Education</i> (ref = college degree)					
High school	No	–	Reverse disparity	–	–
Some college	No	–	–	–	–
<i>Race-ethnicity</i> (ref = White)					
Black	No	–	–	–	–
Other	No	–	–	–	Reverse disparity
Hypothesis 3: Vaccine Series Completion					
<i>Income</i> (ref = high)					
Low	No	–	–	–	–
Middle	No	–	–	–	–
<i>Education</i> (ref = college degree)					
High school	No	–	–	–	–
Some college	No	–	–	–	–
<i>Race-ethnicity</i> (ref = White)					
Black	No	–	–	Disparity	Disparity
Other	No	–	–	–	–

^a “Sig. 3-way interaction?” indicates whether the interaction between *post-mandate period* × *mandated jurisdiction* × *income/education/race-ethnicity* was significant in the respective linear probability model (see [Supplementary Tables 1–3](#)).

^b “Disparity” indicates the marginal effects showed a lower probability of the outcome for the specified income/education/racial-ethnic group compared to the reference group in the specified period and jurisdiction (see [Figs. 1–7](#)).

^c “Reverse disparity” indicates the marginal effects showed a higher probability of the outcome for the specified income/education/racial-ethnic group compared to the reference group in the specified period and jurisdiction (see [Figs. 1–7](#)).

significant pre-mandate-period disparities for low- (vs. high-) income girls (MER = –0.18, or an 18-pp lower probability of recommendation for low vs. high income) were no longer significant once mandates came into effect. In non-mandated jurisdictions, disparities in provider recommendation existed for middle- (vs. high-) income girls in the pre-mandate period (MER = –0.09), and low- (vs. high-) income girls in the post-mandate period (MER = –0.19).

Education inequalities in recommendation. Non-significant three-way interaction coefficients for recommendation by education suggest mandates did not improve provider recommendations for girls whose mothers had less than a college degree (see [Supplementary Table 1, Model 3](#)). Marginal effects, plotted in [Fig. 2](#), show significant educational inequalities did not exist in mandated jurisdictions in either time period. Educational disparities existed in non-mandated jurisdictions:

girls whose mothers completed some college (vs. college degree) had an 11-pp lower probability of receiving a recommendation in the pre- (but not post-) mandate period, and girls whose parents had no more than high school education had 11- and 15-pp lower probabilities of receiving of a provider recommendation in the pre- and post-mandate periods, respectively.

Racial-ethnic inequalities in recommendation. Results of the triple-difference model examining the impact of mandates on racial-ethnic inequalities in provider recommendation reveal mandates increased recommendations for other race-ethnicity girls by 45 pps (see [Supplementary Table 1, Model 4](#)). Marginal effects, plotted in [Fig. 3](#), show in mandated jurisdictions, Black (vs. White) race-ethnicity girls were significantly less likely to receive a recommendation in the pre- (but not post-) mandate period (MER = –0.18). In non-mandated jurisdictions, Black and other race-ethnicity (vs. White) girls had, respectively, 11- and 10-pp lower probabilities of receiving a provider recommendation in the post-mandate period.

Hypothesis 2: Vaccine series initiation

The results for vaccine series initiation by SES, race-ethnicity, provider recommendation, time period, and mandate jurisdiction (see [Supplementary Table 2, Model 1](#)) demonstrate provider recommendation was the most powerful predictor of vaccine initiation overall, increasing girls’ likelihood of receiving at least one shot by 43 pps. Post- (vs. pre-) mandate period ($b = 0.04$), low (vs. high) income ($b = 0.12$), and other (vs. White) race-ethnicity ($b = 0.06$) were also positively associated with vaccine initiation overall.

See [Table 2](#) for a summary of the remaining results for initiation, which are detailed below.

Income inequalities in initiation. The significant interaction between *post-mandate period* × *mandated jurisdiction* × *middle income* (see [Supplementary Table 2, Model 2](#)) indicate mandates were associated with a 30-pp increase in initiation for middle-income girls, while the non-significant three-way interaction estimate for low-income girls suggests mandates did not improve initiation for this group. Marginal effects (see [Fig. 4](#)) reveal no significant income-based disparities in mandated or non-mandated jurisdictions in the pre-mandate period. Reverse disparities in initiation emerged for low (vs. high-) income girls in both mandated (MER = 0.24, or a 24-pp greater probability of initiating vaccination) and non-mandated jurisdictions (MER = 0.14) in the post-mandate period.

Education inequalities in initiation. Non-significant coefficients for the interaction between *post-mandate period* × *mandated jurisdiction* × *education* indicate mandates did not increase initiation for girls whose mothers had less than a college degree (see [Supplementary Table 2, Model 3](#)). Marginal effects (see [Fig. 5](#)) show the emergence of a reverse-disparity: girls with mothers who had no more than high school education (vs. a college degree) in mandated jurisdictions in the post-mandate period had a 13-pp greater probability of initiating vaccination.

Racial-ethnic inequalities initiation. Non-significant three-way interaction estimates for *post-mandate period* × *mandated jurisdiction* × *race-ethnicity* suggest mandates did not improve initiation for Black or other race-ethnicity girls (see [Supplementary Table 2, Model 4](#)). Marginal effects (see [Fig. 6](#)) show the emergence of a reverse-disparity (MER = 0.09, or a 9-pp greater probability of initiating vaccination) for other race-ethnicity (vs. White) girls in non-mandated jurisdictions in the post-mandate period.

Hypothesis 3: Vaccine series completion

Results of the LPM regressing vaccine series completion on income, education, race-ethnicity, recommendation, and all control variables, without any interaction terms (see [Supplementary Table 3, Model 1](#)) show provider recommendation (vs. no recommendation) increased the

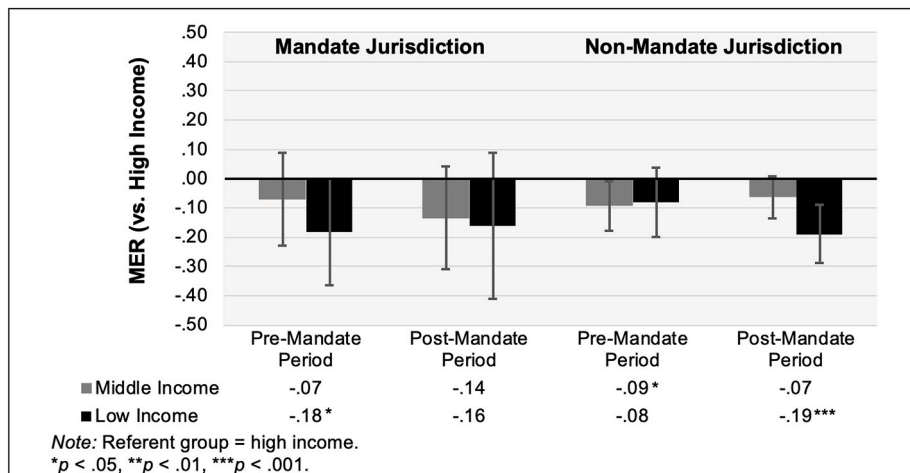


Fig. 1. Marginal effects at representative values and 95% confidence intervals for provider recommendation by income, time period, and mandate jurisdiction.

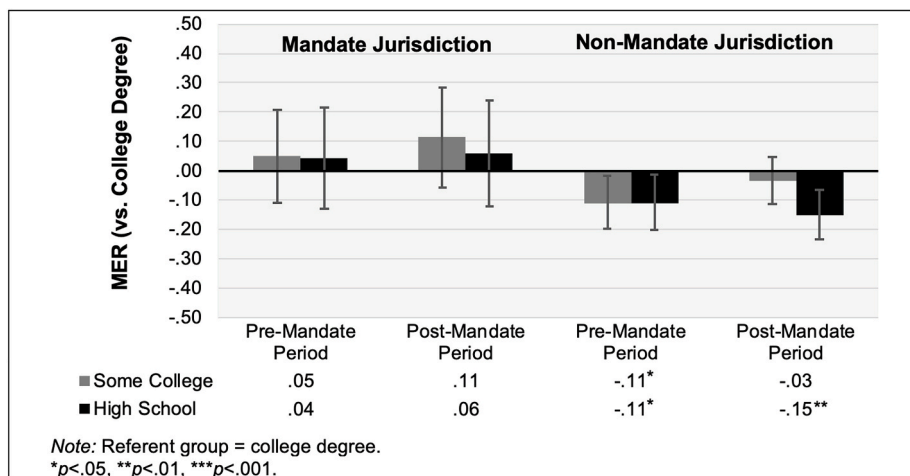


Fig. 2. Marginal effects at representative values and 95% confidence intervals for provider recommendation by education, time period, and mandate jurisdiction.

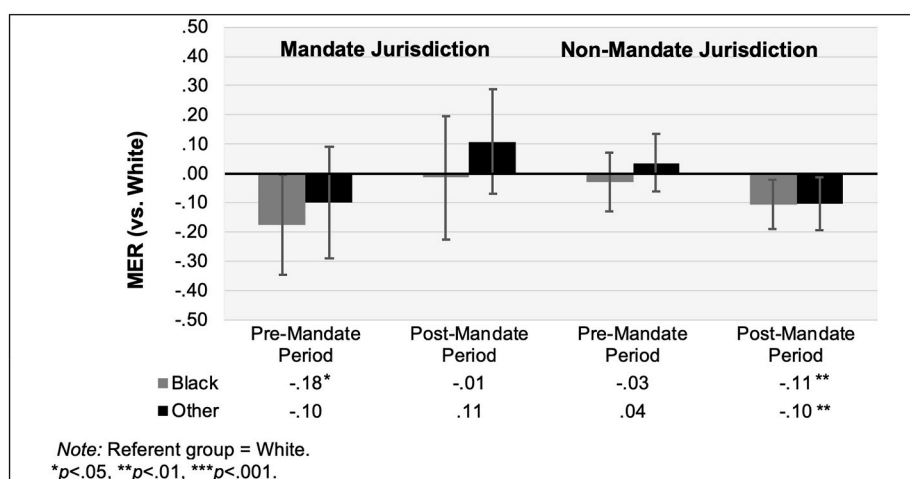


Fig. 3. Marginal effects at representative values and 95% confidence intervals for provider recommendation by race-ethnicity, time period, and mandate jurisdiction.

probability of an adolescent having completed the vaccine series by 22 pps. Living in a low- (vs. high-) income household also increased the probability of an adolescent completing the vaccine series ($b = 0.06$). Being Black (vs. White) decreased the probability of an adolescent

completing the vaccine series by 9 pps, while mother's education, jurisdiction, and period were non-significant.

See Table 2 for a summary of remaining results for completion, which are elaborated upon below.

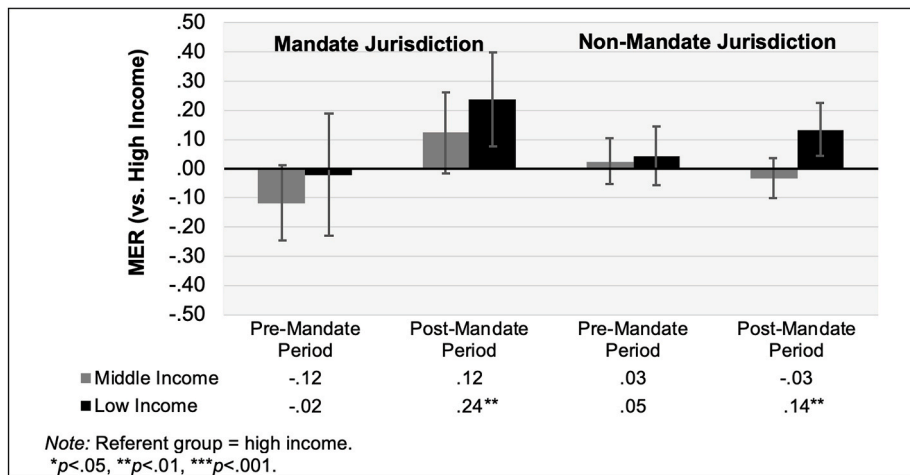


Fig. 4. Marginal effects at representative values and 95% confidence intervals for HPV vaccine series initiation by income, time period, and mandate jurisdiction.

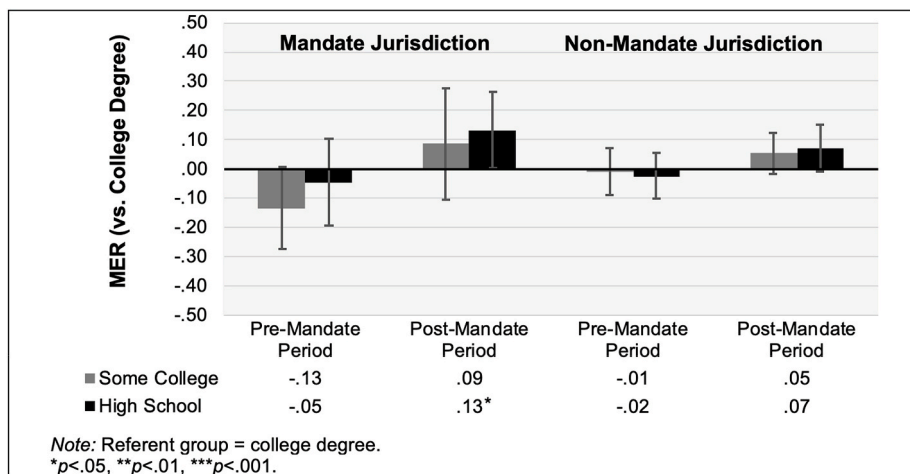


Fig. 5. Marginal effects at representative values and 95% confidence intervals for HPV vaccine series initiation by education, time period, and mandate jurisdiction.

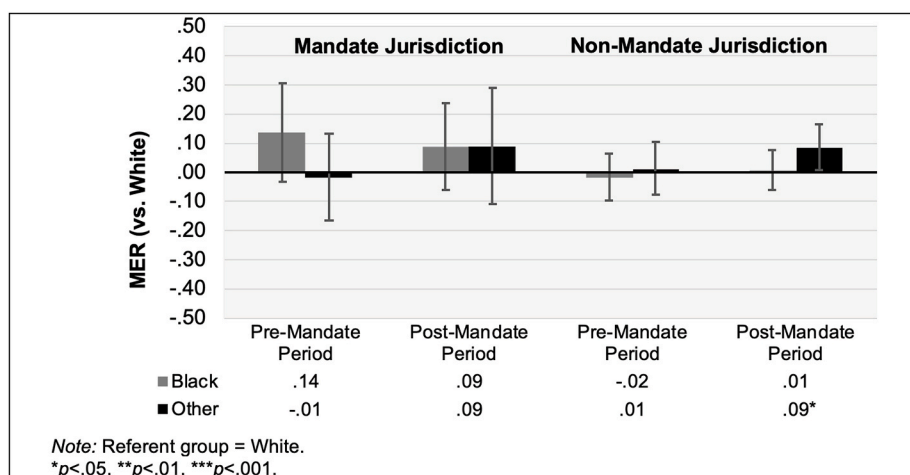


Fig. 6. Marginal effects at representative values and 95% confidence intervals for HPV vaccine series initiation by race-ethnicity, time period, and mandate jurisdiction.

Income inequalities in completion. The LPMs revealed non-significant three-way interaction estimates for income, indicating mandates did not improve completion for low- or middle-income girls (see [Supplementary Table 3](#), Model 2). Marginal effects for this

interaction were also non-significant (plot not shown).

Education inequalities in completion. Non-significant estimates obtained from the three-way interaction for education suggest mandates did not improve completion for girls whose mothers had less than a

college degree (see [Supplementary Table 3](#), Model 3). Marginal effects for this interaction were also non-significant (plot not shown).

Racial-ethnic inequalities in completion. Non-significant three-way interaction estimates for *post-mandate period* × *mandated jurisdiction* × *race-ethnicity*, suggest mandates did not improve vaccine completion for Black or other race-ethnicity girls (see [Supplementary Table 3](#), Model 4). The marginal effects (see [Fig. 7](#)) indicate Black (vs. White) girls had an 8- and 10-pp lower probability of completing the HPV vaccine series in non-mandate jurisdictions in the pre- and post-mandate periods, respectively.

Discussion

FCT contends policy promoting the equal diffusion of medical innovations across populations may help reduce health inequalities. Virginia and DC’s school-entry mandates provided a case to examine whether a policy aimed at standardizing the age of HPV vaccine administration and increasing parental knowledge about HPV vaccines facilitated the equal uptake of this innovation across SES and racial-ethnic groups. Findings supported some of my hypotheses, yet also yielded some contradictory results. Below, I discuss factors that explain these findings.

Mandates and inequalities in health provider recommendation

Consistent with previous research ([Holman et al., 2014](#)) this study identifies a strong association between provider recommendation and HPV vaccine uptake. As adolescents and their parents must access vaccination via health providers and enter clinical encounters with varying levels of cultural health capital ([Shim, 2010](#)), providers may exacerbate inequalities in vaccination via differential recommendation practices based on assumptions about patients’ risk and willingness to vaccinate ([Carhart et al., 2018](#); [Gilkey & McRee, 2016](#)). From an FCT perspective, mandates should mitigate inequalities in recommendation, hence, I predicted mandates would be associated with more equal receipt of provider recommendations across socioeconomic and racial-ethnic groups.

In the pre-mandate period, I observed income- and race-ethnicity-based disparities in mandated jurisdictions and income- and education-based disparities in non-mandated jurisdictions. Supporting FCT-based predictions, no disparities in recommendation were identified in mandated jurisdictions after mandate implementation. Additionally, mandates appeared to improve recommendations for some racial-ethnic minority girls. In contrast, education- and income-based inequalities in provider recommendation persisted in non-mandate

jurisdictions in the post-mandate period and new racial-ethnic disparities emerged. These findings suggest mandates helped shrink pre-existing disparities and prevented the emergence of new disparities in the diffusion of information about HPV vaccines via health providers for lower-SES and some marginalized racial-ethnic groups.

Providers’ failure to discuss HPV vaccination with patients contributes to non-vaccination—particularly for low-income and racial-ethnic minority adolescents ([Guerry et al., 2011](#); [Perkins et al., 2012](#))—signifying inequalities reflect persistent differences in provider behavior. School-entry HPV vaccination mandates may have provided the impetus for providers to discuss HPV vaccination with sixth-grade girls and their parents as part of routine care ([Gilkey & McRee, 2016](#)), mitigating inequalities in recommendation receipt. However, strength of provider recommendation also influences uptake and—even in the presence of mandates—fear of patient attrition may deter providers from strongly recommending HPV vaccines ([Carhart et al., 2018](#)). In the presence of school-entry mandates, social position may continue to shape the strength of provider recommendations received, which may help explain some of the differential patterns of inequalities in uptake described below.

Mandates and inequalities in HPV vaccine uptake

I predicted mandates would be associated with more equal initiation and completion of HPV vaccination across socioeconomic and racial-ethnic groups. Findings suggest mandates improved vaccine initiation for middle-income girls. Additionally, while neither socioeconomic nor racial-ethnic disparities were observed in either jurisdiction in the pre-mandate period, reverse disparities in initiation emerged in the post-mandate period benefitting low-income girls, regardless of jurisdiction; girls whose parents had no more than high school education in mandated jurisdictions; and other race-ethnicity girls in non-mandated jurisdictions. For vaccine completion, only racial-ethnic disparities were identified: Black (vs. White) girls were less likely to complete the vaccine series in non-mandated (but not mandated) jurisdictions across time.

Findings for uptake by income, revealing no and/or reverse-disparities favoring lower-income girls—regardless of jurisdiction—in the post-mandate period, likely reflect the importance of additional policy targeting low-income adolescents. For example, the VFC program covers the cost of HPV vaccination for un- and underinsured adolescents and low-income adolescents are target populations for safety-net health clinics ([Tsui et al., 2013](#)). These findings may also reflect differing perceptions physicians have about this population ([Shim, 2010](#))—including assumptions about sexual risk-taking behavior—that lead to

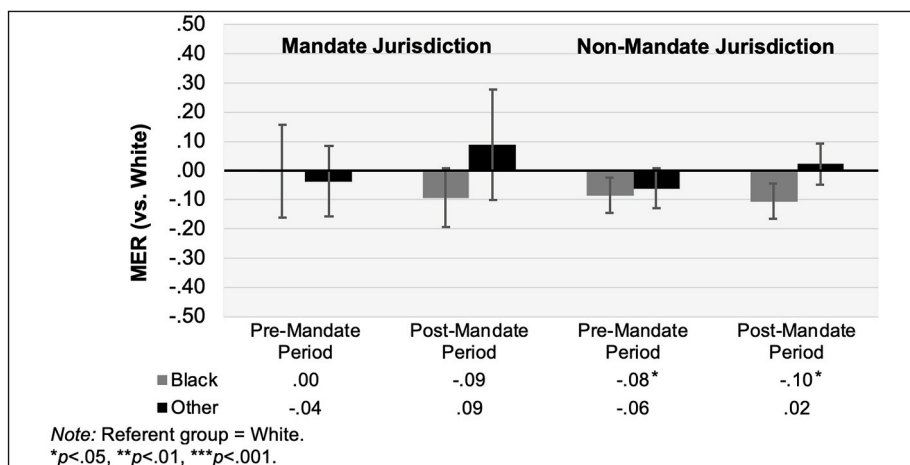


Fig. 7. Marginal effects at representative values and 95% confidence intervals for HPV vaccine series completion by race-ethnicity, time period, and mandate jurisdiction.

stronger HPV vaccination recommendations (Gilkey & McRee, 2016).

The emergence of reverse disparities in vaccine initiation in mandated jurisdictions for adolescents with the least educated parents also supports my hypotheses and speaks to the role of education for taking part in—and opting out of—vaccination. DC and Virginia's broad opt-out provisions, which allow parents to refuse HPV vaccination after reviewing educational materials, may remove a barrier to knowledge for lower-educated parents (Moghtaderi & Adams, 2016; Perkins et al., 2016); however, the most educated parents—who are most likely to question and refuse vaccines (Reich, 2014)—may be less likely to comply.

In contrast to findings for vaccine initiation by SES, evidence did not support the FCT-based prediction that mandates shaped racial-ethnic patterns of vaccine initiation. Mandates also did not influence vaccine completion by SES. Unexpectedly, rates of initiation and completion were lower in mandated (vs. non-mandated) jurisdictions in the post-mandate period, and completion declined in mandated jurisdictions once mandates came into effect. This suggests low enforcement of—and adherence to—HPV vaccine mandates, which is surprising given school-entry mandates have been effective for achieving high uptake of other adolescent and childhood vaccines (Abrevaya & Mulligan, 2011; Olshen et al., 2007). However, these findings complement other studies identifying no impact of school-entry HPV vaccine mandates on overall uptake (but, that did not consider their impact on social inequalities) (Cuff et al., 2016; Perkins et al., 2016).

Considered with previous research, this study's findings reflect three key factors unique to HPV vaccine mandate implementation, which make them ineffective for increasing overall uptake. First, despite mandates, parents often do not perceive HPV vaccination to be routine or mandatory because HPV cannot be transmitted through casual contact (Carhart et al., 2018). A survey of Virginia parents found only 14% believed HPV vaccination was required for their daughter, while 100% believed their daughters were “up-to-date” on vaccinations—despite only 50% having received any HPV shots (Cuff et al., 2016).

Second, mandates were accompanied by pharmaceutical manufacturer lobbying and generated political debate and controversial news coverage, eroding public support (Gollust et al., 2010). White parents, in particular, opposed mandates based on the rationale that they infringe on parental autonomy (Perkins et al., 2010). A qualitative study of Virginia parents demonstrated many parents prefer to opt their daughters out of HPV vaccination in sixth grade and decide, on their own terms, when and if their child is vaccinated (Pitts & Tufts, 2013).

Third, mandates specify girls should initiate HPV vaccination before entering sixth grade, but do not include a timeline for completion. While enforcing initiation requires the cooperation of individual healthcare providers to distribute vaccines and schools to enforce mandates, there was no widely used surveillance system tracking adolescent's vaccination status or reminding patients to return for follow-up shots (Carhart et al., 2018). Hence, enforcing timely initiation and completion is difficult.

Overall, findings for uptake highlight specific conditions that may limit the effectiveness of policies for reducing health inequalities. FCT emphasizes policy is more likely to mitigate health inequalities when it leaves little room for personal decision making (e.g., dental health inequalities are more likely to be reduced by fluoridating the water supply than advising individuals to purchase fluoride supplements; Phelan et al., 2010). Policies such as smoking bans and seat belt laws have achieved high compliance and reduced disparities in specific health behaviors (Harper et al., 2014; Hernandez et al., 2019), despite leaving room for individual non-compliance. However, these policies include sanctions, such as monetary fines, to encourage adherence. In contrast, school-entry HPV vaccination mandates both allow a high degree of individual decision-making and lack any sanctions for noncompliance. In addition, while school-entry mandates may disperse health-enhancing knowledge more equally across the population, they have not changed how vaccines are distributed or whom they can be

administered by. Consequently, barriers to uptake (e.g., lack of health-care access, time constraints) may persist and differences in provider behaviors may continue to shape patterns of uptake. School-entry HPV vaccine mandates thus illustrate specific conditions under which policy is unlikely to succeed at facilitating the widespread and/or equal diffusion of health-promoting innovations across populations.

Implications for medical sociology and health policy

This study has implications for medical sociology in terms of understanding the role of policy for facilitating the equal uptake of health-promoting innovations across social groups. By explicitly testing FCT in relation to school-entry HPV vaccination mandates, it identified a case in which policy helped to equalize health provider recommendation practices. In doing so, it emphasizes the importance of policy for mitigating inequalities in provider interactions with patients of varying social positions—interactions that may shape disparities in immediate health behaviors and latent health outcomes. Future research should consider how policy shapes inequalities in both the frequency and strength of provider recommendations for other health-promoting innovations.

This study also identified a number of disparities—and reverse-disparities—at distinct stages of HPV vaccine uptake, as well as differences in the impact that mandates had on shaping inequalities at these stages. Accordingly, it highlights the unique roles that SES and race-ethnicity play in shaping inequalities in the diffusion of health-promoting innovations and emphasizes the need for policy to take these complex inequalities into account. This study also highlights the differential impact policy can have on the actions of various individuals involved in adolescent health decision-making. While providers may respond to mandates that seek to standardize the age of HPV vaccine administration with more universal recommendations, a parent or adolescent's social position and individual experience may shape their unique conceptualizations of risk (Brown, 1992) and lead some to question whether compliance is in their best interest.

Finally, this study practically evaluates a current policy and identifies limitations of HPV vaccine mandates for supporting equal and widespread HPV vaccination. In doing so, it underscores the limited impact policy has on health inequalities when it is easy for individuals to opt-out of participation (see Phelan et al., 2010). Without widespread public support, monitoring, sanctions for noncompliance, or changes to the method of vaccine administration, school-entry HPV vaccine mandates do little to encourage uptake. This finding may be applicable to other policies that increase basic education about an intervention—yet lack means to facilitate compliance. Examination of how other policies shape inequalities in the diffusion of health-promoting innovations would be useful for further understanding the conditions under which policy shapes the relationship between social position and health.

Limitations and strengths

This study used the best available U.S. nationally representative data for examining social inequalities in HPV vaccination. Although the NIS-Teen relies on parent recall, analyses identify parent-reported data as a valid measure of population-level HPV vaccine uptake, and find higher agreement between parent recall and provider verification among 13- and 14-year-olds (the sample analyzed in this study) versus older teens (Dorell et al., 2011; Hirth et al., 2016). Studies assessing NIS-Teen data validity also suggest low-income and Hispanic parents are more likely to underreport HPV vaccination, while Black parents are more likely to overreport (Hirth et al., 2016). However, this study revealed the opposite: low-income adolescents had higher rates of vaccine initiation and completion, other race-ethnicity adolescents (a large proportion of which were Hispanic) had higher rates of initiation, and Black adolescents had lower rates of completion. Mandates might also make HPV vaccination easier to recall for parents living in mandated

jurisdictions, and the desire to adhere to mandates could result in overreporting uptake. However, differences in reporting did not appear to drive this study's findings as awareness of HPV vaccines was similar across jurisdictions, and uptake of HPV vaccines declined in mandated jurisdictions after mandate implementation.

A relatively small subsample of respondents resided in mandated jurisdictions across all study years ($n = 1035$), which may have left some models underpowered to detect significant three-way interactions. Nonetheless, the results corroborate with studies examining the overall impact of school-entry mandates that find mandates have not increased HPV vaccination rates (Bugenske et al., 2012; Moghtaderi & Adams, 2016).

While this study identifies how disparities in HPV vaccination are generated and reproduced within the United States, findings are not generalizable to other geographic contexts with distinct histories of social inequality and different health and social policies in place. From an FCT perspective, we would expect more equal uptake of HPV vaccines (and, by extension, smaller latent inequalities in HPV-related cancers) in countries with stronger welfare states and universal vaccination and healthcare policies (e.g., Australia, Canada, Scotland; Lee & Garland, 2017). Cross-national comparisons would complement this study's findings.

Conclusion

HPV vaccine mandates appeared to mitigate racial-ethnic inequalities in provider recommendation and educational inequalities in vaccine initiation. While mandates supported the equal diffusion of HPV vaccines among girls at some stages of uptake, policy weaknesses prevented mandates from improving vaccine uptake overall. This study suggests policy that merely aims to increase lay knowledge about a health-promoting innovation or standardize the age of its administration is insufficient for ensuring equal or widespread uptake. Future research documenting the impact of specific policy changes on (a) the uptake of other health-promoting innovations and (b) long-term inequalities in morbidity and mortality (e.g., incidence of HPV-related cancers and mortality) will be important for further understanding the conditions under which policy can impact the fundamental cause relationship between social position and health.

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Author statement

Andrea Polonijo: conceptualization, methodology, formal analysis, writing – original draft, writing – review & editing, visualization.

Declaration of competing interest

None.

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Appendix A. Supplementary data

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