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Drivers of HPV vaccine hesitancy in New York and Florida

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ABSTRACT

Background: This study aimed to identify drivers of HPV vaccine hesitancy and effective public health interventions to increase HPV vaccination rates in two U.S. states (New York and Florida) and 12 counties within each state. The findings provide insights into the impact of demographics, state policies, and vaccine confidence on HPV vaccination.

Methods: We utilized a mixed-method approach, integrating quantitative analysis of county-level surveys, qualitative interviews, and secondary data on HPV vaccine coverage. Surveys, adapted from the Vaccine Confidence Project (VCP) and the World Health Organization (WHO), assessed HPV vaccine confidence, socio-demographics, and behavioral determinants. Interviews explored barriers, interventions, and policies related to HPV vaccination.

Findings: Parents and providers have not prioritized HPV vaccination compared to other vaccines, with less concern about HPV than other vaccine-preventable diseases. Socio-demographic factors, such as race, age, gender, religion, employment, and income impacted children's vaccination status. Female parents aged 35–44 and those with a professional degree were more likely to vaccinate their children. Perceptions of the vaccine's importance and safety significantly influenced vaccination.

Interpretation: Identifying socio-demographic determinants and behavioral motivators can guide targeted interventions. Our study highlights complex factors influencing HPV vaccination at the state and county level, offering policymakers strategies to tailor interventions addressing barriers and hesitancy in areas with lower vaccination rates.

1. Introduction

Despite introducing the human papillomavirus (HPV) vaccine nearly 20 years ago, coverage has remained low in the United States, partly due to negative publicity, fear around the vaccine's safety, perceived connection to sexual activity, and public backlash against adolescent mandates [1–4]. HPV vaccination coverage has varied widely across U. S. regions, with adults in the U.S. South having higher odds of not completing the HPV vaccine series [5].

Research has shown that state-level socio-demographic characteristics and policies, such as religiosity, sex education policies, and HPV vaccine mandates, are associated with vaccination coverage [6]. Additionally, higher maternal education and enrollment in Medicaid have been associated with higher odds of vaccinating children for HPV [7,9].

In 2022, the Vaccine Confidence Project (VCP) conducted a study in the European Union (EU) examining the impact of socio-demographic characteristics on vaccine confidence, including HPV vaccination [10]. The VCP examined four measures of vaccine confidence for HPV, as well as for measles, mumps, and rubella (MMR), seasonal influenza, COVID-19, and vaccines in general: the belief in the importance, safety, effectiveness, and compatibility of vaccines. Among EU countries, they found religion, education level, and gender significantly impacted vaccine confidence for the HPV vaccine.

Variation in vaccine confidence and vaccine confidence across countries provides insight into the contextual factors that influence vaccine confidence determinants. Between 2015 and 2018, most EU countries saw an increase in confidence regarding the safety and importance of all vaccines [10]. In the most recent report from 2022,

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overall vaccine confidence declined since the pandemic began in 2020 [10]. Specifically, between 2020 and 2022, the importance and belief in the safety of the HPV vaccine were reported to decrease. Even with this decline, the average agreement of the four measures of vaccine confidence is around 75 % [10].

Due to their large and diverse populations, New York and Florida offer valuable insights into HPV vaccination trends and hesitancy in the United States. In 2016, New York had a higher proportion of vaccinated teens (70.1 %), while Florida had a lower proportion of vaccinated teens (55.1–60 %) [11]. A study in New York City found that over half of surveyed adolescents were interested in HPV vaccination across various demographic variables [12]. However, there is a lack of local-level data on parents' attitudes in either of these states [13]. Along with socio-demographic determinants, vaccine confidence is influenced by various complex factors, including the impact of COVID-19.

The study aims to identify key demographic drivers of HPV vaccination in the U.S. and qualitatively inquire immunization partners about interventions or policies that have most effectively improved HPV immunization within the selected U.S. states and counties.

2. Methods

2.1. Study design

A mixed-methods approach was employed to comprehensively examine HPV vaccination confidence, barriers, and potential interventions. We administered a county-level survey to assess HPV vaccine uptake, intent to vaccinate, and factors influencing parents' and caregivers' confidence in the vaccine within selected counties in New York and Florida. Additionally, the study team conducted key informant interviews (KII) with national, state, and local-level HPV vaccination partners to identify critical and successful programs, policies, or practices being used to improve HPV uptake and confidence.

2.2. Identification of sample sites

For state selection, we utilized National Immunization Survey-Teen data to calculate HPV vaccination rates between 2008 and 2020. States were categorized based on changes in vaccination coverage, and potential states were identified based on population size, county characteristics, and availability of HPV vaccination data at the county level. Appendix A and Table S1 in the supplementary materials outline the process that led us to the sample selection. The study team selected two states, New York (NY) and Florida (FL), for further investigation. Initially, four counties (two in each state) were selected for data collection, including Broward and Orange Counties in Florida and the Bronx and Kings Counties in New York. After expereincing low survey uptake, to increase our sample size, additional counties from New York and Florida were included in survey distribution based on initial inclusion criteria and proximity to the initial four counties surveyed (Broward, Orange, Bronx, and Kings counties), including Hillsborough, Miami-Dade, Palm Beach, and Pinellas in Florida, and Nassau, Queens, Suffolk, and Westchester in New York.

2.3. Quantitative

2.3.1. Instrument development

The study team, which included VCP team members, modified the 2022 VCP EU State of Vaccine Confidence survey questionnaire to focus on HPV, COVID-19, and parents/caregivers. Additionally, the survey included an adaptation of the United Nations Special Fund (UNSF) and World Health Organization (WHO) COVID-19 Behavioral and Social Drivers (BeSD) toolkit tailored to HPV [14]. Data were collected on parent/caregiver socio-demographic information, number of children, child characteristics, BeSD personal perceptions regarding HPV, BeSD of non-HPV vaccines, and political beliefs. The survey, Appendix D, is available in the supplementary materials.

2.3.2. Data collection

The survey included adults (18+) who were parents/caregivers of children 11–18 in the 12 selected counties, with a sample size goal of 650 respondents per county. The study team contracted ORB International to conduct the survey. The University of Washington (UW) and VCP teams approved the survey study, which was scripted into Qualtrics. ORB piloted the survey and monitored the metadata quality (i.e., removing respondents who flatlined or completed the survey too quickly/slowly).

We received 9137 surveys and 7409 eligible respondents. 1728 respondents were excluded because they did not reside in the counties selected for the study or selected "other," reported 'other/non-binary' as their gender, 'do not know' as their highest level of education, as these socio-demographic categorizations do not exist in the U.S. census microdata records, and/or did not finish the survey. Males. Sample sizes by county are presented in Table 1.

2.3.3. Data and survey weights

Weights were assigned to respondents based on the probability of selection and post-stratification to reflect the population totals from the U.S. census [15,16]. Ranked weights were obtained by matching the survey sample and U.S. population subset according to sex, age, highest level of education, race, Hispanic status, personal income, and whether the individual has healthcare coverage. Reweighting was done separately for each county.

2.3.4. Response variables

Respondents reported the number of children aged 11–18 and their vaccination status. Parents/caregivers were asked about their future HPV vaccination plans for children who had received fewer than two doses of the vaccine. Five parent/caregiver-level indicators summarized HPV vaccination status (Table S2 in supplementary materials). Two cohorts, 11+ and 13+, were created to compare HPV acceptance. The second dose of the HPV vaccine is administered at age 13. Dividing into two cohorts allows for a clearer view of trends in first and second dose uptake and summary of HPV vaccine acceptance at the level of parents and caregivers.

2.3.5. Exploratory variables

Parent/caregiver-level data were collected for socio-demographic characteristics: sex, age, highest level of education, race, whether the respondent was Hispanic, language other than English spoken at home, personal income, employment status, healthcare coverage, and religion. We then collected parent/caregiver-level data for each BeSD item [14,17]. Each of these exploratory factors is summarized in Table 2.

2.3.6. Regression analysis

We conducted a multilevel Bayesian multiple logistic regression for each response variable to identify the socio-demographic determinants associated with our outcome variable. This analysis served to highlight the socio-demographic factors associated with HPV acceptance and how these associations changed depending on the HPV schedule. Separate multilevel Bayesian multiple logistic regressions were performed, with random intercept and slope models, for each response variable to investigate the relationship between HPV status and BeSD items. All models were implemented using the rstanarm package in R [18]. Four chains were run with 2000 iterations for each model, with the first 1000 in each chain discarded for model burn-in, then assessed convergence using the Gelman-Rubin diagnostic, and all parameters across all models had $\widehat{R} < 1.02$ [19].

Table 1
Florida and New York sample size by county.

County (Florida)	Broward	Hillsborough	Miami-Dade	Orange	Palm Beach	Pinellas	Other counties
Respondents	718	747	744	905	552	522	909
County (New York)	**Bronx**	**Queens**	**Kings**	**Suffolk**	**Nassau**	**Westchester**	**Other counties**
Respondents	737	670	945	377	348	197	766

Table 2
Children's HPV vaccination summaries as reported by parents/caregivers.

Indicator	Definition	Rationale
All children zero-doses (11 plus)	All children of a parent/caregiver aged 11 or over have not received any HPV vaccine doses, and the parent/caregiver indicates low intent to vaccinate ('no, definitely not' or 'unsure, but leaning towards no') [see Table S2].	To account for that a child may not have been offered an HPV vaccine at age 11; future intent to vaccinate is also considered.
All children with one or more doses (11 plus)	All children of a parent/caregiver aged 11 or over have received at least one HPV vaccine dose, or the parent/caregiver indicates high intent to vaccinate if the child has no doses ('yes, definitely' or 'unsure, but leaning towards yes) [see Table S2].	
All children zero-doses (13 plus)	All children of a parent/caregiver aged 13 or over have not received any HPV vaccine doses	All children should have been offered an HPV vaccine at age 13, so future intent is not considered in forming the response indicator.
All children with one or more doses (13 plus)	All children of a parent/caregiver aged 13 or over have received at least one HPV vaccine dose	
All children with two or more doses (13 plus)	All children of a parent/caregiver aged 13 or over have received at least two HPV vaccine doses	

2.4. Qualitative

2.4.1. Instrument development

The interview guide focused on individuals engaged in HPV immunization efforts to complement survey data collection, identifying programs, policies, or practices that have most improved HPV vaccination rates, and key factors that contributed to the success or failure of specific interventions. The interview guide complements the survey using open-ended questions in three categories: experience and current roles related to HPV vaccination, interventions/barriers to HPV vaccination, and HPV vaccination policies. The interview guide (Appendix B) can be viewed in supplementary materials.

2.4.2. Recruitment

Recruitment involved selecting national and state-level individuals engaged in HPV immunization efforts for KIIs. Outreach was conducted via email to recruit potential informants identified through public health department websites, published research, news stories, and recommendations from interviewees. Potential participants were public health personnel with expertise in managing state and county immunization programs, medical providers vaccinating teens through the Vaccine for Children (VFC) Program, and other non-governmental organizations implementing interventions to increase immunization coverage for the HPV vaccine.

2.4.3. Interview sample

The study team conducted 13 qualitative interviews with key national ($n = 7$) and state ($n = 6$) representatives, including governmental agencies, national HPV associations, and higher education institutions. Trained research staff (KB) facilitated interviews via Zoom. Each interview lasted ~45 min. Participants received a $40 gift card incentive.

2.4.4. Coding and analysis

After each interview, research team members (KB, TM) reviewed and cleaned Zoom interview transcriptions. TM and KB coded the 13 transcripts using inductive and deductive coding. Codes were refined through iterative consensus-building to reach coder agreement and identify patterns and emerging themes. Study findings were organized by HPV vaccination barriers, vaccine hesitancy drivers, strategies/interventions, effectiveness, and policies.

2.4.5. Human participant compliance statement

The UW Human Subjects Division reviewed our study protocol and deemed it low risk for participants. Participants verbally consented to participate and to have conversations recorded using Zoom.

3. Results

3.1. Survey results

3.1.1. Quantitative insights

A total of 7409 eligible respondents participated in the study; 43.9 % were NY residents, and 56.1 % were FL residents. The respondents were comprised of 52 % females and 48.0 % males. Of the NY participants, 49.2 % were female, and 50.8 % were male; of the FL participants, 54.1 % were female, and 45.9 % were male. Complete socio-demographic details by state are in Table 3.

Table 4 presents the distribution of respondents' relationships (number and percentage) categorized by child gender and age group. Notably, as shown in Table 3, 33.3 % of respondents reported having two or more children aged 11+. The totals for each gender and age group reflect data corresponding to each child.

3.1.2. County-level trends in HPV acceptance

Figs. 1 and 2 show the weighted responses to each measure defined in Table 4. The percentage of parents for whom all their children aged 11–18 have not received a single HPV vaccination (or would not accept this vaccine for their child) and have all received at least one HPV dose is shown in Fig. 1. Among parents/caregivers of all children aged 11+ in Palm Beach County, FL, the highest percentage had zero-dose children (29.5 %), while Pinellas County, FL, had the lowest rate of zero-dose children, with fewer than 15 %. While in New York, Suffolk County had the highest peercentage of children with zero-doses at nearly 23 % and Westchester County had the lowest proportion of zero dose children (13.3 %) Additionally, Fig. 2 shows the percentage of parents for whom all their children aged 13–18 had not received any HPV vaccinations, had received at least one dose, and had received at least two doses. Of all children 13+, Palm Beach County, Fl, again had the highest percentage of zero-dose children (53.7 %), while Pinellas again had the lowest percentage of zero-dose children (31.1 %). In New York, Bronx County had the highest proportion of children aged 13+ who had not received any HPV vaccination, with nearly 50 % of parents/caregivers reporting

Table 3
Respondent socio-demographics by state.

	Florida (FL) (*N* = 4157)	New York (NY) (*N* = 3252)	Overall (*N* = 7409)
Age			
18–24	334 (8.0 %)	281 (8.6 %)	615 (8.3 %)
25–34	1259 (30.3 %)	812 (25.0 %)	2071 (28.0 %)
35–44	1550 (37.3 %)	1495 (46.0 %)	3045 (41.1 %)
45–54	805 (19.4 %)	519 (16.0 %)	1324 (17.9 %)
55–64	160 (3.8 %)	120 (3.7 %)	280 (3.8 %)
over 65	49 (1.2 %)	25 (0.8 %)	74 (1.0 %)
Sex			
Female	2248 (54.1 %)	1601 (49.2 %)	3849 (52.0 %)
Male	1909 (45.9 %)	1651 (50.8 %)	3560 (48.0 %)
Education level			
Elementary school or less	67 (1.6 %)	74 (2.3 %)	141 (1.9 %)
High school	1255 (30.2 %)	985 (30.3 %)	2240 (30.2 %)
At least some college/university	1639 (39.4 %)	1056 (32.5 %)	2695 (36.4 %)
Professional degree beyond Bachelor's	311 (7.5 %)	253 (7.8 %)	564 (7.6 %)
Master's or doctoral degree	885 (21.3 %)	884 (27.2 %)	1769 (23.9 %)
Employment status			
Employed (Full-time or Part-time)	3630 (87.3 %)	2805 (86.3 %)	6435 (86.9 %)
Not in the labor force	202 (4.9 %)	163 (5.0 %)	365 (4.9 %)
Unemployed	325 (7.8 %)	284 (8.7 %)	609 (8.2 %)
Religion			
Christian	2961 (71.2 %)	1936 (59.5 %)	4897 (66.1 %)
Muslim	148 (3.6 %)	465 (14.3 %)	613 (8.3 %)
Jewish	237 (5.7 %)	162 (5.0 %)	399 (5.4 %)
Buddhist	78 (1.9 %)	51 (1.6 %)	129 (1.7 %)
Hindu	42 (1.0 %)	33 (1.0 %)	75 (1.0 %)
Atheist or Agnostic	222 (5.3 %)	187 (5.8 %)	409 (5.5 %)
Other	469 (11.3 %)	418 (12.9 %)	887 (12.0 %)
Race			
White	2761 (66.4 %)	1967 (60.5 %)	4728 (63.8 %)
Black/African American	777 (18.7 %)	772 (23.7 %)	1549 (20.9 %)
American Indian or Alaska Native	160 (3.8 %)	46 (1.4 %)	206 (2.8 %)
Chinese	12 (0.3 %)	51 (1.6 %)	63 (0.9 %)
Japanese	7 (0.2 %)	11 (0.3 %)	18 (0.2 %)
Other Asian or Pacific Islander	47 (1.1 %)	69 (2.1 %)	116 (1.6 %)
2 or more races	240 (5.8 %)	173 (5.3 %)	413 (5.6 %)
Other	153 (3.7 %)	163 (5.0 %)	316 (4.3 %)
Hispanic, Latino, or of Spanish origin			
No	3080 (74.1 %)	2455 (75.5 %)	5535 (74.7 %)
Yes, Hispanic, Latino, or of Spanish origin	1077 (25.9 %)	797 (24.5 %)	1874 (25.3 %)
Birthplace			
In the United States	3706 (89.2 %)	2963 (91.1 %)	6669 (90.0 %)
Outside of the United States	451 (10.8 %)	289 (8.9 %)	740 (10.0 %)
Language spoken at home			
English	2232 (53.7 %)	1840 (56.6 %)	4072 (55.0 %)
Other than English	1925 (46.3 %)	1412 (43.4 %)	3337 (45.0 %)
Total personal income (last 12 months)			
Under $15,000	281 (6.8 %)	266 (8.2 %)	547 (7.4 %)
$15,000 to $34,999	660 (15.9 %)	482 (14.8 %)	1142 (15.4 %)
$35,000 to $74,999	1055 (25.4 %)	816 (25.1 %)	1871 (25.3 %)
$75,000 to $149,000	1687 (40.6 %)	1196 (36.8 %)	2883 (38.9 %)
$150,000 or over	474 (11.4 %)	492 (15.1 %)	966 (13.0 %)
Healthcare coverage from any source			
Yes, has healthcare coverage	3864 (93.0 %)	3117 (95.8 %)	6981 (94.2 %)
No, does not have healthcare coverage	293 (7.0 %)	135 (4.2 %)	428 (5.8 %)
Number of children between age 11 and 18			
1	2895 (69.6 %)	2049 (63.0 %)	4944 (66.7 %)
2	1021 (24.6 %)	961 (29.6 %)	1982 (26.8 %)
3 or more	241 (5.8 %)	242 (7.4 %)	483 (6.5 %)

that their children had not received any HPV vaccination. Westchester County reported the lowest percentage of zero-dose children, at just over 30 %. Overall, among the parents/caregivers surveyed, there is variation across counties within the state; however, New York consistently has lower rates of zero-dose children.

3.1.3. BeSD results

County-level trends in BeSD survey responses are detailed in Appendix C, with visualizations presented in Figs. S1 and S2 in the supplementary materials.

Adjusted odds ratios between BeSD and HPV vaccination status are presented in Table 5. Bold values indicate statistically significant results. Several BeSD factors are significant determinants of HPV vaccination status. The perception that the HPV vaccine is essential and safe is associated with improved HPV vaccination outcomes across all five models. Parents/caregivers reporting that the HPV vaccine was very important and safe were far less likely to have all children without a single dose and more likely to have all their children vaccinated with at least two doses. A higher perception of the risk of contracting HPV was also associated with better HPV vaccination status outcomes. Parents who self-identified in the survey as concerned were less likely to have zero-dose children and more likely to have all their children vaccinated with two or more doses.

A healthcare worker's recommendation consistently predicted improved HPV vaccination status. Being contacted about a child being due for the HPV vaccine was also linked to enhanced vaccination outcomes in the 13–18 age group. Additionally, knowing where to get HPV vaccines and having them available at school predicted improved HPV vaccination status in this age group. Being satisfied with HPV vaccination services was consistently associated with better HPV vaccination status outcomes across all models, with parents who were very satisfied with these services having significantly improved odds of achieving better vaccination outcomes for their children. Social support played a key role in determining children's HPV vaccination status. Individuals who believed that their close friends and family, community leaders, and most adults they knew wanted them to get the HPV vaccine for their child were more likely to have all their children aged 11–18 receive at least one HPV vaccination.

Four BeSD factors showed weaker/no correlation with children's vaccination status: financial difficulty, needing permission for HPV vaccination, trusting healthcare workers giving the HPV vaccine, and being turned away from HPV vaccination.

Table 4
Respondent relationship by child gender and age group.

	Female		Male		Other/Non-Binary		Overall	
	11–15 (*N* = 3476)	16–18 (*N* = 968)	11–15 (*N* = 4757)	16–18 *N* = 1311)	11–15 (*N* = 38)	16–18 (*N* = 25)	11–15 (*N* = 8271)	16–18 (*N* = 2304)
Relationship								
Mother	1986 (57.1 %)	578 (59.7 %)	1863 (39.2 %)	620 (47.3 %)	13 (34.2 %)	11 (44.0 %)	3862 (46.7 %)	1209 (52.5 %)
Father	1172 (33.7 %)	274 (28.3 %)	2568 (54.0 %)	601 (45.8 %)	6 (15.8 %)	5 (20.0 %)	3746 (45.3 %)	880 (38.2 %)
Uncle or aunt	98 (2.8 %)	22 (2.3 %)	104 (2.2 %)	17 (1.3 %)	5 (13.2 %)	3 (12.0 %)	207 (2.5 %)	42 (1.8 %)
Grandparent	75 (2.2 %)	30 (3.1 %)	69 (1.5 %)	23 (1.8 %)	3 (7.9 %)	2 (8.0 %)	147 (1.8 %)	55 (2.4 %)
Brother or sister	119 (3.4 %)	51 (5.3 %)	107 (2.2 %)	32 (2.4 %)	6 (15.8 %)	3 (12.0 %)	232 (2.8 %)	86 (3.7 %)
Other	26 (0.7 %)	13 (1.3 %)	46 (1.0 %)	18 (1.4 %)	5 (13.2 %)	1 (4.0 %)	77 (0.9 %)	32 (1.4 %)

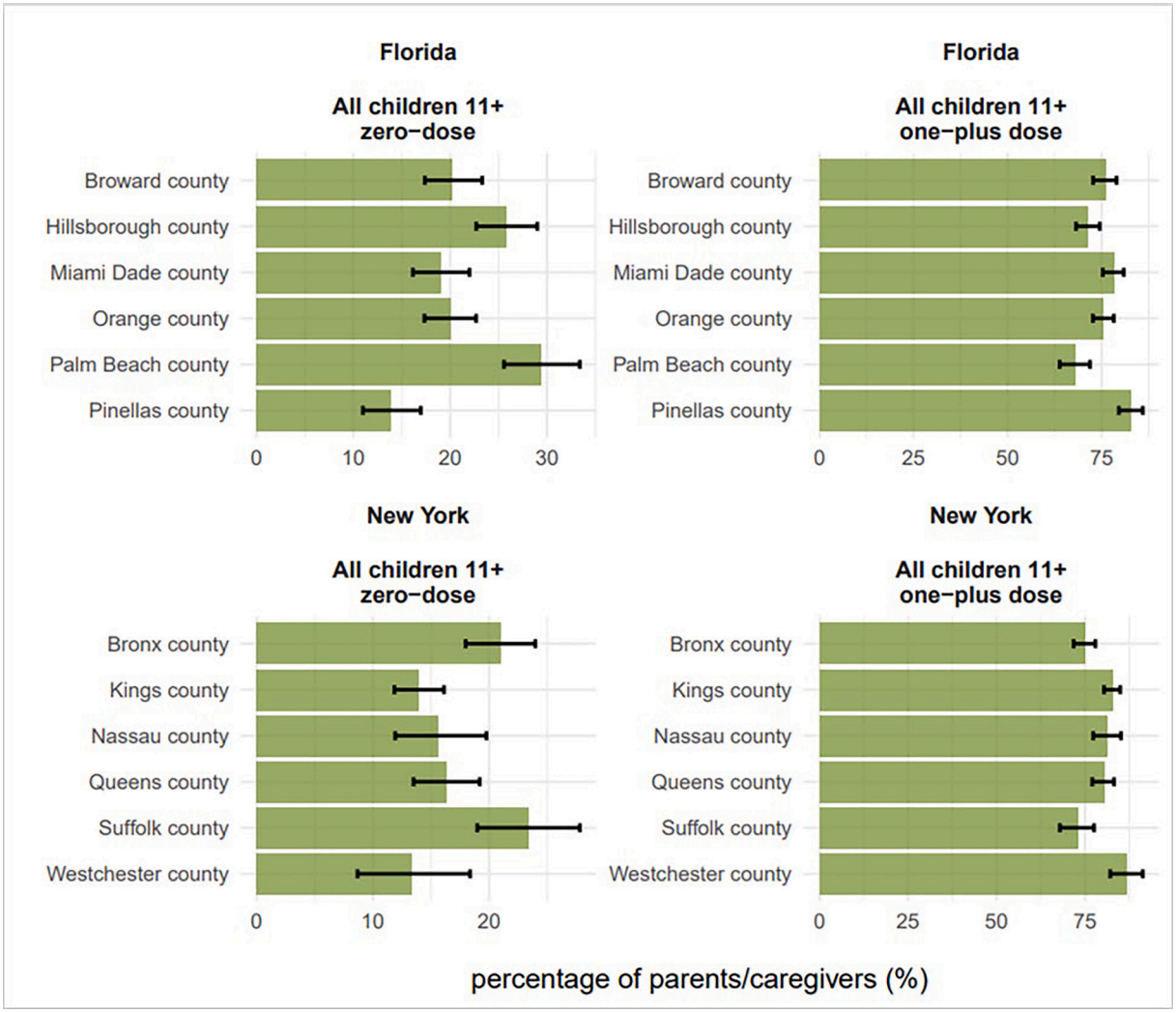

Fig. 1. Summary of HPV vaccination status of children aged 11 and over as reported by parents/caregivers.
Authors Note: Bars denote the percentage of parents/caregivers for whom all their children have not received a single HPV vaccination (left column) and for whom all their children have received at least one HPV vaccination. Black bars denote a 95 % bootstrapped confidence interval. Percentages are calculated using raked weights.

3.1.4. Socio-demographic determinants

Adjusted odds ratios for the fixed-effect parameters in each multilevel logistic regression are reported in Table 6 with associated 95 % credible intervals. Bold values indicate statistically significant results. Specific socio-demographic determinants, including age, income, and employment status, exhibited consistent trends across models. The respondent's sex consistently showed associations when predicting HPV vaccination status among children aged 13 and over. Female parents were more likely to have children aged 13 and over vaccinated compared to male parents. Compared to respondents aged 35–44, parents or caregivers aged 18–24 and 25–34 were more likely to vaccinate their children against HPV, while those aged 45–54, 55–64, and over 65 were less likely, with a higher proportion reporting that none of their children had received the vaccine.

The study suggests that parents' or caregivers' education level has limited predictive value for determining whether children aged 11 or older have received at least one HPV dose. A parent or caregiver's education level does not show significant variation for children with no

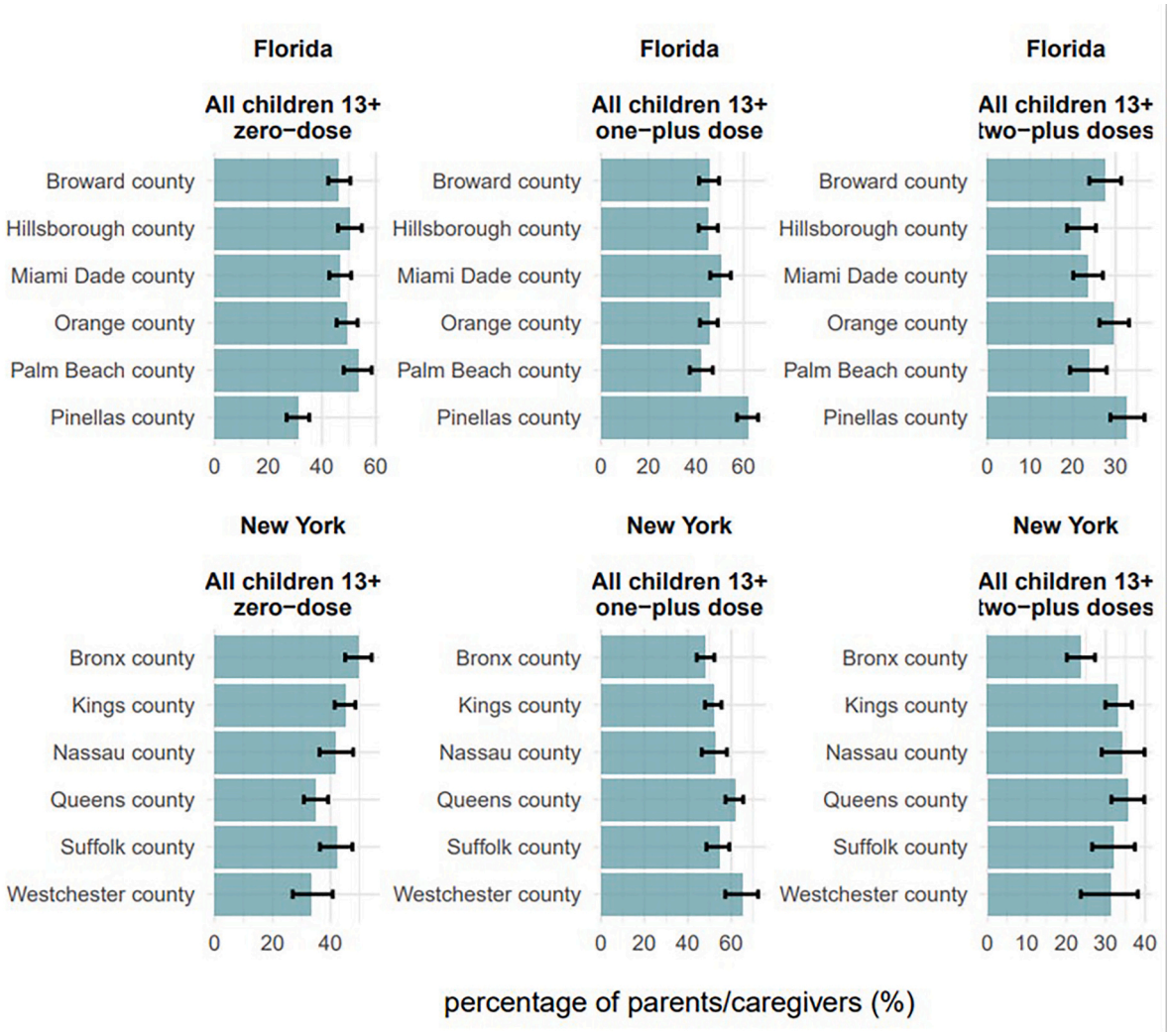

Fig. 2. Summary of HPV vaccination status of children aged 13 and over reported by parents/caregivers.
Authors Note: Bars denote the percentage of parents/caregivers for whom all their children have not received a single HPV vaccination (left column), all their children have received at least one HPV vaccination (center column), and all children have received at least two doses of an HPV vaccine (right column). Black bars denote a 95 % bootstrapped confidence interval. Percentages are calculated using ranked weights.

dose.

White respondents were more likely to have children aged 13 or over vaccinated with at least one HPV dose than parents/caregivers who are Black or African American, American Indian or Alaska Native, and 'some other race alone.' However, for children aged 11 and over, American Indian or Alaska Native respondents were less likely to have zero-dose children than White respondents. Hispanic parents or caregivers did not show a significant difference compared to non-Hispanic parents/caregivers. Non-English speaking households were more likely to have children with at least one HPV dose and less likely to have children without any HPV vaccine than English speaking households.

Compared to Christian respondents, atheist or agnostic and Muslim respondents were more likely to have children aged 11 and over with at least one HPV vaccine, while those indicating 'other religion' were less likely to have children vaccinated. Jewish or Buddhist responses were not statistically significant.

The study found that income significantly influenced vaccination rates. Compared to respondents who earn less than $35,000, parents/caregivers earning over $75,000 were more likely to have vaccinated children. Employment status also played a role, with parents who are employed or report being 'not in the labor force' consistently more likely to have vaccinated their children than those who are unemployed.

3.1.5. Vaccine confidence measures

The Vaccine Confidence Index (VCI) comprises several questions relating to individuals' vaccine confidence. These VCI scores – on the importance, safety, effectiveness, and compatibility of beliefs, varied across the four measures within different counties and states. In general, NY averaged higher for all four VCI measures: importance, safety, effectiveness, and compatibility with beliefs, 72.7 %, 75.8 %, 71.8 %, and 67.4 %, respectively, compared to FL, 69.5 %, 74.5 %, 69.5 %, and 65.9 %. For both states, parents had the most confidence in safety and the least in compatibility with their beliefs, a finding consistent across all twelve counties.

The ranges in VCI scores across the twelve counties surveyed in FL and NY displayed significant geographic variability. In the U.S. counties (FL and NY), the most consistent VCI measure with the highest score was confidence in the safety of HPV vaccines. Generally, the highest levels range from 82.8 % - 84.9 % (Westchester County, NY, and Pinellas County, FL), and the lowest range from 62.4 % - 71.6 % (Palm Beach County, FL, and Hillsborough County, FL).

Table 5
Adjusted odds ratios for the fixed-effect terms in the five multilevel logistic regression models on BeSD determinants of HPV vaccination among children.

		children aged 11 and over		children aged 13 and over		
		all children zero-dose	all children one + dose	all children zero-dose	all children one + dose	all children two + doses
		adjusted odds ratio (95 % credible interval)				
concerned about children contracting HPV (baseline: not at all)	somewhat	**0.97 (0.95, 1.00)**	**1.03 (1.01, 1.06)**	**1.04 (1.00, 1.09)**	**0.95 (0.90, 0.99)**	0.95 (0.91, 1.00)
	moderately	**0.95 (0.93, 0.97)**	**1.07 (1.04, 1.10)**	1.04 (0.99, 1.08)	**0.95 (0.90, 0.99)**	**0.94 (0.90, 0.99)**
	very	**0.96 (0.94, 0.98)**	**1.05 (1.02, 1.08)**	**1.06 (1.02, 1.11)**	**0.93 (0.89, 0.98)**	**0.93 (0.89, 0.98)**
	do not know/ nr	**0.93 (0.89, 0.97)**	**1.07 (1.02, 1.12)**	0.99 (0.91, 1.07)	0.98 (0.90, 1.06)	1.02 (0.94, 1.12)
HPV vaccine important for child's health (baseline: not at all)	somewhat	**0.79 (0.76, 0.82)**	**1.27 (1.23, 1.32)**	**0.90 (0.84, 0.96)**	**1.10 (1.02, 1.18)**	1.06 (0.99, 1.14)
	moderately	**0.78 (0.75, 0.81)**	**1.30 (1.25, 1.35)**	**0.91 (0.85, 0.97)**	**1.10 (1.03, 1.18)**	1.07 (0.99, 1.15)
	very	**0.76 (0.73, 0.78)**	**1.37 (1.32, 1.42)**	**0.85 (0.80, 0.91)**	**1.18 (1.11, 1.27)**	**1.13 (1.05, 1.21)**
	do not know/ nr	1.01 (0.96, 1.06)	1.00 (0.96, 1.05)	1.03 (0.95, 1.12)	1.02 (0.93, 1.11)	1.04 (0.95, 1.14)
HPV vaccine safe for child (baseline: not at all)	somewhat	**0.83 (0.80, 0.87)**	**1.16 (1.11, 1.20)**	**0.91 (0.85, 0.98)**	**1.10 (1.03, 1.18)**	1.03 (0.96, 1.11)
	moderately	**0.81 (0.78, 0.84)**	**1.20 (1.15, 1.25)**	**0.89 (0.83, 0.96)**	**1.13 (1.06, 1.22)**	**1.07 (1.00, 1.16)**
	very	**0.80 (0.77, 0.83)**	**1.23 (1.18, 1.28)**	**0.86 (0.80, 0.92)**	**1.19 (1.11, 1.29)**	**1.17 (1.08, 1.27)**
	do not know/ nr	**0.88 (0.84, 0.92)**	**1.10 (1.05, 1.16)**	0.96 (0.89, 1.05)	1.04 (0.96, 1.13)	0.97 (0.89, 1.07)
trust healthcare workers who give HPV vaccine (baseline: not at all)	somewhat	0.99 (0.96, 1.03)	1.02 (0.98, 1.07)	1.04 (0.97, 1.11)	0.94 (0.87, 1.01)	0.95 (0.88, 1.02)
	moderately	0.99 (0.95, 1.02)	**1.05 (1.01, 1.09)**	1.02 (0.95, 1.09)	0.96 (0.90, 1.04)	0.98 (0.90, 1.05)
	very	0.98 (0.94, 1.01)	**1.05 (1.01, 1.10)**	1.01 (0.94, 1.08)	0.97 (0.90, 1.05)	0.96 (0.89, 1.04)
	do not know/ nr	0.99 (0.94, 1.04)	1.02 (0.97, 1.08)	0.98 (0.90, 1.08)	0.99 (0.90, 1.09)	0.98 (0.88, 1.08)
think most adults you know will get HPV vaccine for their children (baseline: no)	yes	**0.97 (0.95, 0.99)**	**1.04 (1.02, 1.06)**	**0.89 (0.86, 0.93)**	**1.11 (1.07, 1.16)**	**1.06 (1.02, 1.10)**
	do not know/ nr	0.99 (0.97, 1.02)	1.01 (0.98, 1.04)	0.96 (0.91, 1.01)	1.03 (0.98, 1.09)	**1.07 (1.02, 1.13)**
think most work colleagues would get HPV vaccine for their children (baseline: no)	yes	**0.97 (0.95, 0.99)**	**1.03 (1.01, 1.05)**	0.99 (0.95, 1.02)	1.03 (0.98, 1.07)	1.00 (0.96, 1.05)
	do not know/ nr	1.00 (0.97, 1.02)	1.00 (0.97, 1.02)	0.98 (0.93, 1.03)	1.03 (0.98, 1.08)	1.01 (0.96, 1.07)
think close friends & family want you to get HPV vaccine for your child (baseline: no)	yes	**0.94 (0.92, 0.96)**	**1.06 (1.04, 1.08)**	0.94 (0.90, 0.97)	**1.07 (1.03, 1.12)**	1.02 (0.98, 1.06)
	do not know/ nr	**0.96 (0.94, 0.99)**	**1.05 (1.02, 1.08)**	1.02 (0.97, 1.07)	0.99 (0.94, 1.03)	0.96 (0.91, 1.01)
think your religious leaders want you to get HPV vaccine for your child (baseline: no)	yes	**0.99 (0.97, 1.00)**	1.01 (0.99, 1.03)	**1.03 (1.00, 1.07)**	0.97 (0.94, 1.01)	0.99 (0.95, 1.03)
	do not know/ nr	1.00 (0.98, 1.03)	1.00 (0.98, 1.03)	1.01 (0.97, 1.06)	0.99 (0.95, 1.04)	1.00 (0.95, 1.05)
think your community leaders want you to get HPV vaccine for your child (baseline: no)	yes	**0.99 (0.97, 1.00)**	**1.02 (1.00, 1.04)**	**1.04 (1.00, 1.07)**	0.98 (0.95, 1.02)	1.00 (0.96, 1.04)
	do not know/ nr	0.98 (0.96, 1.01)	**1.03 (1.00, 1.05)**	0.98 (0.93, 1.02)	1.02 (0.97, 1.06)	1.04 (0.99, 1.09)
healthcare worker recommended your child receive HPV vaccine (baseline: no)	yes	**0.96 (0.94, 0.97)**	**1.04 (1.02, 1.06)**	**0.90 (0.87, 0.93)**	**1.10 (1.07, 1.14)**	**1.07 (1.04, 1.11)**
	do not know/ nr	1.00 (0.97, 1.03)	1.01 (0.98, 1.04)	0.96 (0.91, 1.01)	**1.05 (1.00, 1.11)**	1.02 (0.96, 1.08)

(*continued on next page*)

Table 5 (*continued*)

		children aged 11 and over		children aged 13 and over		
		all children zero-dose	all children one + dose	all children zero-dose	all children one + dose	all children two + doses
		adjusted odds ratio (95 % credible interval)				
ever contacted about child being due for HPV vaccine (baseline: no)	yes	1.00 (0.98, 1.02)	1.00 (0.98, 1.02)	**0.92 (0.89, 0.95)**	**1.08 (1.05, 1.12)**	**1.03 (1.00, 1.07)**
	do not know/ nr	0.99 (0.96, 1.02)	1.02 (0.99, 1.05)	1.00 (0.95, 1.06)	1.01 (0.95, 1.07)	1.00 (0.94, 1.06)
need permission to get HPV vaccine for your child (baseline: no)	yes	0.99 (0.98, 1.01)	1.01 (0.99, 1.03)	1.01 (0.98, 1.05)	0.99 (0.96, 1.02)	1.00 (0.97, 1.03)
	do not know/ nr	**1.03 (1.01, 1.06)**	**0.96 (0.93, 0.99)**	1.01 (0.96, 1.06)	1.00 (0.95, 1.06)	1.00 (0.95, 1.06)
know where to get HPV vaccine (baseline: no)	yes	1.00 (0.99, 1.02)	1.00 (0.98, 1.02)	**0.94 (0.91, 0.97)**	**1.05 (1.02, 1.09)**	**1.05 (1.02, 1.09)**
	do not know/ nr	1.00 (0.96, 1.03)	0.97 (0.93, 1.01)	0.99 (0.93, 1.06)	0.96 (0.90, 1.03)	0.98 (0.92, 1.05)
HPV vaccines available for child at school (baseline: no)	yes	1.00 (0.98, 1.02)	1.00 (0.98, 1.02)	**0.95 (0.91, 0.99)**	**1.06 (1.02, 1.10)**	**1.05 (1.01, 1.08)**
	do not know/ nr	1.01 (0.99, 1.03)	1.00 (0.98, 1.02)	1.00 (0.97, 1.04)	1.00 (0.96, 1.04)	1.00 (0.96, 1.04)
easy to access HPV vaccine services for your child (baseline: not at all)	somewhat	**1.10 (1.05, 1.14)**	**0.94 (0.90, 0.99)**	1.06 (0.98, 1.15)	0.99 (0.91, 1.08)	1.00 (0.92, 1.09)
	moderately	**1.07 (1.03, 1.11)**	0.96 (0.92, 1.01)	1.01 (0.93, 1.09)	1.05 (0.96, 1.13)	0.99 (0.91, 1.08)
	very	**1.09 (1.05, 1.14)**	**0.94 (0.90, 0.99)**	1.01 (0.93, 1.09)	1.05 (0.97, 1.14)	1.03 (0.95, 1.12)
	do not know/ nr	**1.10 (1.04, 1.15)**	**0.94 (0.89, 0.99)**	1.07 (0.97, 1.17)	0.96 (0.87, 1.06)	0.98 (0.88, 1.08)
incur financial difficulty in getting HPV vaccine for your child (baseline: no)	yes	0.99 (0.97, 1.01)	1.01 (0.99, 1.03)	0.98 (0.94, 1.01)	1.03 (0.99, 1.06)	1.02 (0.98, 1.06)
	do not know/ nr	1.01 (0.98, 1.04)	1.00 (0.97, 1.03)	0.99 (0.94, 1.04)	1.03 (0.98, 1.08)	1.01 (0.96, 1.06)
satisfied with HPV vaccination services (baseline: not at all)	somewhat	**0.92 (0.89, 0.96)**	**1.08 (1.03, 1.13)**	0.96 (0.89, 1.03)	1.03 (0.95, 1.11)	1.04 (0.96, 1.13)
	moderately	**0.92 (0.88, 0.96)**	**1.09 (1.04, 1.14)**	**0.87 (0.81, 0.93)**	**1.12 (1.04, 1.21)**	**1.10 (1.01, 1.19)**
	very	**0.90 (0.87, 0.94)**	**1.10 (1.06, 1.15)**	**0.84 (0.78, 0.90)**	**1.14 (1.06, 1.23)**	**1.13 (1.04, 1.22)**
	do not know/ nr	**1.06 (1.01, 1.10)**	0.96 (0.92, 1.01)	**1.09 (1.00, 1.17)**	0.94 (0.86, 1.02)	0.98 (0.89, 1.07)
ever turned away from HPV vaccination (baseline: no)	yes	0.99 (0.97, 1.01)	1.01 (0.99, 1.03)	0.99 (0.95, 1.02)	1.01 (0.97, 1.05)	0.99 (0.95, 1.03)
	do not know/ nr	**1.05 (1.02, 1.08)**	**0.95 (0.92, 0.98)**	**1.07 (1.01, 1.13)**	**0.94 (0.89, 0.99)**	**0.94 (0.88, 0.99)**

3.2. Qualitative results

3.2.1. Barriers to HPV vaccination

3.2.1.1. Access to care and HPV vaccination. Respondents highlighted barriers to HPV vaccination, including access to care/HPV vaccine, individual-level social determinants of health (SDOH), and structural barriers. SDOHs are nonmedical factors influencing health outcomes [20], such as work conflicts, scheduling, transportation, inadequate health insurance, and economic instability, which were significant parental barriers. These challenges often impact rural and underserved communities, making it difficult for parents to prioritize prevention and keep up with recommended vaccinations. One participant shared:

"Rural communities have a lot of barriers, and they're related to social determinants of health…poverty makes prevention not a priority."

With competing priorities, families may overlook preventative care, especially when access is challenging. One participant stated: *"[Y]ou could do education all day, but if you don't make it easy for people to get vaccinated, then it…becomes a challenge."*

3.2.1.2. Lack of knowledge and parental resistance around the vaccine. Participants highlighted inadequate HPV knowledge among both providers and parents as a significant barrier. Changing recommendations have made it difficult for them to stay informed, resulting in an insufficient understanding of HPV guidelines among providers, which in turn delays vaccine introduction. One participant remarked, "One of the biggest barriers is just knowledge deficits and misinformation, not only among the public but among providers."

Parents often receive HPV information from their child's provider or media. When providers lack current knowledge, it contributes to

Table 6
Adjusted odds ratios for the fixed-effect terms in the five multilevel logistic regression models on socio-demographic determinants of HPV vaccination among children.

		children aged 11 and over		children aged 13 and over		
		all children zero-dose	all children one + dose	all children zero-dose	all children one + dose	all children two + doses
		adjusted odds ratios (95 % credible interval)				
SEX	male (baseline)	–	–	–	–	–
	female	1.10 (0.91, 1.33)	0.90 (0.75, 1.08)	**0.79 (0.67, 0.93)**	**1.26 (1.07, 1.51)**	**1.38 (1.10, 1.75)**
	35–44 (baseline)	–	–	–	–	–
	18–24	**0.59 (0.43, 0.84)**	1.10 (0.82, 1.47)	0.77 (0.55, 1.05)	0.97 (0.70, 1.34)	0.99 (0.72, 1.34)
	25–34	**0.63 (0.50, 0.79)**	**1.49 (1.19, 1.86)**	**0.81 (0.66, 0.99)**	**1.26 (1.04, 1.55)**	1.18 (0.95, 1.48)
	45–54	**1.48 (1.16, 1.89)**	**0.68 (0.55, 0.84)**	**1.43 (1.17, 1.75)**	**0.72 (0.59, 0.90)**	0.84 (0.68, 1.04)
	55–64	**1.91 (1.33, 2.78)**	**0.53 (0.37, 0.75)**	**1.61 (1.17, 2.24)**	**0.69 (0.49, 0.97)**	**0.61 (0.42, 0.88)**
AGE	over 65	**2.12 (1.14, 3.86)**	**0.46 (0.26, 0.87)**	**2.60 (1.43, 4.85)**	**0.49 (0.26, 0.91)**	0.71 (0.38, 1.31)
	elementary school or less (baseline)	–	–	–	–	–
	high school	1.30 (0.77, 2.29)	**1.54 (1.01, 2.33)**	1.37 (0.81, 2.24)	0.95 (0.57, 1.59)	1.21 (0.68, 2.16)
	at least some college/university	1.01 (0.59, 1.78)	**1.92 (1.21, 3.01)**	1.15 (0.68, 1.91)	1.18 (0.72, 1.96)	1.40 (0.80, 2.52)
	Master's or doctoral degree	0.59 (0.33, 1.09)	**2.72 (1.67, 4.39)**	1.03 (0.60, 1.74)	1.18 (0.71, 2.02)	1.46 (0.82, 2.59)
EDU	professional degree beyond Bachelor's	0.81 (0.43, 1.56)	**2.01 (1.20, 3.36)**	1.12 (0.63, 1.93)	1.11 (0.65, 1.96)	**1.83 (1.02, 3.37)**
	White (baseline)	–	–	–	–	–
	Black or African American alone	1.29 (0.98, 1.67)	**0.68 (0.53, 0.88)**	**1.55 (1.21, 1.95)**	**0.62 (0.48, 0.80)**	0.79 (0.62, 1.02)
	American Indian or Alaska Native alone	**0.49 (0.22, 1.00)**	1.18 (0.65, 2.12)	1.80 (0.92, 3.34)	**0.47 (0.25, 0.88)**	0.79 (0.42, 1.50)
	some other race alone	**1.82 (1.30, 2.51)**	**0.54 (0.39, 0.75)**	**2.32 (1.57, 3.46)**	**0.51 (0.34, 0.75)**	**0.66 (0.44, 0.98)**
RAC	Two or more races	1.42 (0.98, 2.00)	**0.69 (0.49, 0.99)**	1.18 (0.86, 1.61)	0.74 (0.53, 1.01)	0.79 (0.55, 1.10)
	Not Hispanic (baseline)	–	–	–	–	–
HIS	Hispanic	0.92 (0.69, 1.24)	0.99 (0.77, 1.30)	1.15 (0.87, 1.50)	0.84 (0.64, 1.10)	1.04 (0.82, 1.33)
	speaks English at home (baseline)	–	–	–	–	–
LAN	speaks language other than English at home	**0.63 (0.48, 0.83)**	**1.47 (1.17, 1.85)**	**0.62 (0.46, 0.82)**	**1.50 (1.13, 1.99)**	1.00 (0.80, 1.24)
	less than $35,000 (baseline)	–	–	–	–	–
	$35,000 to $74,999	0.85 (0.64, 1.12)	1.07 (0.84, 1.37)	0.89 (0.66, 1.20)	1.15 (0.88, 1.53)	1.08 (0.83, 1.41)
INC	over $75,000	**0.60 (0.45, 0.78)**	**1.58 (1.23, 2.04)**	**0.57 (0.42, 0.77)**	**1.71 (1.27, 2.27)**	**1.53 (1.18, 2.00)**
	unemployed (baseline)	–	–	–	–	–
	not in labor force	**0.56 (0.38, 0.82)**	**1.54 (1.10, 2.18)**	0.68 (0.44, 1.03)	1.39 (0.92, 2.11)	**1.67 (1.13, 2.47)**
EMP	employed (full- or part-time)	**0.60 (0.46, 0.77)**	**1.68 (1.32, 2.16)**	**0.63 (0.47, 0.86)**	**1.55 (1.16, 2.06)**	**1.35 (1.00, 1.83)**
	has healthcare coverage (baseline)	–	–	–	–	–
HCO	no healthcare coverage	**2.00 (1.47, 2.66)**	**0.46 (0.35, 0.61)**	2.91 (2.05, 4.18)	**0.35 (0.25, 0.49)**	**0.46 (0.31, 0.65)**
	Christian (baseline)	–	–	–	–	–
	atheist or agnostic	**0.64 (0.42, 0.94)**	**1.43 (1.00, 2.04)**	**0.61 (0.43, 0.83)**	1.24 (0.89, 1.72)	1.00 (0.73, 1.38)
	Buddhist	0.61 (0.26, 1.29)	1.17 (0.63, 2.31)	0.63 (0.34, 1.13)	1.45 (0.82, 2.52)	1.26 (0.75, 2.06)
	Jewish	1.18 (0.76, 1.79)	0.81 (0.55, 1.20)	1.13 (0.73, 1.71)	0.73 (0.47, 1.12)	0.76 (0.50, 1.12)
	Muslim	**0.59 (0.38, 0.90)**	**1.51 (1.03, 2.27)**	0.74 (0.48, 1.15)	1.14 (0.68, 1.86)	0.94 (0.59, 1.46)
REL	other religion	1.49 (1.17, 1.90)	**0.63 (0.50, 0.79)**	1.23 (0.94, 1.60)	**0.73 (0.56, 0.94)**	0.83 (0.63, 1.10)

parental confusion. Providers are crucial in educating parents and countering misinformation, so it's important to address their obstacles, such as religious beliefs, time constraints, reimbursement issues, and knowledge gaps.

Furthermore, parental resistance to the vaccine persists. Parents depend on clear recommendations and education from providers. Changes in recommendations since the vaccine's launch in 2006, along with outdated information from providers, have fueled this resistance. A participant noted, "Parents come in with hesitancy and concern; for some…they need clarification, more information, and reassurance." To overcome parental hesitancy, providers must stay updated on HPV messaging and recommendations.

3.2.1.3. Not seen as a priority compared to other vaccines. Participants discussed the lack of prioritization for the HPV vaccine compared to other routine vaccines, noting that required or seasonal vaccines, such as MMR, influenza, RSV, or Hep B, often take precedence over the "optional" HPV series. Interviewees suggested factors like time, reimbursement rates, and religious beliefs could influence providers' motivation for discussing HPV with parents. One participant described their perception of the issue:

"There are still providers who do not value the HPV vaccine as they do other vaccines. They don't want to get into conversations with parents about HPV because they anticipate resistance…Providers remain a barrier to HPV vaccination."

Recent HPV recommendations are now being expanded to include gender-neutral guidelines. Healthcare providers play a crucial role in prioritization, but the final decision ultimately lies with the parents. One participant shared:

"The lack of prioritization around this vaccine for conservative parents who don't think that HPV is an important disease to protect against is one issue…not prioritizing younger age 9 and… not prioritizing boys is another."

3.2.2. HPV vaccine hesitancy drivers

3.2.2.1. Misinformation. Participants emphasized the increasing prevalence of misinformation, particularly regarding vaccine safety. This pressures healthcare providers to stay updated and address parental concerns/hesitancies. One interviewee shared:

"I think it's a hesitant parent…Stories pop up every so often about fertility…safety concerns are probably one of the biggest contributors to hesitancy."

Participants discussed the challenges of addressing HPV misinformation, noting misconceptions about its transmission through sexual intercourse. Myths and misinformation falsely link HPV to increased promiscuity in girls and the belief that it encourages girls to have sex or leads to early puberty. This tends to be more prevalent among conservative and religious parents, especially in rural, conservative, and religious communities. One participant noted that "*parents are not willing to have this discussion because they're not willing to even think about how you contract it."*

3.2.2.2. Political and religious reasons. Participants discussed increased polarization and politicization of vaccines and their influence as drivers of vaccine hesitancy. Interviewees shared that parents can be hesitant because they "*believe [their] trusted messenger… It's there, political family, it's their religious family,"* which can outpace the work being done by HPV vaccination providers or researchers. Specific populations have been more impacted by vaccine polarization. As politics becomes more intertwined with medical issues, some parents feel pressured to adhere to their party's stance. A participant stated:

"Most people are…getting caught up within the political lines [and]… some of the religious practices and beliefs… they prefer to listen to what the climate is saying versus what research has shown us."

Interviewees discussed religious hesitancy and pockets of religious groups that are very vaccine-hesitant, especially regarding HPV due to its link to sexual intercourse. They also stated that some providers' hesitancy stems from their religious beliefs, leading them not to recommend the vaccine.

3.2.2.3. Residual impacts from the COVID-19 pandemic. Participants believed the residual impacts of the COVID-19 pandemic were a significant driver of HPV vaccine hesitancy. The confusion and misinformation surrounding COVID-19 increased hesitancy and safety concerns among parents, leading many to decline routine and voluntary vaccines. One participant stated:

"The mis/disinformation got worse during COVID…there seems to be some increases in hesitancy just based on the media reports and that kind of thing."

Interviewees felt that implementing vaccination programs seemed daunting post-COVID and tarnished previous efforts to address vaccine hesitancies. They recognized residual benefits, such as new community-based initiatives, emergency funding, and expanded roles for pharmacists in vaccination.

3.2.3. Strategies/interventions to improve HPV vaccination

3.2.3.1. Provider communication, education/and knowledge building. Participants noted a deficiency in provider education and knowledge that has hindered HPV vaccination. Interviewees stressed the importance of provider education and training to enhance evidence-based practices for HPV recommendations. Interventions to build provider knowledge were crucial. To illustrate, one interviewee stated:

"Provider training has been another important strategy because if you can model what a conversation looks like in daily clinical practice, where you're giving people the tools with words, they're able to see how an interaction can go."

Participants discussed training tools, including motivational interviewing, vaccine champions, and system-level training on HPV recommendation language. The "Start at 9" campaign, endorsed by multiple U.S. states, focuses on preparing providers to initiate HPV discussions with parents when their child is 9. Early vaccination can boost uptake and provide more time for parental education and concerns. One participant shared their experience: *"Having the language starting earlier and giving equipment with the tools to have these conversations earlier in the clinical care. It's been proven to be effective."*

3.2.3.2. Community and Parent education (partnerships with trusted partners). Participants highlighted the importance of community education, partnerships, and trusted CBOs in enhancing HPV vaccination interventions. They noted that public health systems work with CBOs to engage the community and deliver culturally relevant education. One informant discussed outreach through community engagement to increase awareness.

Pharmacists' role in vaccination access was also discussed, particularly when they began vaccinating 18-year-olds, which benefited communities with limited resources and "increased access to care, particularly if it's a community that doesn't have a lot of resources, and a local pharmacist is part of the family."

Parental education about HPV typically occurs during regular visits, and initiatives like the "Start at Age 9" campaign aim to improve this education. Informants emphasized the importance of provider-patient recommendations as a key predictor of vaccination uptake.

Additionally, participants acknowledged challenges in developing effective parental strategies due to the varying levels of knowledge and misinformation. They emphasized the importance of incorporating parent groups and perspectives into strategy development.

3.2.3.3. Teen empowerment and education. Participants identified two key groups for vaccination: parents and teens/young adults. Vaccinating children before the age of 15 is a priority, as is educating and empowering parents to vaccinate their children. However, some children are not vaccinated. In some states, when these children become teenagers or young adults, they can legally make their own medical decisions, presenting an opportunity to educate them on the HPV vaccine.

Many teens and young adults desire autonomy, and providing them with the necessary information empowers them to take control of their health. One participant shared:

"Targeting…states where it's more conservative, or…cities, counties, areas - targeting those youth, the young adults that are able to get the vaccination…on their own, or even in those states where youth are able to sign off and get certain health services at a young age."

Informants also discussed peer-to-peer programs tested on college campuses. These programs aim to educate young women about the importance of the HPV vaccine and to facilitate access to HPV vaccination. Interviewees highlighted opportunities with catch-up strategies but emphasized that vaccination should occur before potential exposure. One participant noted:

"We want young adults to know about it [HPV vaccine], especially in low-vaccination states. Because they are in a position at age 18-19 to decide for themselves."

3.2.4. Effectiveness and enabling factors for strategies

3.2.4.1. Partnerships and community engagement. Interviewees discussed community engagement and partnerships in improving HPV vaccination strategies, highlighting the effectiveness of involving communities in messaging and campaigns and the value of strong partnerships between health departments and trusted organizations to expand intervention reach. One interviewee stated:

"We're getting better as a field doing things like meaningful community engagement, about involving others in decision making that have historically been left out of making decisions about their future. I still don't think we're

involving them in making policy decisions."

Participants discussed targeted multi-level interventions that effectively served and addressed disparities in underserved communities. Identifying communities they serve, observing vaccination gaps, and utilizing community partnerships and trusted organizations, specifically for HPV education, including language adaptations for materials. One interviewee shared:

"When you talk about underserved populations of which there's often over-representation of minority communities or low English proficiency communities, it is aligned with multi-level interventions …there is value in terms of…focusing on specific populations."

3.2.5. Policy

3.2.5.1. Current policy. The interviewees had limited discussion on the current HPV policy at both local and national levels. Participants shared that some policies have been introduced but have not gained much traction or died when they reached the decision-making process. It has been challenging to make progress in the policy space for HPV vaccinations. One participant stated:

"A few different types of legislation have been introduced, for example, providing all parents with education or information about HPV vaccination. But to my knowledge, nothing has ever actually been implemented."

One of the interviewees discussed the Prevent HPV Cancers Act (2021), which aims to educate people about HPV, expand vaccination efforts, and develop new treatments for HPV-related cancers. HPV stakeholders and advocates have been urging the passage of this and other policies, but they have not yet succeeded.

3.2.5.2. Ideal policy. Interviewees expressed concerns about the absence of HPV vaccination policies, the impact of the COVID-19 pandemic, and the rollback of vaccination policies by local and state governments. They emphasized the need to improve vaccine access, making HPV vaccination standard care, and suggested increasing reimbursement and incentivizing providers. Informants noted the importance of integrating HPV vaccination into routine care. They also discussed policies for childcare and school entry requirements, focusing on access, prioritization, and mandates. Participants are collaborating with coalitions and organizations to advocate for enhanced HPV and general vaccination policies.

4. Discussion

This mixed-methods study employed a survey and interviews to understand the demographic drivers of HPV vaccine hesitancy and to identify effective public health interventions for improving HPV vaccination rates. We found that HPV is not prioritized by parents and, at times, providers compared to other vaccines, and there is less concern about HPV compared to other vaccine-preventable diseases. Various socio-demographic factors such as race, age, gender, religion, employment, and parental income were associated with children's HPV vaccination status at the county-level. Perceiving the HPV vaccine as important and safe influences vaccination status, but it is not viewed in the same way as other vaccines. By identifying socio-demographic determinants and behavioral drivers, we can create more targeted and effective interventions.

4.1.1. Lack of prioritization and role of providers

*A significant finding that emerged in both the survey and interviews is the lack of prioritization of the HPV vaccine by p*roviders, health systems, and parents/caregivers, despite its proven safety and effectiveness since its approval in 2006. Adolescent vaccination remains lower than targets, with over half of adolescents not fully vaccinated [21,22]. Interviewees and recent studies have highlighted that providers significantly impact HPV vaccine prioritization and improve parental acceptability, primarily through early vaccination recommendations [23]. Study findings highlighted that prioritization and starting HPV vaccination as early as nine is crucial to on-time vaccination. The American Academy of Pediatrics (AAP) and Advisory Committee on Immunization Practices (ACIP) recommend fully vaccinating male and female adolescents by age 11 or 12 [22].

Differences in policies, insurance coverage, and provider motivation contribute to the lack of prioritization of the HPV vaccination. One study found that insurance companies do not prioritize HPV for quality improvement incentives compared to other vaccines [22]. This provides opportunities for insurers/payers to influence provider and clinic prioritization and HPV improvement through quality incentives. Providers must commit to staying current on HPV recommendations and emphasizing safety, prioritization, and effectiveness.

4.1.2. Barriers to HPV vaccination

Nearly 50 % of survey participants reported difficulty accessing HPV vaccines. Key barriers included work constraints, limited clinic hours, wait times, a lack of vaccine knowledge among providers and parents, and parental resistance. This difficulty in accessing HPV vaccines was echoed by key informants. Access to preventive health care is a significant barrier for many people in the U.S., affecting vaccination rates [13]. The study findings demonstrated how barriers to vaccination must be understood in terms of socio-demographic and BeSD factors. Addressing structural and individual barriers to HPV vaccination is critical for increasing confidence and uptake.

4.1.3. Roles of socio-demographic drivers and drivers of vaccine hesitancy

Various socio-demographic and BeSD among parents/caregivers were associated with their children's HPV vaccination status. Studies have examined vaccination levels among racially diverse communities; limited research addresses the socio-demographic drivers of HPV vaccine hesitancy. Tailored interventions can effectively address parental hesitancy, particularly among racial/ethnic minorities [13]. Our research on local, county-level socio-demographic drivers of HPV vaccination will help providers, community organizations, and policymakers address the unique needs of priority populations.

Study findings highlight that religious beliefs are a common driver of vaccine hesitancy, especially for HPV vaccines, particularly among conservative religious communities, due to concerns about HPV transmission, associated cancers, and the age of vaccination. Despite the importance of HPV vaccines for all children, parents are more likely to refuse HPV vaccination if they believe their child is not sexually active, involved in religious practice, or has conservative sexual attitudes [23,24]. Additionally, young religious women are under-informed and under-vaccinated for HPV, posing significant health risks for those within religious communities [24,25]. While religiosity in America has declined, there is a concerning increase in religious vaccine exemptions and higher outbreaks linked to non-medical exemptions [26].

Parent perceptions about the importance and safety of the HPV vaccine were the strongest BeSD predictors of HPV vaccination in the study. Safety concerns have been a significant source of parental hesitancy since the vaccine was introduced [23]. To improve parental acceptance and intention to vaccinate, healthcare providers should emphasize the importance and safety of HPV vaccination.

Since vaccine hesitancy and the drivers of HPV vaccination are complex, providers must be supported through improved data and technical and financial support to create tailored interventions based on community-specific needs.

4.1.4. Interventions to improve HPV vaccination

Interview participants discussed the need for multi-level interventions to address parental hesitancy and barriers to enhancing HPV

vaccination, including provider communication and education, community partnerships, parental education, and catch-up strategies for teenagers. Previous studies found that presumptive recommendation techniques and motivational interviewing can enhance provider communication and educational methods [4].

HPV vaccination rates for adults aged 13–26 and 27–45 remain lower than desired.27,28 The CDC and ACIP recommend vaccine catch-up programs through age 26.27,28 both the literature and study participants highlight catch-up and teen strategies being used for secondary approaches for increasing HPV vaccination rates. [27,28] These strategies are effective and commonly used to increase HPV vaccination rates [8] and could be beneficial to employ in counties, such as those found in this study, with high percentages of zero-dose children; however, the primary goal should be to encourage parents to vaccinate their children before age 15.

It is challenging to gauge the effectiveness of interventions. Still, providers and HPV vaccine partners should employ comprehensive strategies to address parental hesitancies and reach teenagers and adults through catch-up approaches.

4.1.5. HPV policy

Study findings suggest that policy has a significant influence on vaccination uptake, as seen through the VFC Program, school entry requirements, and exemption policies for routine childhood vaccinations [29]. As of 2020, only five states or jurisdictions in the U.S. have recommended HPV as a school entry requirement [22]. Study participants expressed hope for exploring school entry requirements and strengthening HPV policy at all levels (federal, local, and organizational) to improve HPV vaccination.

HPV vaccination policy should also focus on improving data tracking and monitoring. Healthcare systems and payer strategies have significant opportunities to strengthen on-time HPV vaccination and data monitoring at state and local levels [22].

4.1.6. COVID-19 impacts

Before the COVID-19 pandemic (2010−2020), HPV vaccination rates, while lower than desired, had been steadily increasing [23]. The pandemic created logistical challenges and shifts in priorities that impacted the uptake of the HPV vaccine throughout the U.S. [30] The VCP also identified declining HPV confidence scores among EU countries after the pandemic (between 2020 and 2022) [10]. Parental concerns about vaccine safety, side effects, and the perceived newness of the HPV vaccine were amplified post-COVID-19 pandemic [13]. Interview participants discussed these COVID-19 impacts and their effects on the interventions and previous work gained before the pandemic. These impacts prioritize the various HPV interventions/strategies discussed to counteract them.

4.1.7. Limitations

The surveys were distributed to two states and six counties each; therefore, the findings may not be generalizable. Additionally, the response rate in our first four counties was lower than expected, so we increased our scope from four to 12 counties to meet survey goals. Furthermore, several sampling biases may exist in the use of online survey panels, such as self-selection and digital access biases. Respondents to vaccine-related surveys often hold strong opinions on the topic, which may not accurately reflect the views of the general population.

4.1.8. Recommendations

The findings from this study highlight several interventions that could enhance HPV vaccination uptake, address the complex socio-demographic and BeSD of vaccination, and enhance the resilience of local immunization strategies (Table 8).

5. Conclusion

Our study identified the complex factors affecting HPV vaccination uptake in New York and Florida. This information can help policymakers create policies, interventions, and strategies to combat the diverse and geographically variable barriers to HPV vaccination and hesitancy. Addressing these factors through tailored interventions, education, and healthcare provider involvement can increase vaccine confidence and uptake, particularly in areas with lower vaccination rates. The geographical variability of the VCI and survey outcomes highlights the need for continued research and regular monitoring of local-level determinants of vaccination.

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CRediT authorship contribution statement

Kaitlin (Quirk) Brumbaugh: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Alex de Figueiredo:** Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Frances R. Gellert:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Formal analysis. **Francisco Rios Casas:** Methodology, Conceptualization. **Tara McCoy:** Methodology, Investigation. **Heidi J. Larson:** Writing – review & editing, Supervision, Conceptualization. **Ali H. Mokdad:** Writing – review & editing, Supervision, Conceptualization.

Table 8
Recommendations to Improve HPV Vaccination.

1. Enhance Provider Education and Communication
Train healthcare providers to prioritize HPV vaccination and effectively communicate its importance and safety to parents. Presumptive recommendation techniques and motivational interviewing could be beneficial.
2. Implement Tailored Interventions
Develop and implement interventions targeted at specific socio-demographic groups identified as having higher rates of vaccine hesitancy. This could involve community partnerships and culturally sensitive educational campaigns.
3. Improve Access to Vaccination
Address structural barriers to HPV vaccination by extending clinic hours, reducing wait times, and offering vaccinations in alternative settings like schools or community centers.
4. Strengthen HPV Vaccination Policies
Advocate for the inclusion of the HPV vaccine in school entry requirements, improve insurance coverage policies to encourage vaccination, and incentivize insurance prioritization of HPV quality improvement programs. Additionally, focus on improving data tracking and monitoring at the state and local levels.
5. Address COVID-19 Impact
Develop strategies to counteract the pandemic's impact on HPV vaccination rates, including reassuring parents about vaccine safety and the importance of resuming routine vaccinations.
6. Support Catch-up Vaccination
Encourage catch-up vaccination programs for teenagers and young adults who missed their HPV vaccinations, utilizing educational strategies and policy incentives.

Institutional review board statement

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2025.127395.

Data availability

The data that has been used is confidential.

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