RESEARCH PAPER

Associations between HPV vaccination among women and their 11–14-year-old children

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ABSTRACT

The human papillomavirus (HPV) vaccine has been available in the United States for over a decade. We sought to examine the associations between self-reported receipt of HPV vaccination among women and their 11–14-year-old children in 27 low-coverage states. Among the 3,261 mothers we surveyed, 18% reported receiving ≥ 1 dose of HPV vaccine. A significantly higher proportion of vaccinated women reported vaccination of their children compared to unvaccinated women (83% vs. 56%, $p < .001$). In multivariable logistic regression, vaccinated women (vs. unvaccinated) had 3.58 (95% CI: 2.81–4.56) times the adjusted-odds of vaccinating their children (≥ 1 dose HPV vaccine). Among unvaccinated children, vaccinated mothers (vs. unvaccinated) had 3.32 (95% CI: 2.09–5.26) times the adjusted odds of high intention to vaccinate their children in the next 12 months. We did not observe associations between mothers' vaccination confidence and their vaccination status. We conclude that mothers who received ≥ 1 dose of HPV vaccine may be more likely to initiate or highly intend to initiate the HPV vaccine series for their children. This may have important implications for meeting population goals for HPV vaccination coverage as an increasing proportion of mothers are likely to be vaccinated over time.

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Introduction

The human papillomavirus (HPV) vaccine has been available to females in the United States (US) since 2006 and to males since 2009.¹ Routine vaccination has the potential to eliminate virtually all cervical cancer, and substantially reduce the number of head, neck, anal, penile and vaginal cancers.² It is recommended for both sexes at ages 11–12 years, with “catch-up” vaccination from ages 13–26.³ However, uptake of the vaccine series is lower than that of other vaccines recommended at the same age. While over 88% of adolescents ages 13–17 received a Tdap vaccine in 2017, only 66% received at least the first dose of HPV vaccine, and less than 50% completed the series.⁴ Among young adults ages 18–26, 46% of women and 15% of men ages 18–26 reported previous HPV vaccination.⁵ While national estimates of adolescent and young adults uptake of the HPV vaccine are obtained through surveys such as the National Immunization Survey-Teen (NIS-Teen) and the National Health Interview Survey,⁴ less is known about the current rates of HPV vaccination among adults older than age 26. Assessment of adult HPV vaccination coverage may be of particular importance as on-time vaccination of 11–12-year-old adolescents requires parental acceptance of the HPV vaccine. Yet there have been no previous studies on how parents, who themselves received the HPV vaccine, may perceive vaccination of their children.

Mothers continue to be the major health-care decision-makers for their children, including for immunizations.^{6–8} To benefit intervention development and increase vaccination acceptance among mothers, many studies have investigated the factors associated with mothers' decisions to vaccinate.^{8,9} However, no prior research has examined mothers' own HPV vaccination history and the effect this may have on their propensity to vaccinate their children. As HPV vaccine has been available for females for over 12 years and was originally approved and promoted as a “female” vaccine for cervical cancer prevention,^{10,11} it is becoming increasingly likely that many mothers of adolescent children are themselves vaccinated. These mothers experienced late adolescence and early adulthood during a time when the HPV vaccine was widely available and potentially made the decision to be vaccinated. Examining their own immunization history may provide a more thorough understanding on their vaccination decisions for their children. Reasons for such an association may be the result of heightened awareness about HPV and HPV vaccines. Additionally, previously vaccinated mothers may more likely be early adopters which is an important predictor of the acceptance of new recommendations and has been associated with intention to recommend HPV vaccines among providers.^{12–14}

Therefore, as part of a larger study of HPV vaccination in 27 low-uptake states, we sought to (a) assess the HPV vaccination status of mothers of 11–14 year-olds, (b) examine associations between receipt of HPV vaccine among mothers and among their children, and (c) among those mothers whose children had not received HPV vaccine, examine associations between mothers' receipt of HPV vaccine and intent to vaccinate their children in the next 12 months.

Results

Demographics

Among the 3261 mothers who completed our survey, over half (59%) lived in the US South (Table 1). Respondents most frequently reported from Texas ($n = 402$), Florida ($n = 390$), and Ohio ($n = 257$). The mean age of the mothers was 40.4 (SD 8.10); 70% were non-Hispanic white. Approximately 42% had completed some college or vocational school. The mean child age was 12.5 (SD = 1.1) and 53% of the children were female.

Maternal and child HPV vaccination status

The majority of mothers (82%) reported they had not received HPV vaccination; 18% reported receiving one

or more doses (Table 1). Among the 595 women who reported ≥ 1 dose, 31% ($n = 183$) reported three doses. Mothers who reported receiving ≥ 1 dose of HPV vaccination (vs. not) were slightly younger (mean age 36.6 (SD 7.3) vs. 41.2 (SD 8.1)), and were more likely to report their race/ethnicity as non-Hispanic Black or Hispanic (Table 1, $p < .001$). Over half of all mothers (61%, $n = 1995$) reported that their children had received ≥ 1 doses of HPV vaccine. Among the 1266 unvaccinated children, 36% ($n = 450/1266$) of mothers reported high intention to vaccinate in the next 12 months.

Associations between maternal and child vaccination statuses

Women who received HPV vaccine themselves were more likely to report vaccinating their child as compared to unvaccinated women. Over 80% of the 595 vaccinated women reported vaccination of their child vs. 56% of the 2666 unvaccinated women ($p < .001$). In multivariable analysis, women who were vaccinated (vs. not) had 3.58 times the adjusted odds of vaccinating their child (95% CI: 2.81–4.56; Table 2). We did not observe substantial differences in the effect when restricting to the 987 age-eligible mothers: OR 3.59 (95% CI 2.53–5.08).

Associations between maternal and intent to vaccinate child in next 12 months

Among the 1266 women who reported their child had not been vaccinated, 60% of vaccinated mothers vs. 33% of unvaccinated mothers reported high intent to vaccinate their child in the next 12 months ($p < .001$). After adjusting for sociodemographic characteristics, vaccinated mothers (vs. unvaccinated) had 3.32 (95% CI: 2.09–5.26) times the adjusted odds of high intent to vaccinate their children in the next 12 months (Table 3). We observed similar results for vaccination intent when we restricted the sample to the 362 mothers who were age-eligible for the vaccine and had not yet vaccinated their child (OR 3.21, 95% CI 1.64–6.25).

Sex as an effect modifier

We observed a larger effect on the association between mother's vaccination status and the vaccination of their children for female children as compared to male children. Among mothers of male children, 77% of the 264 vaccinated mothers reported vaccination of their sons vs. the 56% of the 1280 unvaccinated mothers ($p < .001$). Among mothers of female children, 87% of the 330 vaccinated mothers reported vaccination of their daughters vs. the 57% of the 1386 unvaccinated mothers ($p < .001$). In the multivariable logistic regression analyses stratified by child sex (Table 4), among the 1716 mothers of female children, those who were vaccinated (vs unvaccinated) had 5.43 (95% CI: 3.78–7.80) times the adjusted odds of vaccinating their female child. Among the 1545 mothers of male children, those who were vaccinated (vs. not) had

Table 1. Demographic characteristics by maternal HPV vaccination status.

	Total		0 doses		≥ 1 doses		<i>p</i>
	N	(%)	N	(%)	N	(%)	
N	3261		2666	(82)	595	(18)	
Mother characteristics							
Age (mean (SD))	40.4	(8.1)	41.2	(8.1)	36.6	(7.3)	**
Race/ethnicity							**
Non-Hispanic White	2295	(70)	1963	(74)	332	(56)	
Non-Hispanic Black	360	(11)	261	(10)	99	(16)	
Hispanic	434	(13)	313	(12)	121	(20)	
Asian	59	(2)	43	(1)	16	(3)	
Other	113	(4)	86	(3)	27	(5)	
Educational attainment							**
College	1144	(35)	980	(37)	164	(28)	
Some College/Vocational	1358	(42)	1116	(42)	242	(41)	
High School	680	(21)	517	(19)	163	(27)	
Less than High School	79	(2)	53	(2)	26	(4)	
Vaccination confidence							
Low	1500	(46)	1225	(46)	275	(46)	
High	1761	(54)	1441	(54)	320	(54)	
Child characteristics							
Age (mean (SD))	12.5	(1.1)	12.5	(1.1)	12.5	(1.1)	
Sex							
Male	1545	(47)	1280	(48)	265	(45)	
Female	1716	(53)	1386	(52)	330	(56)	**
Insurance status							
Insured	2975	(91)	2465	(92)	510	(86)	
Uninsured	286	(9)	201	(8)	85	(14)	
Household characteristics							
Household Income							**
$\geq \$100,000$	644	(20)	568	(21)	76	(13)	
\$75,000–\$99,999	501	(15)	419	(16)	82	(14)	
\$50,000–\$74,999	731	(22)	614	(23)	117	(19)	
\$25,000–\$49,999	844	(26)	665	(25)	179	(30)	
<\$25,000	541	(17)	400	(15)	141	(24)	
Region of US ¹							*
South	1924	(59)	1540	(58)	384	(65)	
Midwest	868	(27)	741	(28)	127	(21)	
West	343	(10)	275	(10)	68	(11)	
Northeast	126	(4)	110	(4)	16	(3)	

p – * < .01, ** < .001

¹Region of US – states grouped based on US Census regions. South – AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, TX, WV; Midwest – IL, IN, KS, MO, OH, SD; West – AK, AZ, ID, MT, NV, NM, UT, WY; Northeast – NJ.

Table 2. Multivariable logistic regression for child HPV vaccination statuses (≥ 1 dose vs. 0) based on maternal HPV vaccine status and other sociodemographic variables.

	≥ 1 dose (child)		Univariate		<i>P</i>	Multivariable		<i>P</i>
	n/N	(%)	COR ¹	(95% CI)		AOR ¹	(95% CI)	
N	1995/3261	(61)	2791	(82)		625	(18)	
Mother characteristics								
Mother HPV vaccine status								
0 doses	1502/2666	(56)	Ref			Ref		
≥ 1 doses	493/595	(83)	3.75	(2.99–4.70)		3.58	(2.81–4.56)	**
Age – years			0.99	(0.98–1.00)		1.00	(0.99–1.01)	
Race/ethnicity								
Non-Hispanic White	1312/2295	(57)	Ref			Ref		
Non-Hispanic Black	257/360	(71)	1.87	(1.47–2.38)	**	1.90	(1.46–2.47)	**
Hispanic	313/434	(72)	1.94	(1.55–2.43)	**	1.88	(1.47–2.49)	**
Asian	46/59	(78)	2.65	(1.42–4.93)	*	2.59	(1.34–4.98)	*
Other	67/113	(59)	1.09	(0.74–1.60)		1.24	(0.82–1.88)	
Educational attainment								
College	669/1144	(58)	Ref			Ref		
Some College/Vocational	814/1358	(60)	1.06	(0.91–1.25)		1.13	(0.93–1.36)	
High School	457/680	(67)	1.46	(1.19–1.77)	**	1.40	(1.10–1.77)	*
Less than High School	55/79	(70)	1.63	(0.99–2.67)		1.40	(0.80–2.42)	
Vaccination confidence								
Low	782/1500	(52)	Ref			Ref		
High	1213/1761	(69)	2.03	(1.76–2.34)		2.26	(1.93–2.63)	**
Child characteristics								
Age – years			1.40	(1.31–1.50)	**	1.46	(1.36–1.57)	**
Sex								
Male	923/1545	(60)	Ref			Ref		
Female	1072/1716	(62)	1.12	(0.97–1.29)		1.11	(0.95–1.29)	
Insurance status								
Insured	1799/2974	(60)	Ref			Ref		
Uninsured	196/286	(69)	1.42	(1.10–1.85)	*	1.27	(0.96–1.69)	
Household characteristics								
Household Income								
$\geq \$100,000$	395/644	(61)	Ref			Ref		
\$75,000–\$99,999	301/501	(60)	0.95	(0.75–1.20)		0.89	(0.69–1.16)	
\$50,000–\$74,999	410/731	(60)	0.81	(0.65–1.00)		0.70	(0.55–0.89)	*
\$25,000–\$49,999	504/844	(26)	0.93	(0.76–1.15)		0.77	(0.60–0.99)	
<\$25,000	385/541	(71)	1.56	(1.22–1.99)	**	1.28	(0.96–1.72)	
Region of US ¹								
South	1194/1924	(62)	Ref			Ref		
Midwest	525/868	(60)	0.94	(0.79–1.10)		1.04	(0.87–1.24)	
West	212/343	(62)	0.99	(0.78–1.25)		0.97	(0.75–1.25)	
Northeast	64/126	(51)	0.63	(0.44–0.91)		0.65	(0.43–0.96)	

¹COR – Crude Odds Ratio, AOR – Adjusted Odds Ratio*P* – * $<.01$, ** $<.001$ ¹Region of US – states grouped based on US Census regions. South – AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, TX, WV; Midwest – IL, IN, KS, MO, OH, SD; West – AK, AZ, ID, MT, NV, NM, UT, WY; Northeast – NJ.²Multivariable logistic regression model adjusted for maternal characteristics (age, race/ethnicity, education attainment, vaccination confidence), child characteristics (age, sex, insurance status), and household characteristics (annual household income, US census region).**Table 3.** Multivariable logistic regression for intent to vaccinate (among unvaccinated children) based on maternal HPV vaccination status ($N = 1266$).

	Intends to vaccinate		Univariate		<i>P</i>	Multivariable ²		<i>P</i>
	n/N	(%)	COR ¹	(95% CI)		AOR ¹	(95% CI)	
Mother HPV vaccine status								
0 doses	389/1164	(33)	Ref			Ref		
≥ 1 doses	61/102	(60)	2.96	(1.96–4.48)	**	3.32	(2.09–5.26)	**

¹COR – Crude Odds Ratio, AOR – Adjusted Odds Ratio*P* – * $<.01$, ** $<.001$ ²Multivariable logistic regression model adjusted for maternal characteristics (age, race/ethnicity, education attainment, vaccination confidence), child characteristics (age, sex, insurance status), and household characteristics (annual household income, US census region).**Table 4.** Multivariable logistic regression for child HPV vaccination statuses (≥ 1 dose vs. 0) based on maternal HPV vaccination status, stratified by child sex.

	Female		<i>P</i>	Male		<i>P</i>
	1072/1716			923/1545		
≥ 1 dose (child) n/N	AOR ¹	(95% CI)		AOR ¹	(95% CI)	
Mother HPV vaccine status						
0 doses	Ref			Ref		
≥ 1 doses	5.43	(3.78–7.80)	**	2.49	(1.78–3.46)	**

¹AOR – Adjusted Odds Ratio*P* – ** $<.001$ ²Multivariable logistic regression model adjusted for maternal characteristics (age, race/ethnicity, education attainment, vaccination confidence), child characteristics (age, insurance status), and household characteristics (annual household income, US census region).

2.49 (95% CI: 1.78–3.46) times the adjusted odds of vaccinating their male child. Overall, mothers of female vs. male children were 1.95 (95% CI: 1.21–3.14, $p = .006$) more likely to vaccinate their child if they had been vaccinated themselves vs. not vaccinated. Among mothers who had not yet vaccinated their children, we did not observe significant effect modification by sex on the association between mother's vaccination status and their intent to vaccinate their child in the next 12 months.

Discussion

In this first study to assess parental HPV vaccination, we found a significant association between mothers' vaccination status and likelihood to have vaccinated/intend to vaccinate their adolescent children. Our findings suggest that from a health promotion perspective, parental vaccine status can play an important role in their willingness to vaccinate their own children and may be an effective vaccination promotion strategy. On-time HPV vaccination coverage continues to lag behind other recommended adolescent vaccines, including tetanus, diphtheria and acellular pertussis (Tdap), and meningococcal conjugate (MenACWY).⁴ Although series completion is recommended by age 13, only 39% of 13 year-olds have completed the series, as compared to 53% of 17 year-olds.⁴ This coverage is suboptimal to achieve the vaccine's cancer prevention potential.^{15,16} While a health-care provider recommendation for HPV vaccination has been shown to strongly affect HPV vaccination,^{17,18} parents' attitudes towards vaccination likely also play a role in lower coverage, especially in low-uptake states.⁹ The extent to which parental behaviors, beliefs, and attitudes affect their decision to vaccinate continues to be an area under study and of particular interest for targeted intervention development.^{8,15,19,20}

Since HPV vaccine introduction, a growing number of adult women and men have been vaccinated in the US, and many have preadolescent or adolescent children who are vaccine-eligible. To our knowledge, there have been no previous studies that examined the proportion of HPV-vaccinated parents of vaccine-eligible adolescents. Our study, therefore, fills an important gap in knowledge on this topic. It is essential to track the growing number of parents who are vaccinated against HPV. As more vaccinated parents make the decision to vaccinate their children, it is vital for intervention development to understand how this cohort of parents' attitudes and beliefs towards vaccination may differ from their non-vaccinated peers. Targeted intervention development may also be enhanced by a better understanding of factors that are associated with maternal vaccination status.

In examining associations between mothers' vaccination status and sociodemographic factors, we observed variability in race/ethnicity, educational attainment, annual household income, and region of the US. Similar to patterns seen in adolescent HPV vaccination,⁴ vaccinated women trended toward lower ages, educational attainment, and annual household income. They were also more likely to self-report as a minority race/ethnic group. The sociodemographic variations may reflect differences in social communication about

the vaccine leading to increased belief in its efficacy among some subgroups.²¹ These trends also highlight disparities in HPV vaccine receipt that may reflect the tendency of health-care providers to recommend HPV vaccination to members of sociodemographic groups who they considered to be at "higher risk" of HPV infection.²² There has been a substantial public health push to encourage health-care providers to follow the ACIP recommendation that HPV vaccine be universally given to all age-eligible adolescents.^{15,23,24} However, we continued to observe sociodemographic disparities in HPV vaccination uptake among adolescents in the present study, suggesting that these disparities in maternal vaccination may persist into the next generation.

We observed significant effect modification by child sex on the association between mothers' vaccination status and their child's status. While overall, vaccinated vs. unvaccinated mothers were more likely to vaccinate their children, the effect was stronger among female vs. male children. Mothers of females were twice as likely to vaccinate their children than mothers of males, when they themselves had been vaccinated. This difference in effect by child sex may be related to the historical context in which HPV vaccine was first approved as a vaccine for females only. This early marketing of the vaccine toward prevention of cervical cancer among women may have contributed to the feminization of HPV and the vaccine.¹⁰ While HPV vaccine has been approved and recommended for both males and females since as early as 2009, and HPV infections occur in men more often than women,²⁵ coverage among adolescent males continues to lag behind coverage of females.⁴ Given that many women in our study may have been vaccinated at a time when the vaccine was only available to women, this may result in reinforcing the feminization of HPV vaccine and increasing their propensity to vaccinate their daughters. Despite this, it is encouraging to observe that vaccinated women were more likely to vaccinate their sons as compared to unvaccinated women, suggesting that other factors beyond the child's sex, such as increased awareness and knowledge about the vaccine, may be impacting the relationship between vaccination status and the decision to vaccinate their children. As per the diffusion of innovation theory, previously vaccinated mothers, especially those who were vaccinated soon after licensure, may be early adopters of new recommendations.^{14,26} Early adopters may in turn be more likely to accept HPV vaccination for their child. In this way, we might define these women as double early-adopters: early adoption – technically, an "innovator" in Roger's original conceptualization of the model – of the HPV vaccine for themselves (an individual behavior) and relatively early adopters or early majority of deciding to get the HPV vaccination for their children (as proxy decision-maker).¹³

Finally, as HPV vaccine continues to disseminate throughout the population, identifying effective targeting strategies will continue to be important, especially in geographic areas with low coverage.¹⁵ For example, tailoring HPV vaccine promotion messages to mothers who have already themselves been vaccinated may be particularly effective in motivating vaccination of their children. Our findings suggest the potential to use mothers' own vaccination status as a motivation for vaccinating her child.

Further work is needed to determine the most efficacious messaging strategies to target vaccinated vs. unvaccinated mothers. Interestingly, we did not observe differences in vaccination confidence by maternal vaccination status, suggesting that vaccinated mothers' attitudes toward vaccinating their children were not moderated by a higher vaccine confidence in adolescent vaccines in general. To tailor interventions to vaccinated vs. unvaccinated mothers, research is needed to determine mothers' pre-existing attitudes and behavioral intentions toward adolescent HPV vaccination, and how their own vaccination status modifies their beliefs.

Our study strengths include a large sample of mothers recruited from states with low HPV vaccination coverage. As HPV vaccination coverage varies substantially between states, surveying parents from low-coverage states contributes to filling the gap in knowledge on factors associated with lower HPV vaccination in these populations.^{4,15} Another study strength was our focus on parents of younger adolescents ages 11–14, as compared to older adolescents, providing valuable insight into decision-making regarding on-time vaccination.

A limitation to our study is that we conducted our survey prior to the FDA approval for the increased upper age range for 9vHPV. It remains to be determined how this more permissive age range will affect parent attitudes toward adolescent vaccination as there are more opportunities for mothers to get vaccinated. In addition, we are limited by the cross-sectional study design and self-reported data. Finally, our recruitment of only mothers/female guardians did limit our population by excluding men and/or individuals who are non-binary. However, previous research suggests that female caregivers are predominantly the primary decision makers for adolescent HPV vaccination.⁷ Consistent with these findings, 95.6% of the mothers in our study reported that they alone or together with their partner make health-care decisions for their child.

Conclusions

A growing number of women in the US have been vaccinated against HPV, and now face the decision to vaccinate their eligible adolescent children. We found that vaccinated mothers were more likely to initiate HPV vaccination for their children, or intended to initiate in the next 12 months if their children were not yet vaccinated. Our findings may have important implications for targeted intervention development in US geographic areas with traditionally low HPV vaccination coverage.

Methods

Study design

We conducted a cross-sectional, online survey of mothers of children ages 11–14 in September 2018. We collected the data presented here as part of a larger, randomized controlled trial in which we recruited participants from a national survey panel maintained by Survey Sampling International (SSI). Email invitations for the online Qualtrics survey were sent to members of SSI's US-based panel who met inclusion criteria (see below). Participants were not compensated directly

for their participation in this study, but they receive nominal payments for participating in the survey panels maintained by SSI. The study was approved as exempt by Indiana University's Institutional Review Board.

Study objectives

We sought to evaluate the association between maternal receipt of HPV vaccination and child's HPV vaccination status among women living in states with low HPV vaccination coverage.

Study participants

English-speaking mothers or other female guardians with a child ages 11–14 years living in low HPV vaccination-uptake states were eligible to participate in the study. "Low uptake states" were defined as the 27 states with the lowest HPV vaccine series initiation rates (≥ 1 doses) for children 13–17, as reported by the 2017 National Immunization Survey-Teen.⁴ Although clusters of hesitancy exist in states with generally high HPV vaccine uptake, we restricted to low-uptake states to maximize the efficiency of enrollment in the intervention component of the larger study. These states were located mainly in the South – AL, AR, FL, GA, KY, MS, NC, OK, SC, TN, TX, WV; Midwest – IL, IN, KS, MO, OH, SD; and West – AK, AZ, ID, MT, NV, NM, UT, WY. One state (NJ) was in the Northeast. The states ranged in HPV vaccination uptake among 13–17-year-olds from 46.9% (WY) to 65.8% (NJ).⁴ We excluded fathers/male guardians, participants living outside the target states, and those without a child in the target age range. We focused on mothers/female guardians to maximize the number of participants who primarily or jointly were the decision-maker for their child's immunizations.⁷

Among the 3,416 study respondents who met initial eligibility criteria and completed the survey, we excluded 93 participants with missing information on the following variables: child age ($n = 3$), child's insurance status ($n = 29$), mothers' educational attainment ($n = 15$), mothers' age ($n = 18$), and household income ($n = 28$). We also excluded 62 participants with missing information on maternal race/ethnicity. Our final sample eligible for the present analyses included 3261 mothers.

Outcome

Our primary outcome of interest was child's HPV vaccination status, which we defined with the following question:

How many shots of the HPV vaccine has [TEEN] had? It's also called the human papillomavirus vaccine, Gardasil, or Gardasil 9.

We dichotomized the responses into none vs. ≥ 1 dose of HPV vaccine.

Among mothers who reported that their child had not been vaccinated against HPV, we asked about their intent to vaccinate with the following question:

How likely are you to get [TEEN] the HPV vaccine sometime in the next 12 months? Would you say ... [DEFINITELY WILL; NOT SURE/I HAVE QUESTIONS OR CONCERNS]

We defined "definitely will" as high intent to vaccinate in the next 12 months, and "Not sure/I have questions or concerns" as low intent.

Exposures

Our main exposure of interest was mothers' HPV vaccination status, which we defined with the following prompt and question:

The next few questions are about **your background**: Have you received HPV vaccine? [NO/YES]

Covariates

We assessed via mothers' report for the following child characteristics associated with HPV vaccination status: age (years), sex, race/ethnicity, insurance status (insured vs. uninsured). We categorized race/ethnicity as non-Hispanic white, non-Hispanic black, Hispanic, Asian, or other (including Native American, Alaskan, or some combination of the above).

We assessed the following mothers' characteristics via self-report: age, race/ethnicity, educational attainment, and confidence in adolescent vaccination (vaccination confidence). We assessed vaccination confidence using the brief four-item scale developed by Gilkey et al.²⁷ We averaged responses to the four items and defined high vaccination confidence as at or above the median score (median = 4.5, score range 1–5). A higher score on the vaccination confidence scale indicates greater belief in the efficacy and importance of adolescent vaccination in general. We also evaluated the following household characteristics: annual income and state of residence. We grouped states by US Census region (South, West, Midwest, and Northeast).

Statistical analyses

We used descriptive statistics to compare mothers' and children's demographic characteristics by mothers' HPV vaccination status. We assessed for significant univariate differences using Pearson's chi-square tests or univariate linear regression where appropriate.

We assessed the association between mothers' and child's HPV vaccination statuses using multivariable logistic regression. To build the separate multivariable logistic regression models for (1) adolescent HPV vaccination status, and (2) mothers' intent to vaccinate their unvaccinated children, we included sociodemographic variables associated with adolescent HPV vaccination based on prior literature, regardless of univariate significance, including child age and sex, mothers' race/ethnicity and educational attainment, and household income.^{4,28–31} We also included the following variables based on significant univariate association ($p < .10$) with adolescent vaccination status: child's insurance status, mothers' vaccination confidence, and US Census region of residence. Based on these criteria, we controlled for the following variables in the final models: child – age, sex, insurance status; mother – age, race/ethnicity, educational attainment, vaccination confidence; and household – annual income and US Census region. Due to collinearity with mothers' race/ethnicity, we did not include child's race/ethnicity in the final model. We did not have adequate sample sizes within individual states to control for intra-state variation. In a sensitivity analysis, we further restricted the study sample to women who were age-eligible to receive the HPV vaccine (i.e., <27 years old in 2006). Finally, to

assess for effect modification by the child's sex, we stratified our multivariable logistic regression models by child sex and compared the adjusted odds ratios. We then included an interaction term between child's sex and mothers' vaccination status to assess the extent of effect modification.

Disclosure of potential conflicts of interest

No potential conflicts of interest were disclosed.

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