



Social determinants of human papillomavirus vaccine series completion among U.S. adolescents: A mixed-methods study

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ABSTRACT

Introduction: Human papillomavirus (HPV) vaccination can significantly reduce HPV-associated cancers. In the US, two doses are recommended for vaccine completion for younger adolescents. However, series completion rates remain below the nation's goal of 80% coverage. Multi-faceted factors may influence adolescent series completion. The purpose of this study was to identify individual-level, relationship-level, and community-level factors of timely series completion among adolescents, ages 11–14, initiating the HPV vaccine series in 2017.

Methods: A convergent, mixed-methods design was used combining adolescent electronic health record data ($n = 803$) and qualitative interviews with adolescents and their parents ($n = 32$) to assess timely series completion within 14-months (e.g., January 2018 to February 2019). Multivariable logistic regression analysis examined individual-level and community-level factors influencing timely series completion. Directed content analysis was used to identify relevant themes and subthemes. We provided an integrative summary to assess patterns of convergence or divergence between quantitative and qualitative data.

Results: In the quantitative phase, 61.0% of adolescents completed the vaccine series and 47.3% completed it on-time. Higher odds of timely series completion were among younger adolescents at vaccine initiation (aOR = 1.82, 95%CI = 1.07, 3.11) and lower among adolescents who were Black (aOR = 0.57, 95%CI = 0.37, 0.89) and Hispanic (aOR = 0.54, 95%CI = 0.30, 0.95) compared to Non-Hispanic White adolescents and those without private insurance (aOR = 0.56, 95%CI = 0.37, 0.85). Qualitative findings revealed increased risk for HPV at sexual debut as a motivator for timely series completion. Family/peers and healthcare providers influenced timely series completion among minority adolescents. Community-level factors were not significantly associated with timely series completion, however, qualitative findings revealed lack of transportation as a barrier to timely series completion.

Conclusion: Multi-level factors continue to influence timely series completion, despite fewer doses needed for series completion. Innovative strategies are needed to improve care coordination for receiving vaccine doses, patient-provider communication about series completion and increase access to HPV vaccine.

1. Introduction

Human papillomavirus (HPV) vaccines hold promise for preventing HPV-associated cancers (Meites, Gee, Unger, & Markowitz, 2021). In 2016, the number of recommended doses for vaccine completion was reduced from three to two doses for adolescents starting the series before their 15th birthday (Meites, Kempe, & Markowitz, 2016). HPV vaccine is

routinely administered at ages 11 to 12, with doses administered 6 to 12-months apart (Meites et al., 2016). Series completion rates—the percentage of adolescents starting and completing all recommended doses—are shy of the nation's goal of 80% coverage (U.S. Department of Health and Human Services, 2021), with rates at 75.8% (Elam-Evans et al., 2020). Fewer doses for series completion may improve national adolescent HPV vaccination rates. However, receiving subsequent doses

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for series completion may present challenges for parents and adolescents.

Multi-level factors may influence HPV vaccine series completion. To date, most quantitative studies examining factors of series completion largely identified individual-level factors influencing three-dose series completion, with fewer studies exploring factors influencing two-dose series completion. Although younger adolescents have higher rates of vaccine completion (Freeman, Gamboa, Darbinian, Littell, & Torrente, 2018; Gold, Naleway, & Riedlinger, 2013; Inguva et al., 2020; St Sauver et al., 2016), they were less likely to complete the series on-time (Hirth, Tan, Wilkinson, & Berenson, 2012) and adhere to the vaccine schedule (Liu, Kong, & Du, 2016). Timely series completion with the two-dose regimen also decreased overtime (Spencer, Brewer, Traogdon, Wheeler, & Dusetzina, 2018). Racial/ethnic disparities in series completion also exist with Black and Hispanic adolescents less likely to complete the series (Ackerson et al., 2017; Agawu et al., 2020; Freeman et al., 2018; Schluterman, Terplan, Lydecker, & Tracy, 2011). Inconsistent findings were noted by insurance type reporting both private and public insurance increasing and decreasing the odds of series completion (Agawu et al., 2020; Inguva et al., 2020; Schluterman et al., 2011). Vaccine series completion was higher among adolescents living in high-income households (Dorell, Yankey, Santibanez, & Markowitz, 2011; Niccolai, Mehta, & Hadler, 2011). Regional disparities in vaccine series completion exists (Hirth, 2019; Liu et al., 2016; Spencer et al., 2018), however, how geographic characteristics influence series completion is not well-understood. Although these studies identify important factors, they do not consider how factors interact to influence vaccine series completion.

Quantitative variables, such as socioeconomic status and race/ethnicity, are commonly used proxies to measure social determinants of health (Solar & Irwin, 2010), however, are limited in explaining the underlying associated social experiences. Research integrating quantitative and qualitative perspectives are needed to provide a deeper understanding of how multi-level determinants influence HPV vaccine series completion. This mixed-method study is part of a larger study that

examined individual-level and community-level factors influencing timely series completion among younger adolescents in a university healthcare system (Mansfield, Silva, Merwin, Chung, & Gonzalez-Guarda, 2021). The purpose of this study is to identify individual-level, relationship-level, and community-level factors of timely HPV vaccine series completion among adolescents, ages 11 to 14, who initiated the series across two pediatric clinics in the same healthcare system. Specifically, we seek to 1.) examine individual-level (e.g., age at first dose, sex, race/ethnicity, and insurance type) and community-level (e.g., neighborhood deprivation and distance to clinic) factors associated with timely series completion, and 2.) explore barriers and facilitators to timely series completion among adolescents and their parents across individual, relationship and community levels of influence.

1.1. Theoretical framework

Socioecological models are often used to understand the intersectionality between individual and environmental factors on health behaviors (Golden & Earp, 2012). We used the CDC (2022) social-ecological model to explore barriers and facilitators to timely series completion across three levels: Individual, relationship, and community (Fig. 1). Individual-level factors included adolescent demographic characteristics and parents' and adolescents' perceptions of the first dose experience. Relationship-level factors explored social influences on timely series completion including family/peer support and perceptions about decision-making for HPV vaccine, and communication about HPV vaccination among parents, adolescents, and providers. Community-level factors included adolescents' neighborhood characteristics and distance to the clinic. This model was used to specify important quantitative variables used as proxies for social determinants of health, to guide qualitative questions to uncover important drivers of timely series completion for adolescents, and to inform data integration of quantitative determinants and qualitative experiences across levels.



Fig. 1. Center for Disease Control and Prevention (CDC) Social-Ecological Model from “The Social-Ecological Model: A Framework for Prevention,” by National Center for Injury Prevention and Control, Division of Violence Prevention, 2022, (<https://www.cdc.gov/violenceprevention/publichealthissue/social-ecologicalmodel.html>). Reference to this framework does not constitute its endorsement or recommendation by the U.S. Government, Department of Health and Human Services, or Centers for Disease Control and Prevention. The material is otherwise available on the agency website for no charge.

2. Methods

We used a convergent mixed-method design (Creswell & Plano-Clark, 2018) that combined electronic health record (EHR) data and individual qualitative interviews with parents and adolescents to examine multi-level barriers and facilitators of timely series completion among adolescents. IRB approval was obtained from Duke University Health System.

2.1. Study sample

2.1.1. Quantitative sample

A waiver of informed consent was granted to access retrospective EHR data from two pediatric clinics located in an urban county in the southeastern U.S. Selected clinics were a subsample of clinics from a larger healthcare system network that serviced 25,000 pediatric patients from multiethnic backgrounds and low-income communities (Duke Health Performance Services, 2019). We created a cohort of adolescents, ages 11 to 14, who initiated the HPV vaccine series between January 2017 to December 2017 and followed all adolescents from January 2018 to February 2019 to assess timely series completion (e.g., within 14-months).

2.1.2. Qualitative sample

We used purposive sampling to recruit parents and adolescents across the two clinics with similar characteristics to the quantitative sample. Key informants were male or female adolescents and one of their parents. Eligibility criteria included: (a) adolescents, ages 11 to 14, who received their first dose in 2017; and, (b) caregivers—defined as adolescents' biological parents or legal guardians—self-identifying as the primary caregiver who made medical decisions for the adolescent. Parental influence was a key part to assess relationship-level factors of timely series completion. Thus, adolescents emancipated from their parents were excluded. Pregnant adolescents were also excluded because vaccine administration is contraindicated in this population (Meites et al., 2021). If parents had multiple eligible adolescents, the adolescent with the next birthday on the calendar year was selected to control for selection bias (Morales-Campos & Parra-Medina, 2017). Adolescents were stratified into two groups: (1) completers, defined as adolescents receiving their second dose within 14-months of their first dose, and (2) non-completers, defined as adolescents who received their first dose, but never received a second dose.

Recruitment occurred via face-to-face, mail, telephone, or email from January 2019 to May 2019 across two pediatric clinics. We pre-screened for eligibility using adolescents' charts and the North Carolina Immunization Registry (NCIR) database (NC Department of Health and Human Services, 2019). The NCIR was used to verify series completion if adolescents received vaccine doses outside the healthcare system and for new patients without an established immunization record. For face-to-face and telephone recruitment, healthcare providers were notified of eligible participants and provided a brief study introduction. Eligible participants were then approached by the study coordinator in the clinic room or by phone to further screen for eligibility. Signed letters from healthcare providers were sent to eligible participants via mail or email in English and Spanish. Informed consent, child assent, and interviews were provided in English or Spanish. Parents and adolescents provided consent prior to scheduled interviews and participated in separate, concurrent interviews that were audio-recorded. Participants completed a demographic survey and received \$45 in cash (\$30 for parents and \$15 for adolescents) for their participation.

2.2. Measures

The primary outcome was timely series completion, defined as receiving two or three doses within 14-months from the first dose. This timeframe was chosen in accordance with the recommended HPV vaccine administration schedule and to account for scheduling delays for subsequent doses. Two doses are recommended for vaccine completion for adolescents starting the series before their 15th birthday, administered 6 to 12-months apart. Three doses are recommended if the second dose is received less than five months from the first dose, or if adolescents are immunocompromised, with doses recommended for completion within 6 to 12-months (Meites et al., 2016). The first-author assessed dates of vaccine administration for each dose to determine whether adolescents were recommended two or three doses for series completion.

2.2.1. Individual-level factors

Individual-level factors obtained from the EHR included age at first dose, sex, race/ethnicity, and insurance type. Age at first dose was recorded in years. Sex was coded as female or male. Race/ethnicity was combined into four groups: Hispanic, Non-Hispanic White, Non-Hispanic Black, and Non-Hispanic Other. The listed primary insurance provider was used to determine insurance type. We created a private insurance variable with two groups: 'No,' combining self-pay and public insurance, and 'Yes' for private insurance. Parents and adolescents' beliefs about HPV vaccine and adolescents' first dose experiences were explored in the qualitative interviews.

2.2.2. Relationship-level factors

Relationship-level factors were assessed through qualitative interviews with parents and adolescents. Interview questions assessed the role of social influences on decision-making for initiating and completing the vaccine series and communication about HPV vaccination with parents, adolescents, healthcare providers, family, and peers.

2.2.3. Community-level factors

Community-level factors obtained from the EHR included neighborhood deprivation and distance to clinic. We used the 2015 U.S. Area Deprivation Index dataset to determine neighborhood deprivation associated with the nine-digit zip code from each adolescents' home address (University of Wisconsin School of Medicine and Public Health, 2015). A description of this dataset and methodology used to determine the deprivation index values are described elsewhere (Mansfield et al., 2021). State-level deprivation index values were used, ranging from 1 to 10, with higher index values indicating higher levels of neighborhood deprivation. Deprivation values were coded as 1–2, 3–4, 5–6, 7–8, and 9–10.

Using Google Maps, we manually entered adolescents' home addresses and clinic addresses where vaccine doses were received to calculate distance to clinic for each clinic encounter. The shortest distance in miles were recorded. We preset the departure time to 12:00 p.m. and 3:00 p.m. in Google Maps to account for the influence of traffic on selecting the shortest route. Similar procedures were used in other studies (Mabeya et al., 2018; Tsui et al., 2013). Distances were combined into three groups: 0–15, 16–30, and 31–45 miles, due to the variable's non-normal distribution and based on the assumption that 15-mile intervals would present increasing challenges for accessing care for vaccine doses.

2.3. Interview guides

Interview guides were developed for parents and adolescents based on the adolescent's completion status in English and Spanish (Appendices A-D). Questions were developed a priori using constructs and concepts from the social-ecological model (CDC, 2022). Individual-level questions included adolescents' first dose experience and further explored the quantitative individual-level factors. Relationship-level questions explored communication about HPV vaccine and decision-making for series completion with healthcare providers, peers, and family members. Community-level questions assessed how neighborhood characteristics and clinic distance affected adolescents' ability to complete the series. We probed for participants' thoughts about series completion and assessed which characteristics had the greatest influence on timely series completion.

2.4. Data analysis

2.4.1. Quantitative data

Descriptive statistics detailed the characteristics of adolescents and key study variables. Non-directional statistical tests were conducted with significance set at 0.05 and were analyzed using SAS 9.4 (SAS Institute Inc., Cary, NC). Multivariable logistic regression analyses examined the influence of individual-level and community-level factors on timely series completion. Adjusted odds ratios (aORs) and 95% CI were reported to address effect size. A minimum of 300 adolescents was required to achieve 80% power based on: (a) statistical significance set at 0.05 for each two-tailed test; (b) 6 predictors in the final regression model; (c) 50 adolescents per predictor; (d) medium effects, specified by an aOR of 2.47 or 0.40; and (d) a missing rate of less than 5%. The sample of 803 adolescents provided over 80% power for the planned analyses.

2.4.2. Qualitative data

Qualitative interviews were analyzed using directed content analysis in NVIVO 11 (QSR International Pty Ltd, 2015). English-language interviews were transcribed by L.M. and Spanish-language interviews were transcribed and translated by a hired, bilingual transcriptionist. Transcriptions were read in entirety to identify essential features. Key statements were highlighted and provided a brief description to capture the distinctive elements of the text (Sandelowski, 1995). L.M. and R.G.G., who have expertise in qualitative analysis, coded data using open coding (Marshall & Rossman, 2016). The initial coding scheme (Lincoln & Guba, 1985) was developed using pre-existing codes informed by concepts from the social-ecological model and were operationally defined then categorized into conceptual categories. Data unable to be categorized within the initial coding scheme emerged as a new code (Hsieh & Shannon, 2005). A codebook was used to detail all codes and definitions and analytic memos recorded researchers' thoughts of emerging codes and themes. The research team compared emerging codes and conducted an iterative code-recode procedure until a consensus was reached (Lincoln & Guba, 1985).

Codes were grouped into categories, sub-categories, and then into themes and sub-themes using an iterative process (Marshall & Rossman, 2016) and guided by constructs from the social-ecological model. Thematic memos were recorded to summarize key ideas representing each category and sub-category emerging from coding. Categories and sub-categories were assessed for similarities in definitions and meanings and clustered when commonalities were identified. L.M. and R.G.G. created conceptual mapping diagrams to identify relationships and patterns among the categories and sub-categories. When no new relationships and patterns emerged, the final categories and

sub-categories were assessed to determine the overarching theme best describing the patterns and data.

2.5. Data integration

Quantitative and qualitative data were organized by each social-ecological level using joint data display tables (Creswell & Plano-Clark, 2018). Quantitative findings presented individual-level and community-level factors explored in the EHR data, followed by qualitative data that contextualizes supportive evidence or differences in findings. Quantitative and qualitative data were then compared to assess patterns of convergence or divergence and an integrative mixed-method interpretation was provided to further describe each factor's influence on timely series completion.

3. Results

Among 803 adolescents receiving their first dose in 2017, 61.0% completed the vaccine series and 47.3% completed it on-time. Most adolescents were recommended two doses for series completion (98.6%) (Table 1). Nearly half of adolescents were females (49.7%), with most

Table 1
Sample characteristics for quantitative sample.

Characteristics	n (%)
HPV Vaccine Completion Status (N = 803)	
Overall Series Completion	490 (61.0%)
Timely Series Completion	380 (47.3%)
Required Dose for Completion (N = 803)	
Two Doses	792 (98.6%)
Three Doses	11 (1.4%)
Type of Visit at First Dose (N = 785)	
Well-Child Visit	734 (93.5%)
Non-Well-Child Visit	51 (6.5%)
Age at First Dose (N = 803)	
11	331 (41.2%)
12	261 (32.5%)
13	127 (15.8%)
14	84 (10.5%)
Sex (N = 803)	
Female	399 (49.7%)
Male	404 (50.3%)
Race/Ethnicity (N = 749)	
Hispanic	109 (14.6%)
Non-Hispanic White	246 (32.8%)
Non-Hispanic Black	307 (41.0%)
Non-Hispanic Asian	47 (6.3%)
Non-Hispanic Multiracial	22 (2.9%)
Non-Hispanic Other	18 (2.4%)
Insurance at First Dose (N = 803)	
No insurance	4 (0.50%)
Private	399 (49.7%)
Public	400 (49.8%)
Area Deprivation Index Value at First Dose* (N = 775)	
1-2	329 (42.5%)
3-4	187 (24.1%)
5-6	103 (13.2%)
7-8	71 (9.2%)
9-10	85 (11.0%)
Distance to Clinic at First Dose (N = 782)	
0-15 miles	536 (68.5%)
16-30 miles	216 (27.6%)
31-45 miles	30 (3.9%)

Note. *Index value reported at the state-level ranging from 1 to 10. Low values = low-deprivation neighborhoods; high values = high-deprivation neighborhoods.

Table 2
Sample characteristics of qualitative sample.

Adolescents (N = 16)		Caregivers (N = 16)	
Characteristics	n	Characteristics	n
Age		Age	
11	1	Less than 30	2
12	5	31–40	5
13	8	41–50	5
14	2	51–60	3
		61–70	1
Level of Education		Level of Education	
Fifth grade	1	Less than high school	1
Sixth grade	3	Some high school, no diploma	2
Seventh grade	8	High school graduate	2
Eighth grade	3	Trade/technical school	1
Ninth grade	1	Some college, no degree	4
		College graduate (Associates, Bachelors)	2
		Graduate/Professional Degree	4
Race/ethnicity		Race/ethnicity	
Non-Hispanic Black	6	Non-Hispanic Black	5
Non-Hispanic White	3	Non-Hispanic White	5
Non-Hispanic Other*	2	Non-Hispanic Other*	1
Hispanic	5	Hispanic	5
Sex		Relationship to Adolescent	
Girls	9	Mothers	14
Boys	7	Grandmothers	2
Insurance Type		Annual Income ^a	
Private	5	Under \$29,999	5
Medicaid	11	\$30,000 - \$49,999	4
Vaccine Completion Status		\$50,000 - \$74,999	4
Completer	8	\$75,000 - \$99,999	1
Non-completer	8	\$100,00 or more	1
		Marital Status	
		Single	7
		Married	8
		Divorced	1

Note. *Non-Hispanic Other represents participants self-identifying as multi-racial. ^aData collected from 15 of 16 caregivers.

receiving their first dose at age 11 (41.0%) and during a well-child visit (93.5%). Most adolescents were Non-Hispanic Black (41.0%), and nearly half had public insurance (49.8%). Most adolescents traveled 0–15 miles to the clinic (68.5%) and lived in low-deprivation neighborhoods (42.5%). In the qualitative sample (Table 2), most adolescents were boys (n = 9), age 13 (n = 8), Non-Hispanic Black (n = 6), in seventh grade (n = 8), and had Medicaid insurance (n = 11). Half of adolescents completed the vaccine series on-time (n = 8), and half never completed the series (n = 8). Among caregivers, most were mothers (n = 14), between ages 31–50 (n = 10), married (n = 8), had some college, but no degree (n = 4) or graduate/professional levels of education (n = 4), and reported an annual family income of less than \$29,999 (n = 5). There was equal representation of caregivers from Non-Hispanic Black, Non-Hispanic White, and Hispanic groups (n = 5, respectively).

3.1. Themes and subthemes

Thematic narratives included: (1) Protect teens now for the future, (2) family and healthcare providers: a gift and a curse, and (3) overcome the barriers to finish what you've started. Integration of quantitative and qualitative data for individual-level and community-level factors are presented in Table 3 and are also discussed within each respective theme and subtheme.

3.1.1. Protect teens now for the future

Higher odds of timely series completion were among adolescents receiving their first dose at age 11 (aOR = 1.82, [95%CI: 1.07, 3.11], $p = 0.03$). Qualitative data converged with this finding as completers and non-completers expressed an importance to completing the series during adolescence as protection against cancer later in life. Two subthemes emerged to further describe participants' perceptions of timely series completion among younger adolescents: Sexual activity on the horizon and protect our girls.

Sexual activity on the horizon. Parents associated adolescents' age with the onset of puberty and sexual activity. Many parents expressed increased risk for HPV and were motivated to complete the series on-time because "some 13 years old are very active, sexually now." Older adolescents discussed knowing peers who "started sneaking out and going out with boys," so thought it was "good to start the HPV vaccine."

Protect our girls. Findings diverged for timely series completion by sex. Parents and adolescents reported greater consequences of HPV for girls and perceived vaccination less beneficial for boys. Caregivers of adolescent boys perceived vaccination useful for "protecting future partners" or "reducing the spread of HPV," but were less aware of the benefits of HPV vaccination for their sons' health. Adolescent boys also expressed being unaware that, "there was a slight chance that boys could develop certain forms of cancer from this disease."

3.1.2. Family and healthcare provider influences: A gift and a curse

Social relationships influenced timely series completion. Three subthemes emerged: Mom knows best, family/peers, and healthcare providers.

Mom knows best. Parents of completers and non-completers felt that their maternal role is to protect their children, thus executed their authoritative power to make decisions for HPV vaccination. Parents' personal and family experiences with sexually transmitted infections and abnormal Pap tests were motivators for timely series completion. Parents executing their authoritative role, however, created conflict for younger adolescents, who expressed, "My mom just told me to get the shot. I didn't want to get it. But I had to."

Family/peers. Lower odds of timely series completion were among Hispanic (aOR = 0.54, [95%CI: 0.30, 0.95], $p = 0.03$) and Non-Hispanic Black adolescents (aOR = 0.57, [95%CI: 0.37, 0.89], $p = 0.01$) compared to Non-Hispanic White adolescents. Non-Hispanic Black adolescents also had lower odds of timely series completion compared to Non-Hispanic Other adolescents (aOR = 0.58, [95%CI: 0.34, 1.00], $p = 0.05$). Qualitative findings converged with these findings highlighting family social norms and cultural attitudes about vaccines and health care influenced decision-making for series completion. Most Non-Hispanic White parents reported that their racial-ethnic background and cultural values did not influence timely series completion. However, familial distrust in medicine and vaccines negatively influenced the decision of one Non-Hispanic Black parent of a non-completer. The mother initially wanted her daughter to complete the series, but later changed her decision when her relative stated, "You don't know what's in it, [so] why am I giving my child something I don't know nothing about."

Among three Hispanic families, language barriers combined with cultural beliefs that "Latinos don't know vaccines very well" created challenges in communicating with healthcare providers about series completion. A Hispanic mother of a non-completer described that the sources of information provided during clinic visits were ineffective in delivering HPV vaccine education. Language barriers among Spanish-speaking participants created misunderstanding about the number of doses needed for series completion with many reporting, "I didn't know there was a second one."

Table 3
Joint display of individual- and community-level determinants of timely series completion.

Socioecological Domain	Explanatory Variables	aOR (95% CI)	Qualitative Subthemes & Quotes	Mixed-Methods Interpretation
Individual	Age at First Dose 11 vs. 14	1.82 (1.07, 3.11)*	<i>Sexual activity on the horizon.</i> They start their puberty and that's the age that they probably start to have sex relations. Some 13 years old are very active ... sexually now.— <i>Hispanic mother, 12-year-old female completer</i>	<i>Convergence</i> Parents were motivated to complete the series on-time as a protection measure at the onset of sexual activity.
	Race/Ethnicity Hispanic vs. NH-White	0.54 (0.30, 0.95)*	<i>Family/peer influences.</i> My momma feels like it's harmful. So she's against it, [she says], 'you don't know what's in it, you don't know what it's gonna cause, you don't know what it is, but you injecting it into your child.'— <i>NH-Black mother, 13 year-old female non-completer</i>	<i>Convergence</i> Family cultural attitudes and social norms influenced the decision-making for series completion. Among NH-Black families, medical and pharmaceutical mistrust shaped views about vaccines, while language barriers affected Hispanic parents understanding of the vaccine regimen.
	NH-Black vs. NH-White	0.57 (0.37, 0.89)**	We are Hispanic, [and] don't speak or read really good English. And even though they give us the information, whenever they get the vaccines, we never read those brochures that they give us. Because of the language. So I didn't know there was a second one.— <i>Hispanic mother, 13 year-old female non-completer</i>	
	NH-Black vs. NH-Other	0.58 (0.34, 1.00)*		
	Sex Female vs. Male	1.11 (0.81, 1.51)	<i>Protect our girls.</i> In getting my son vaccinated, I can help reduce the spread. I thought less about direct risk to him as opposed to the implications of HPV in general to females.— <i>NH-White mother, 13 year-old male completer</i> Girls have more problems with cancer than guys.— <i>NH-Black 12-year old female completer</i>	<i>Convergence</i> Girls are perceived to have greater consequences of HPV. Parents and adolescents perceive less benefit to vaccinating boys other than to reduce the spread of HPV and protect future partners.
Community	Insurance No Private vs. Private	0.56 (0.37, 0.85)**	<i>Availability of resources.</i> By her having insurance, it was good for me to give it to her. If didn't have it, I probably couldn't afford it and she wouldn't have been able to get it.— <i>NH-Black mother, 12 year-old female completer with Medicaid</i>	<i>Divergence</i> Having health insurance influenced parents' decision to complete the series on-time, regardless of insurance type.
	Distance to Clinic 0–15 miles vs. 16–30 miles	0.87 (0.61, 1.25)	<i>Access to care.</i> We couldn't get there in time to get the shot. The access [van] comes slow, it comes late sometimes. <i>NH-Black 12-year-old male non-completer</i>	<i>Divergence</i> Without transportation, distance to clinic became a barrier. Using public transportation created longer travel times, causing adolescents to miss appointments.
	0–15 miles vs. 31–45 miles	1.01 (0.45, 2.26)		
	16–30 miles vs. 31–45 miles	1.16 (0.50, 2.68)		
	State-Level Deprivation ^a 1–2 vs. 3–4	1.26 (0.83, 1.92)	<i>Availability of resources.</i> [My neighborhood] hasn't really affected it at all.— <i>NH-Black mother, 13-year-old male non-completer</i>	<i>Convergence</i> Despite some parents and adolescents living in high-deprivation neighborhoods, neighborhood characteristics were not perceived barriers to timely series completion.
1–2 vs. 5–6	1.48 (0.86, 2.55)			
1–2 vs. 7–8	0.83 (0.44, 1.56)			
1–2 vs. 9–10	1.11 (0.60, 2.03)			

Note. Timely series completion reflects adolescents who completed recommended vaccine doses within 14-months. Boldface indicates statistical significance (*p < 0.05; **p < 0.01; ***p < 0.001). NH= Non-Hispanic. aOR = Adjusted odds ratios. CI = Confidence interval. ^a = Low values = low-deprivation neighborhoods; high values = high-deprivation neighborhoods.

Among completers, family/peer support of parents' decisions to vaccinate adolescents, and having open parent-child communication about HPV vaccination and sexual health facilitated series completion and fostered shared decision-making. Although, peer communication about painful vaccine experiences increased fear and anxiety to receive the second dose, most adolescents perceived benefits to completing the series. Parents with older children who completed the series reported that they "automatically decided" that their younger child would be vaccinated.

For non-completers, however, siblings' experience with HPV vaccination served as a barrier to timely series completion. A mother of a non-completer reported that her older daughter "no longer got her periods" after vaccination and decided that both children would not finish the vaccine series. The number of siblings in a household was another barrier to timely series completion. An adolescent non-completer, who had five siblings, expressed feeling "stuck on when we should make the appointment" for the second dose.

Healthcare provider. Most parents and adolescents reported healthcare providers as a trusted source for HPV vaccine information. Among completers, having an established patient-provider relationship fostered trust and continuity of care which greatly influenced timely series completion. However, completers and non-completers reported discrepancies in the type of information discussed with providers. An adolescent completer described discussing "the [vaccine] schedule, what happens when you get HPV, what can be done to prevent it, and why this vaccine is useful" with his provider. Non-completers, however, reported no patient-provider discussions about the second dose and desired more vaccine information. One Hispanic mother of non-completer reported, "He [the provider] explained a little and told me it's not mandatory to give her that vaccine." Parents of non-completers also expressed frustration about not receiving clinic reminders for follow-up appointments for the second dose, causing several adolescents to not complete the series.

3.1.3. Overcome the barriers to finish what you've started

Although challenges were reported for timely series completion, both completers and non-completers believed the series should be finished. Barriers to timely series completion were captured in three subthemes: First dose experience, access to care, and availability of resources.

First dose experience. Most adolescents reported no side effects or having minimal pain after receiving the first dose which increased their willingness to complete the vaccine series. However, some adolescents reported the HPV vaccine "hurt more than the flu shot." Receiving reassurance from parents of the importance of vaccination and feeling supported to cope with side effects increased adolescents' willingness to complete the series. Parents believed adolescents should complete the series because "we have to finish what we started."

Access to care. Some parents reported using multiple clinics to receive care to avoid long clinic wait times. Having the ability to access care also inadvertently led to adolescents completing the series on-time. Some parents and adolescent completers reported being "unaware of a second dose" until they attended their annual well-child visits. Findings diverged for distance to clinic. Despite having public transportation to access care, one mother of a non-completer described "if we catch the bus, it's about 45 mins [to get there]." Prolonged travel times made one adolescent miss his scheduled appointment because he "couldn't get there in time to get the shot."

Availability of resources. Although adolescents without private insurance had decreased odds of timely series completion compared with those with private insurance (aOR = 0.56, [95%CI: 0.37, 0.85], $p = 0.01$), qualitative findings diverged from this finding as parents perceived having health insurance in general as a motivator to timely series completion. Findings converged for neighborhood deprivation. Some parents and adolescents living in high-deprivation neighborhoods did not perceive their neighborhood characteristics as a barrier to timely

series completion.

4. Discussion

This mixed-method study examined individual-level, relationship-level, and community-level influences of timely series completion among younger adolescents and provides unique insight into barriers and facilitators experienced for two-dose series completion. Quantitative data identified age, race/ethnicity, and insurance type as significant predictors of timely series completion. Qualitative data enhanced the interpretability of the quantitative findings and identified points of convergence and divergence to further explain how determinants of health influence timely series completion. Using a social-ecological model and integrating quantitative and qualitative data revealed that factors intersect across levels of influence and provide important insight for interpreting and making recommendations for timely HPV vaccine series completion.

4.1. Individual-level factors

Higher odds of timely series completion were among adolescents initiating the series at age 11. Other studies noted lower odds of timely series completion and decreased dose adherence among younger initiators (Freeman et al., 2018; Gold et al., 2013; Inguva et al., 2020; St Sauver et al., 2016). Qualitative findings revealed that parents perceived a risk of HPV during future sexual encounters, thus wanted their children to complete the series on-time during early adolescence. Other adolescent vaccines co-administered with HPV vaccine (e.g., Tdap and meningococcal) required for school entry may create a need for younger adolescents to attend preventive care visits with immunization providers (e.g., pediatricians) more frequently than in older adolescence (Rand et al., 2007), where fewer school required immunizations are administered. This underscores the importance of achieving timely series completion during younger adolescence. Future vaccine programs should consider reframing HPV vaccine messaging that promotes timely series completion during early adolescence.

Consistent with other studies, we noted racial/ethnic disparities in timely series completion among Hispanic and Non-Hispanic Black adolescents (Ackerson et al., 2017; Agawu et al., 2020; Dorell et al., 2011; Freeman et al., 2018; Nicolai et al., 2011; Schluterman et al., 2011). Non-Hispanic Black adolescents also had lower odds of timely series completion compared with Non-Hispanic Other adolescents. We included Asian and Pacific Islander adolescents in the Non-Hispanic Other racial group who had greater odds of series completion than Non-Hispanic Black adolescents in another study (Ackerson et al., 2017). Black and Hispanic families reported barriers in attending multiple visits for additional vaccine doses, including transportation barriers in other studies (Katz et al., 2016; Roncancio, Ward, Carmack, Muñoz, & Cribbs, 2017).

Qualitative findings shed light on racial/ethnic disparities in timely series completion. The distrusting relationship between Non-Hispanic Black individuals and the medical community is rooted in historical unethical mistreatment (e.g., Tuskegee syphilis experiment) and ongoing experiences with racism and discrimination in healthcare systems which creates barriers to healthcare utilization (Scharff et al., 2010). For Hispanic parents, similar findings regarding language barriers and being unaware of the number of doses for series completion were noted in other studies (Gerend, Stephens, Kazmer, Slate, & Reyes, 2019; Luque, Raychowdhury, & Weaver, 2012; Warner et al., 2015). Additionally, one study using a socioecological approach reported inconsistent patient-provider communication about HPV vaccination among Latino parents (Warner et al., 2015). Despite these barriers, our study and others noted that Non-Hispanic Black and Hispanic parents are accepting of HPV vaccine (Lama et al., 2021) to reduce the risk of HPV-associated cancers (Pierre Joseph et al., 2014).

Although these findings are not representative of the experiences of

all Non-Hispanic Black and Hispanic families in this study, the intersection of individual influences (e.g., vaccine beliefs and language proficiency) and relationship influences from family and healthcare providers may impact familial decision-making and communication about HPV vaccine series completion for some Non-Hispanic Black and Hispanic families. Future research should consider developing culturally-relevant interventions that address barriers experienced among racial/ethnic minority groups. Using trusted community partners to deliver HPV education may also dispel misperceptions that shape cultural attitudes. Healthcare systems should also consider budgeting for language services (e.g. interpreters) within clinics to address language barriers.

Adolescents with public or no insurance had lower odds of timely series completion compared to adolescents with private insurance. Qualitative findings diverged from this finding noting that insurance type did not influence timely series completion as parents perceived having insurance coverage for HPV vaccination as a motivating factor. Other studies also noted both positive and negative associations of private insurance on timely series completion (Agawu et al., 2020; Inguva et al., 2020; Schluterman et al., 2011). In North Carolina where the study took place, nearly 35% of Non-Hispanic Black and 17% of Hispanic individuals are enrolled in Medicaid compared to roughly 40% of White individuals (Kaiser Family Foundation, 2022). Given the large percentage of Non-Hispanic Black and Hispanic adolescents in the study sample, divergence in findings may be a result of North Carolina's decision to limit Medicaid expansion during the study time period (Tummalapalli & Keyhani, 2020).

4.2. Relationship-level factors

Qualitative findings shed insight on how social influences impacted timely series completion among adolescents. Future research should consider exploring quantitative measures to assess for relationship-level factors to inform population health. Mothers perceiving adolescents as too young to make health-related decisions created barriers to shared decision-making and communication about HPV vaccination. As recipients of HPV vaccine, adolescents should be included in discussions and decision-making for vaccination and may play a role in reminding parents about other doses for series completion. Future interventions should be tailored for parents with younger adolescents to improve communication and shared-decision making for adolescent health.

Healthcare providers were the most trusted source for HPV information among parents and adolescents. Differences in patient-provider communication about follow-through for series completion, however, existed among completers and non-completers. Mixed-messaging about HPV vaccine and less frequent recommendations for HPV vaccination were noted among providers if they perceived vaccine hesitancy from parents, perceived their patients low-risk for HPV, and personally felt uncomfortable discussing sex with parents (Gilkey & McRee, 2016). However, higher odds of series completion were reported when providers instructed parents about the vaccine schedule (Gerend et al., 2019; Gold et al., 2013). Future research is needed to develop standardized HPV vaccine communication for healthcare providers to provide HPV information consistently, including communication about follow-through for timely series completion.

Navigating the healthcare system to schedule appointments for subsequent doses also influenced timely series completion among non-completers. Healthcare providers are in unique positions to connect patients to health-related information and facilitate coordination for scheduling the second vaccine dose. In the U.S., however, most primary care practices utilize individual scheduling for non-prioritized patient needs, leaving patients responsible to schedule follow-up appointments (Institute of Medicine, 2015). Providers often relied on parents to schedule follow-up appointments for series completion, while parents anticipated clinic reminders for future appointments (Perkins et al., 2016). Using a nurse champion model in primary care may provide an

opportunity to facilitate scheduling for timely series completion. These models improved patient outcomes for other health conditions (Wilson, Chen, & Wood, 2019). Future research should consider testing the feasibility of using nurse champion models to target adolescents who are overdue for HPV vaccine doses and well-child visits. Automated reminder systems (e.g., telephone calls or text messages) for scheduling vaccine doses may also improve timely series completion.

Older siblings' experiences with HPV vaccine and timely series completion emerged as a new finding. Younger siblings were more likely to receive HPV vaccination if their older siblings were vaccinated (Clark, Cowan, Filipp, Fisher, & Stokley, 2015; Garbutt et al., 2018). Qualitative data elucidated that older siblings' experience during HPV vaccination both positively and negatively influenced parents' decisions to vaccinate the youngest child. This finding underscores the importance of parent-provider discussions about adolescents' first dose experiences to identify their concerns about vaccine side effects during clinic visits.

4.3. Community-level factors

Community-level factors were not significantly associated with timely vaccine series completion. Qualitative findings, however, revealed that distance to clinic became a barrier for parents and adolescents without transportation and identified challenges with using public transportation to attend clinic appointments on-time. Access to transportation was a reported barrier to series completion among adolescents living in rural areas (Vanderpool, Dressler, Stradtman, & Crosby, 2015). Divergence in findings may be explained by personal transportation and distance to clinic measuring two different constructs. Future research should assess both characteristics of access in future quantitative and qualitative studies. Using mobile health clinics may increase HPV vaccine access in disadvantaged communities and hard-to-reach populations. Increasing vaccine access in local pharmacies or schools may also decrease barriers to accessing care to complete the series on-time. Neighborhood deprivation was not a perceived barrier to timely series completion. Parents and adolescents may believe they have the necessary resources to access care and may not be directly impacted by neighborhood deprivation. Future qualitative studies are needed to elicit deeper understanding of the role that neighborhood deprivation plays in timely series completion.

Limitations. This study has several limitations. The generalizability of study findings is limited to adolescents and parents from two clinics in one healthcare system and may not be applicable to clinics in other healthcare systems. The parent sample was largely comprised of mothers and contained a small sample of participants by race and ethnicity. HPV vaccine beliefs and perceptions about timely series completion may differ among fathers and study findings are not generalizable to all parents and adolescents from various racial and ethnic backgrounds. Proxy variables used to assess individual-level and community-level determinants were limited to data available in the EHR. Other variables may play a role that were not captured in this study. The area deprivation index dataset was limited in assessing rurality; thus, neighborhood deprivation among rural vs. urban areas could not be assessed. Lastly, the selected distances to the clinic does not reflect the actual route parents traveled for clinic appointments, starting place of origin, nor account for traffic, road closures, and travel time.

5. Conclusion

Despite fewer doses needed for HPV vaccine series completion for younger adolescents, social determinants of health continue to create barriers to timely series completion. Using a social-ecological framework, we identified barriers and facilitators to two-dose series completion and highlighted the intersectionality of factors across levels influencing timely series completion. Beliefs of sexual debut during older adolescence provides healthcare providers with an opportunity to target timely series completion during younger adolescence. Perceived

gender differences in HPV risk warrants a need for improved vaccine messaging and education about the benefits of vaccination for boys and consequences of HPV on men's health. Navigating familial cultural barriers may require more specific training for healthcare providers and collaboration with trusted community partners to appropriately address cultural beliefs and attitudes about HPV vaccine. Lastly, using alternative settings for vaccine administration are needed to reduce structural barriers to access care for HPV vaccine doses.

CRedit author statement

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Ethical statement

The authors declare that there are no conflict of interests or financial disclosures that could be perceived as prejudicing the impartiality of the research reported.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ssmph.2022.101082>.

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