



Awareness of human papillomavirus and reported human papillomavirus vaccine uptake in a high-risk population

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ABSTRACT

Introduction: Disparities in human papillomavirus (HPV) awareness and HPV vaccine uptake are likely exacerbated among racial/ethnic minority populations living in low-income areas. This study aims to determine the prevalence and correlates of HPV awareness and HPV vaccine uptake in an urban, low-income, racial/ethnic minority population.

Methods: Secondary data analyses were performed in 2021 using 380 participants aged 18–45 years from the 2019 National HIV Behavioral Surveillance for high-risk heterosexuals, which monitors HIV risk behaviors among individuals living in high-poverty, high HIV prevalence neighborhoods. Prevalence estimates and modified Poisson regression models were used to assess the relationship between HPV awareness and HPV vaccine uptake, and sociodemographic characteristics.

Results: Only 53% of participants had heard of HPV and 11.5% had received at least one dose of the HPV vaccine. Those who were female, non-Hispanic White or other, had public health insurance, lived above the federal poverty level, had experienced homelessness and incarceration, and had usual source of healthcare showed higher awareness of HPV while those who were younger, female, non-Hispanic White or other, recently incarcerated, had a usual source of healthcare, and had a healthcare encounter in the past year showed higher prevalence of HPV vaccine uptake.

Conclusions: Prevalence of HPV vaccination in this high-risk population was low and there was a lack of preventive care utilization. Further research is needed on how to effectively target these populations to not only increase vaccine uptake, but to mitigate barriers that contribute to low awareness and suboptimal vaccination uptake in high-risk heterosexual populations.

1. Introduction

Human papillomavirus (HPV) infection is highly prevalent and causes several cancers and other poor health sequelae (Hirth, 2019; Centers for Disease Control and Prevention. Human Papillomavirus Fact Sheet, 2020). Certain racial/ethnic groups are disproportionately

affected by poor HPV-related outcomes (Centers for Disease Control and Prevention. HPV-Associated Cancers Rates by Race and Ethnicity, 2020). Specifically, Black and Hispanic women have higher incidence and mortality rates of HPV-related cervical cancer compared to women of other races/ethnicities (Centers for Disease Control and Prevention. HPV-Associated Cancers Rates by Race and Ethnicity, 2020). This is

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attributable primarily to decreased access and use of cervical cancer screening which allows for identification and treatment of pre-malignant lesions. Further, Hispanic men have higher incidence of HPV-related penile cancer compared to non-Hispanic men (Centers for Disease Control and Prevention. HPV-Associated Cancers Rates by Race and Ethnicity, 2020), and Black men have higher incidence of anal HPV-related cancers when compared to non-Hispanic White men (Centers for Disease Control and Prevention. HPV-Associated Cancers Rates by Race and Ethnicity, 2020). Conversely, HPV is responsible for roughly 70% of oropharyngeal cancers, most of which occur in White males with a median age of 61 years (Centers for Disease Control and Prevention. Cancers Associated with Human Papillomavirus, 2021; Centers for Disease Control and Prevention. HPV-Associated Cancer Diagnosis by Age, 2021).

In the U.S., the HPV vaccine is routinely recommended for boys and girls aged 11–12 years, with catch-up vaccination for adolescents and young adults through age 26 (Meites et al., 2019). For older adults aged 27–45 years, shared patient-provider decision-making regarding the vaccine is recommended taking into account individual risk behaviors for HPV acquisition and development of HPV-related disease (Meites et al., 2019). This recommendation recognizes that some individuals aged 27–45 who are not adequately vaccinated may still be at risk for new infections and may benefit from vaccination (Meites et al., 2019). Uptake of the HPV vaccine in the U.S. remains sub-optimal and below the national Healthy People 2020 goal of 80% (Centers for Disease Control and Prevention. National, Regional, State, and Selected Local Area Vaccination Coverage Among Adolescents Aged 13–17 Years, 2019). In a national study assessing vaccine uptake from 2013 to 2018, only 58.6% of adolescents were up-to-date with their HPV vaccination (Pingali et al., 2021). Further, it is estimated that only 22% of the U.S. young adult population (ages 18 to 26) has completed the HPV vaccine series (Boersma and Black, 2020).

Although the factors influencing vaccine uptake are complex, HPV awareness and knowledge are associated with intent to vaccinate and initiation of vaccination (Amboree and Darkoh, 2021). Racial/ethnic minorities have considerably lower levels of accurate HPV knowledge and awareness compared to their White counterparts (Amboree and Darkoh, 2021; Amboree et al., 2021). In a recent study using data from the Health Information National Trends Survey (HINTS), we found that respondents who identified as Black, Hispanic, or other race/ethnicity had significantly lower odds of having heard of the HPV vaccine compared to their White counterparts (Amboree et al., 2021). Furthermore, the observed racial/ethnic differences in HPV awareness and knowledge was not attenuated by having a regular healthcare provider (Amboree et al., 2021).

While significant racial/ethnic disparities in HPV awareness and knowledge are observed at the aggregate level, aggregation often disguises heterogeneity within groups (Budhwani and De, 2017; Kobetz et al., 2010). Disparities are likely exacerbated among racial/ethnic minority populations living in low-income areas that have been historically marginalized and have limited access to appropriate healthcare and preventive care (Del Rio, 2016). Thus, the purpose of this paper is to determine the population-based prevalence of HPV awareness and HPV vaccine uptake in a marginalized, hard-to-reach population, as well as examine factors associated with HPV awareness and vaccine uptake in this population. To our knowledge, there are no recent studies that estimate the prevalence of HPV awareness and HPV vaccine uptake in high-risk racial/ethnic minority populations.

2. Methods

2.1. Study design

Data used for this study were obtained from the 2019 Center for Disease Control and Prevention's National HIV Behavioral Surveillance (NHBS) system in Houston, Texas. This cross-sectional data is collected

every year in populations at increased risk for HIV infection: specifically, men who have sex with men, people who inject drugs, and heterosexually active adults at increased risk for HIV (HET). The HET population, which is the focus of this analysis, is defined based on place-based parameters, including census tract-level poverty, high representation of racial/ethnic minority groups, and increased HIV prevalence (Centers for Disease Control and Prevention. National HIV Behavioral Surveillance System Round 6: Model Surveillance Protocol, 2019). Because of this, the HET population represents a highly vulnerable population. NHBS uses a standardized, interviewer-administered survey to gather information on participant demographics, sexual behaviors, and HIV and sexually transmitted infection (STI) testing (Centers for Disease Control and Prevention. National HIV Behavioral Surveillance System Round 6: Model Surveillance Protocol, 2019).

3. Study population

Data collection took place between July and December 2019 and used Respondent Driven Sampling (RDS) to recruit participants in the HET population as described in detail elsewhere (Denson et al., 2017; Richards et al., 2008; Gile and Handcock, 2010; McPherson et al., 2001; Gile et al., 2018). Briefly, the RDS methodology began with initial recruits from areas with high socioeconomic deprivation and increased HIV prevalence who completed the study activities and recruited up to 5 other people they knew, who then completed the study activities, recruited others, and so on (Centers for Disease Control and Prevention. National HIV Behavioral Surveillance System Round 6: Model Surveillance Protocol, 2019). Inclusion criteria for recruitment into the NHBS HET sample are individuals 18–60 years of age, who lived in the Houston metropolitan statistical area (MSA), identified as male or female, reported having vaginal or anal sex with someone of the opposite sex in the past 12 months, were able to complete the interview in English or Spanish, and who had a valid recruitment coupon. Those who reported injection drug use in the past 12 months as well as males who reported having male sex partners in the past 12 months were excluded, as those populations are captured in other NHBS data collection cycles.

The present study represents a secondary data analysis conducted in 2021 using a subset of NHBS HET individuals who participated in the 2019 survey. NHBS participants were included in this subset if they met NHBS inclusion criteria and were aged 18–45 years at the time of their interview. Whereas NHBS HET analyses exclude individuals who have a household income above 150% of the poverty line, this exclusion was not made for the present study due to all participants living in or around areas with high socioeconomic deprivation and high HIV prevalence. A total of 380 of the 591 NHBS HET participants met these criteria, providing $\geq 80\%$ power to estimate the prevalence of HPV awareness in the population. The data contained no personal identifying information, and the study protocol was reviewed and approved as exempt by the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston (UTHealth).

4. Measures

Awareness of HPV was assessed through the item: "Have you ever heard of HPV?" and categorized as yes and no. Uptake of the HPV vaccine was assessed through the item: "Have you ever received a shot that protects against HPV, for example Gardasil?", and also categorized as yes and no. Sociodemographic variables included age (continuous, 18–45 years), sex (female and male), and self-reported race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, non-Hispanic other). The non-Hispanic other category refers to those participants who reported being Asian, Alaskan Native, or Pacific Islander. Additional sociodemographic variables included education (less than high school diploma, high school diploma or equivalent, and at least some college education), health insurance (no insurance, private insurance, public insurance, and some other insurance), and household poverty (above

the poverty level and below the poverty level). Household poverty was determined by assessing the participant's annual household income and the number of dependents relying on that income and comparing it to federal poverty guidelines. Incarceration (never incarcerated, incarcerated but not in the past 12 months, and incarcerated in the past 12 months), homelessness (never homeless, currently homeless, and has been but is not currently homeless), and healthcare access and utilization were assessed. Specifically, we assessed source of healthcare (no usual source of healthcare, clinic or healthcare center, and doctor's office or HMO), and the time to last healthcare encounter (within the past 12 months, 1–2 years ago, 2–5 years ago, and more than 5 years ago). Barriers to HPV vaccination among those unvaccinated were assessed through the item "What is the main reason you have not received the HPV vaccine?" Response options were provided, as was the option to report "other." In the analyses, responses were categorized as no doctor recommendation, safety concerns, does not know where to get the vaccine, does not need vaccine, does not know enough about the vaccine, and other reason. The other reason category includes those who reported that they did not need the vaccine, the vaccine was too expensive, they already had HPV, and any other unspecified reason.

4.1. Statistical analysis

Data were cleaned and formatted in SAS 9.4 (SAS Institute Cary, NC) and imported into RDS-Analyst (Handcock et al., 2014). Questions about network size estimated the size and characteristics of participants' networks to account for sources of bias inherent to RDS methodology (Gile et al., 2018; Gile, 2011) and to calculate population estimates and sample variances. Giles' sequential sampling (SS) weights were utilized in RDS-Analyst to create population weights (Gile and Handcock, 2010). There are currently no standard methods for estimating high-risk heterosexual population sizes (necessary for calculating population weights); therefore, this was estimated by pooling available data (United States Census Bureau, 2019; National Center for Health Statistics. Key Statistics from the National Survey of Family Growth, 2020). Population prevalence estimates and population cross-tabulations were generated using RDS-Analyst. Bivariable and multivariable regression analyses were conducted in SAS 9.4 (SAS Institute Cary, NC) using the modified Poisson regression approach with log link function and robust variance estimation clustered on recruitment chain (Zou, 2004; McBride and Singh, 2018). Estimates from regression analyses were RDS-adjusted using Gile's SS weights with an estimated population size of 37,236. The PROC GENMOD was used to generate unadjusted and adjusted prevalence ratios and 95% confidence intervals that assessed the association between outcome variables (awareness of HPV and HPV vaccine uptake) and sociodemographic variables. Multivariable models were constructed using forward stepwise model selection with entry and exit *p*-values of less than and greater than 0.15, respectively. Predictors were retained in the model despite statistical significance if there was *a priori* knowledge of epidemiological importance based on literature. All tests performed were two-tailed, with an alpha probability of 0.05.

5. Results

Sample characteristics are described in Table 1. The average age of respondents was 31 years, 62% were female, 74% were non-Hispanic Black, and over half had a high school diploma or equivalent. Almost 60% had no health insurance and 83% were living below the federal poverty level. Over a quarter had experiences with homelessness. While more than half reported not having a usual source of healthcare, 67% reported visiting a healthcare provider within the past 12 months. Over 53% of the population had heard of HPV, yet only 11.5% had received at least one dose of the HPV vaccine.

Table 2 shows population prevalence estimates of HPV awareness and HPV vaccine uptake by sociodemographic characteristics. Individuals who had heard of HPV had an average age of 31.4 years, were

Table 1
Weighted Demographic Characteristics of the Study Population.

	N	Weighted % (95% CI)	SE
Age, continuous (mean, SD)	380	—	30.9, 8.1
Age categorical			
18–26	102	35.3 (26.5–44.6)	4.6
27–45	278	64.7 (55.45–73.52)	4.6
Sex			
Male	160	38.1 (30.0–46.2)	4.1
Female	220	61.9 (53.8–70.0)	4.1
Race/ethnicity			
White	22	4.82 (1.1–8.5)	1.9
Black	288	73.8 (65.9–71.5)	4.0
Hispanic	61	19.5 (12.5–26.6)	3.6
Other	7	1.9 (–0.38–4.2)	1.2
Education			
Less than HS diploma	96	24.4 (17.8–31.0)	3.4
HS diploma or equivalent	181	51.6 (43.6–59.6)	4.1
Some college or above	103	24.0 (17.9–30.1)	3.1
Health insurance type			
No health insurance	226	57.6 (49.3–65.9)	4.2
Private plan	27	7.5 (4.1–11.0)	1.8
Public plan	118	32.9 (24.8–40.7)	4
Other	6	2.1 (–0.2–4.4)	1.2
Poverty			
Above poverty level	72	16.6 (11.2–21.9)	2.7
Below poverty level	308	83.4 (78.1–88.8)	2.7
Homelessness in past 12 months			
Never homeless	254	72.5 (64.7–80.5)	4.0
Currently homeless	63	13.9 (8.2–19.5)	2.9
Has been, but not currently homeless	63	13.5 (8.5–18.6)	2.6
Incarcerated			
Never incarcerated	126	36.7 (28.6–44.8)	4.1
Incarcerated, but not within past 12 months	166	44.6 (35.8–53.6)	4.5
Incarcerated within past 12 months	88	18.7 (12.9–24.3)	2.9
Usual source of healthcare			
No usual source of healthcare	196	51.8 (43.4–60.1)	4.3
Clinic or health care center	124	32.5 (25.0–40.2)	3.9
Doctor's office or HMO	54	15.8 (10.1–21.3)	2.9
Last visit to healthcare provider			
Within past year	244	67.3 (59.7–74.8)	3.8
1–2 years ago	74	16.2 (10.8–21.4)	2.7
2–5 years ago	50	13.8 (8.6–19.1)	2.7
5+ years ago	12	2.7 (0.5–4.9)	1.1
Awareness of HPV			
No	164	46.8 (38.1–55.7)	4.5
Yes	216	53.2 (44.3–61.9)	4.5
Knowledge of HPV-cancer ^{a, b}			
No	26	18.8 (10.3–27.4)	4.4
Yes	158	81.2 (72.6–90.0)	4.4
HPV Vaccine Uptake			
No	334	88.5 (84.2–93.0)	2.2
Yes	46	11.5 (7.1–15.9)	2.2

^a Item includes 216 participants who reported having heard of HPV.

^b Data excluded for 32 participants who reported "Do not know" or "Refused to answer".

CI, Confidence Interval; SD, Standard Deviation; SE, Standard Error.

predominantly female (75.2%), Black (66.2%), lived below the poverty level (77.4%), had never been homeless (74.4%) or incarcerated (43.5%), and had visited a healthcare provider in the past year (65.1%). Additionally, 45.5% had no health insurance, and 38.7% reported their usual source of healthcare being at a clinic or healthcare center. Individuals who had received at least one dose of the HPV vaccine had an average age of 27.2 years, were predominantly female (91.7%), of other race/ethnicity (49%), had at least some college education (41%), lived below the poverty level (66.2%), had never been homeless (59.3%) or incarcerated (55%), and had a healthcare provider visit within the past year (63.4%). Additionally, 38.6% had no health insurance and 44.4% reported their usual source of healthcare being a private doctor's office or HMO. Vaccine uptake was also assessed for differences based on age categories (data not shown in tables), and there were no significant

Table 2
Awareness of HPV and HPV Vaccine Uptake by Sociodemographic Characteristics of a High-Risk Heterosexual Population.

Characteristic	Awareness of HPV		HPV Vaccine Uptake	
	N (column %)	P-value	N (column %)	P-value
Age, years (mean, SD)	31.40, 8.11	0.01*	27.17, 6.47	<0.01**
Age categorical		0.19		0.29
18–26	74.5 (34.9)		28.6 (51.8)	
27–45	138.8 (65.0)		26.6 (48.2)	
Sex		0.03*		<0.001***
Male	53.3 (24.8)		4.6 (8.3)	
Female	161.6 (75.2)		50.1 (91.7)	
Race/ethnicity		0.14		0.03*
White	27.6 (12.7)		6 (5.4)	
Black	144.4 (66.2)		31 (27.9)	
Hispanic	33.8 (15.5)		19.7 (17.7)	
Other	12.2 (5.6)		54.4 (49.0)	
Education		<0.01**		<0.01**
Less than HS diploma	41.4 (19.6)		14.4 (22.7)	
HS diploma or equivalent	98.1 (46.4)		23.1 (36.3)	
Some college or above	72 (34.0)		26.1 (41.0)	
Health insurance type		0.16		0.05
No health insurance	97.5 (45.5)		26.6 (36.8)	
Private plan	24.1 (11.3)		22.6 (31.4)	
Public plan	79.1 (36.9)		19.1 (26.6)	
Other	13.5 (6.3)		3.8 (5.2)	
Poverty		<0.01**		0.05
Above poverty level	48.4 (22.6)		17.9 (33.8)	
Below poverty level	166 (77.4)		35 (66.2)	
Homelessness in past 12 months		0.14		0.53
Never homeless	141.5 (74.4)		32.3 (59.3)	
Currently homeless	25.5 (13.4)		10.5 (19.4)	
Has been, but not currently homeless	23.3 (12.2)		11.6 (21.3)	
Incarcerated		0.39		0.23
Never incarcerated	94.7 (43.5)		32.7 (55.0)	
Incarcerated, but not within past 12 months	89.8 (41.2)		16.7 (28.1)	
Incarcerated within past 12 months	33.4 (15.3)		10 (16.9)	
Usual source of healthcare		0.01*		<0.0001****
No usual source of healthcare	70.5 (37.2)		16.7 (26.9)	
Clinic or health care center	73.3 (38.7)		17.9 (28.7)	
Doctor’s office or HMO	45.5 (24.0)		27.6 (44.4)	
Last visit to healthcare provider		0.88		0.03*
Within past year	140.2 (65.1)		39.2 (63.4)	
1–2 years ago	30.4 (14.1)		14.3 (23.1)	
2–5 years ago	30.7 (14.3)		5.1 (8.3)	
5 + years ago	13.8 (6.4)		3.3 (5.3)	

SD, standard deviation.

Boldface indicates statistical significance (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$).

differences between those aged 18–26 and 27–45 years (14.3% vs 9.8%, $p = 0.29$). Fig. 1 presents the potential barriers to HPV vaccination among those who had not received the HPV vaccine. Over half of the participants reported not knowing enough about the vaccine or where to get it.

HPV awareness was more prevalent among females compared to males [Table 3, adjusted prevalence ratio (aPR): 1.25 (1.06 – 1.49)], those who had public health insurance compared to those who had no

insurance [aPR: 1.29 (1.11 – 1.50)], those who had been, but were not currently homeless compared to those who were never homeless [aPR: 1.39 (1.04 – 1.86)], those who utilized a clinic or healthcare center as a usual source of healthcare compared to those who had no usual source of healthcare [aPR: 1.33 (1.20 – 1.51)], and those who utilized a doctor’s office or HMO compared to those who had no usual source of healthcare [aPR: 1.35 (1.08 – 1.69)]. HPV awareness was less prevalent among non-Hispanic Black and Hispanic participants compared to Whites/Other [aPR: 0.66 (0.47 – 0.92) and aPR: 0.48 (0.28 – 0.82), respectively], and those who lived below the poverty level compared to those who lived above the poverty level [aPR: 0.74 (0.61 – 0.89)]. The interaction effect between homelessness and incarceration was assessed and found to be significant in both bivariable and multivariable models. Those who had been but were not currently homeless and had been incarcerated in the past 12 months had higher prevalence of HPV awareness compared to those who had never been homeless or incarcerated [aPR: 1.61 (1.33 – 1.95)]. Age did not meet statistical significance in the bivariable models yet was retained in multivariable models due to epidemiologic importance. Additionally, the last healthcare visit did not meet model entry criteria and was not retained in the final model.

Vaccine uptake was less prevalent among older respondents compared to younger respondents [Table 4, aPR: 0.91 (0.89 – 0.93)], non-Hispanic Black participants compared to non-Hispanic White/Other participants [aPR: 0.23 (0.12 – 0.46)], those who had private insurance compared to those who had no health insurance [aPR: 0.74 (0.57 – 0.97)], and those who reported 2–5 years since their last healthcare visit compared to those who had a healthcare visit within the past year [aPR: 0.41 (0.18 – 0.98)]. HPV vaccine uptake was more prevalent among females compared to males [aPR: 2.87 (1.81 – 4.55)], those who had been incarcerated within the past 12 months compared to those who had never been incarcerated [aPR: 1.37 (1.10 – 1.70)], those who utilized the clinic or healthcare center as a usual source of healthcare compared to those who had no usual source of healthcare [aPR: 2.19 (1.08 – 4.43)], and those who utilized a doctor’s office or HMO as their usual source of healthcare compared to those who had no usual source of healthcare [aPR: 5.69 (3.42 – 9.47)]. Homelessness did not meet model entry criteria and was not retained in the final model.

6. Discussion

Our findings suggest that urban, adult high-risk populations have dramatically lower HPV vaccination compared to the general U.S. adult population. Uptake of at least one or more doses of the HPV vaccine in this population was almost 4 times lower than the general U.S. population (11.5% versus 40%) (Boersma and Black, 2020). Additionally, we found that awareness of HPV and HPV vaccine uptake are influenced by different factors, most of which are supported by previous research (McBride and Singh, 2018; Blake et al., 2015). Specifically, females had a higher prevalence of HPV awareness and vaccine uptake when compared to men, which is consistent with other literature (Blake et al., 2015; Choi et al., 2016), and is thought to be attributed to earlier vaccine recommendations targeting only females and the prevention of HPV-related cervical cancer (Blake et al., 2015). In other studies, age and education were shown to be associated with HPV awareness (McBride and Singh, 2018; Blake et al., 2015), however those variables did not reach statistical significance in our models. This may reflect relative homogeneity in our sample, as most of our sample were older aged (27–45 years) and had a high school diploma or equivalent. To our knowledge, our finding that HPV awareness is higher among those with experiences of homelessness has not been reported previously and disagrees with literature suggesting much lower HPV awareness, knowledge, and health literacy among homeless women (Asgary et al., 2015). We are unclear why this association was observed in our study, however one hypothesis is that rehabilitative services received by formerly homeless participants may include health education, which is supported by our finding that HPV awareness was only significantly higher among

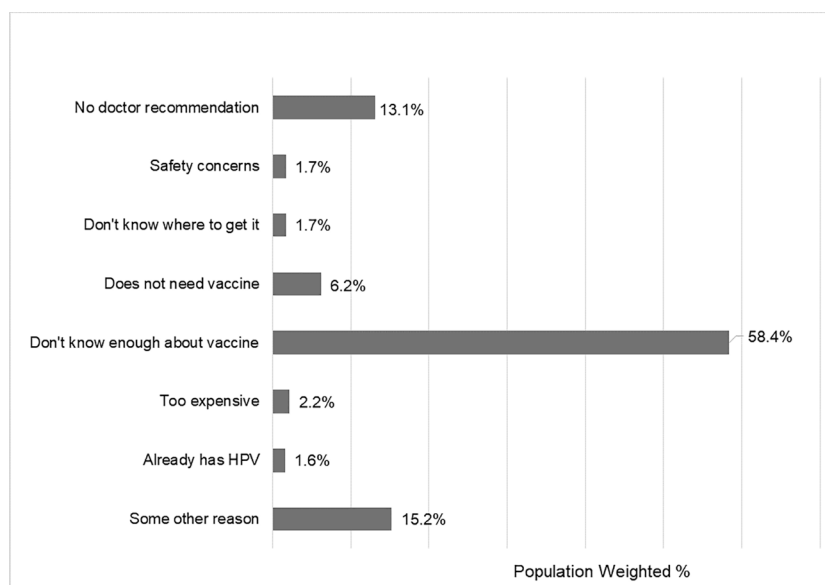


Fig. 1. Self-Reported Barriers to HPV Vaccination Among High-Risk Heterosexual Population.

individuals with experiences with homelessness, not those who were currently homeless.

Education and poverty were not significantly associated with HPV vaccine uptake in our study, although they have been shown to be significant predictors in other studies (Gallagher et al., 2016; Staples et al., 2021; Henry et al., 2018; Niccolai et al., 2011). Further, to our knowledge, our finding that HPV vaccination is lower among those with private or other insurance has not been reported previously, and disagrees with literature suggesting higher HPV vaccination among those with private insurance coverage (Chan et al., 2021; Lu et al., 2018). We are unclear why this association was observed in our study, yet hypothesize that those with private insurance may be older therefore having lower prevalence of vaccination, which is supported by our finding that HPV vaccine uptake decreased significantly as age increased. Further, the insurance type that participants had during adolescence may be relevant to vaccination status, although we do not have data to assess this. Another hypothesis is lack of heterogeneity in our population as most of the population had no insurance coverage or had public insurance. Additionally, to our knowledge, our finding of higher HPV vaccination among recently incarcerated individuals has not been reported previously. The reason for this is unknown but may be related to the Federal Bureau of Prisons' guidance which recommends vaccination against HPV in age-eligible inmates with no documented or self-reported history of vaccination (Bureau, 2018). This may, however, vary depending on where participants were incarcerated (i.e., local jail, state/federal penitentiary, etc.).

Although over half of this population had no usual source of healthcare, two-thirds had a healthcare visit in the past year. However, it appears that these healthcare visits may not have involved discussion of the HPV vaccine, as the predominant self-reported barrier to vaccine uptake was not knowing enough about the vaccine. This suggests that the population may be encountering healthcare in acute settings (emergency rooms and clinics) that do not offer enough time for the provider to address needs of the patient outside of the reason for the visit. Those who had a usual source of healthcare had more than two- and five-times higher prevalence of HPV vaccine uptake. Thus, those who did not have a usual source of healthcare may miss out on opportunities to learn about preventive care and have discussions with their providers. This may lead to fewer opportunities to learn about and receive HPV preventive care, both for themselves and for their children (Vulnerable populations, 2006). Findings from another recent study in a similar population suggested that targeting community healthcare

centers and clinics may be effective in facilitating increased HPV preventive care, specifically screening and vaccination, in this population (Amboree et al., 2022).

6.1. Limitations

The findings from our study should be interpreted with some limitations in mind. First, the inherent biases that come with RDS data (Gile and Handcock, 2010) apply to our study. Cross-sectional studies are limited by temporal ambiguity and no ability to assess causation (Levin, 2006). Interview data is subject to information biases, specifically recall bias as the participant may not remember being vaccinated during childhood or adolescence. The use of the standardized NHBS questionnaire does, however, increase the internal validity of this study (Cataldo et al., 2019). Additionally, due to the changes in HPV vaccine recommendations in the U.S., with vaccination first only being offered to females (2006), then males (2011), and most recently older adults based on patient-provider decision-making (2018) (Meites et al., 2019), the older adults in the current analysis may not have had the opportunity to discuss catch-up vaccination options with their providers. Further, self-reported vaccination status has been shown to be racially biased, with Black, Hispanic, and Asian populations less likely to self-report vaccine initiation (Spencer et al., 2019; Vu et al., 2019). Lastly, the indicator used to estimate HPV vaccine uptake in this study focuses on having received at least one dose of the vaccine rather than completion of all recommended doses.

7. Conclusions

Our findings suggest very low prevalence of HPV vaccination in this high-risk population and a lack of regular preventive care utilization. HPV vaccination is a complex issue with many contributing factors, especially in high-risk populations with limited access to healthcare services. More research is needed on how to effectively target these populations to not only increase vaccination, but to mitigate barriers that attribute to low awareness and suboptimal vaccination uptake. Additionally, our findings suggest significant challenges to progress made in HPV preventive care in the U.S. As research is conducted on the general U.S. population to assess progress toward national targets, high-risk hidden populations may often be left out. Consequently, general population estimates of HPV prevention may be inflated while vaccine uptake in these vulnerable populations remains sparse, leading to

Table 3
Weighted and Unweighted Modified Poisson Regression Models of HPV Awareness among the High-Risk Heterosexual Population.

Characteristic	Awareness of HPV					
	PR (95% CI)	P-value	aPR (95% CI) ^a	Adjusted P-value	aPR (95% CI) ^b	Adjusted P-value
Age, continuous	1.01 (0.98–1.03)	0.52	1.00 (0.98–1.02)	0.87	1.00 (0.99–1.01)	0.67
Age categorical						
18–26	0.79 (0.55–1.15)	0.22	—	—	—	—
27–45 (Ref)	1.00		—	—	—	—
Sex						
Male (Ref)	1.00		1.00		1.00	
Female	1.45 (1.22–1.72)	<0.0001****	1.25 (1.06–1.49)	0.009**	1.37 (1.15–1.62)	0.0003***
Race/ethnicity						
White/other (Ref)	1.00		1.00		1.00	
Black	0.68 (0.59–0.78)	<0.0001****	0.66 (0.47–0.92)	0.01*	0.61 (0.48–0.78)	<0.0001****
Hispanic	0.55 (0.36–0.85)	0.007**	0.48 (0.28–0.82)	0.008**	0.48 (0.30–0.76)	0.002**
Education						
Less than HS diploma (Ref)	1.00		1.00		1.00	
HS diploma or equivalent	1.16 (0.95–1.41)	0.15	0.94 (0.74–1.20)	0.63	1.16 (0.84–1.59)	0.37
Some college or above	1.79 (1.41–2.27)	<0.0001****	1.22 (0.81–1.86)	0.34	1.39 (1.07–1.82)	0.01*
Health insurance type						
No health insurance (Ref)	1.00		1.00		1.00	
Private plan/Other	1.42 (1.12–1.81)	0.004**	1.05 (0.93–1.18)	0.45	1.06 (0.96–1.17)	0.23
Public plan	1.36 (1.05–1.75)	0.02*	1.29 (1.11–1.50)	0.0007***	1.08 (0.98–1.20)	0.13
Poverty						
Above poverty level (Ref)	1.00		1.00		1.00	
Below poverty level	0.67 (0.60–0.75)	<0.0001****	0.74 (0.61–0.89)	0.001**	0.83 (0.75–0.92)	0.0005****
Homelessness						
Never homeless (Ref)	1.00		1.00		1.00	
Currently homeless	1.06 (0.72–1.55)	0.77	1.07 (0.70–1.64)	0.75	0.85 (0.58 – 1.26)	0.42
Has been, but not currently homeless	1.40 (1.15–1.70)	<0.001***	1.39 (1.04–1.86)	0.03*	1.18 (1.00 – 1.38)	0.05
Incarceration						
Never incarcerated (Ref)	1.00		1.00		1.00	
Incarcerated, but not within past 12 months	0.84 (0.60–1.17)	0.29	1.18 (0.64–2.15)	0.59	1.02 (0.74–1.41)	0.89
Incarcerated within past 12 months	0.78 (0.67–0.91)	<0.01**	1.12 (0.68–1.85)	0.64	1.22 (1.01–1.47)	0.04*
Source of healthcare						
No usual source of healthcare (Ref)	1.00		1.00		1.00	
Clinic or health care center	1.48 (1.29–1.70)	<0.0001****	1.35 (1.20–1.51)	<0.0001****	1.19 (1.00–1.43)	0.05
Doctor's office or HMO	1.53 (1.26–1.85)	<0.0001****	1.35 (1.08–1.69)	0.009**	1.10 (0.90 – 1.35)	0.35
Healthcare provider visit						
Within past year	1.00		—	—	—	—
1–2 years ago	0.92 (0.72–1.17)	0.47	—	—	—	—
2 + years ago	1.01 (0.71–1.43)	0.97	—	—	—	—
Homelessness*Incarceration (interaction)						
Never homeless*never incarcerated	1.00		1.00		1.00	
Currently homeless*incarcerated but not in the past 12 months	0.87 (0.48–1.56)	0.63	0.87 (0.48–1.56)	0.64	0.67 (0.41–1.10)	0.11
Currently homeless*incarcerated in the past 12 months	0.80 (0.50–1.26)	0.33	0.87 (0.43–1.77)	0.70	1.03 (0.69–1.54)	0.89
Has been, but not currently homeless*incarcerated but not in the past 12 months	1.12 (0.82–1.53)	0.47	1.11 (0.76–1.63)	0.58	1.00 (0.76–1.30)	0.98
Has been, but not currently homeless*incarcerated in the past 12 months	1.44 (1.24–1.66)	<0.0001****	1.61 (1.33–1.95)	<0.0001****	1.47 (1.26–1.72)	<0.0001****

aPR, adjusted prevalence ratio; CI, confidence interval; PR, prevalence ratio.

^a Model adjusted with RDS-weights.

^b Model not adjusted with RDS-weights.

Boldface indicates statistical significance (**p* < 0.05, ***p* < 0.01, ****p* < 0.001, *****p* < 0.0001).

Table 4
Weighted and Unweighted Modified Poisson Regression of HPV Vaccine Uptake among the High-Risk Heterosexual Population.

Characteristic	HPV Vaccine Uptake					
	PR (95% CI)	P-value	aPR (95% CI) ^a	Adjusted P-value	aPR (95% CI) ^b	Adjusted P-value
Age, continuous	0.94 (0.90–0.98)	<0.01**	0.91 (0.89–0.93)	<0.0001****	0.94 (0.92–0.97)	0.0001***
Age categorical						
18–26	1.46 (0.58–3.69)	0.42	—	—	—	—
27–45 (Ref)	1.00		—	—	—	—
Sex						
Male (Ref)	1.00		1.00		1.00	
Female	3.78 (2.01–7.11)	<0.0001****	2.87 (1.81–4.55)	<0.0001****	2.12 (1.52–2.97)	<0.0001****
Race/ethnicity						
White/other (Ref)	1.00		1.00		1.00	
Black	0.33 (0.19–0.57)	<0.0001****	0.23 (0.12–0.46)	<0.0001****	0.72 (0.46–1.12)	0.15
Hispanic	0.35 (0.14–0.86)	0.02*	0.24 (0.05–1.13)	0.07	0.66 (0.20–2.15)	0.49
Education						
Less than HS diploma (Ref)	1.00		1.00		1.00	
HS diploma or equivalent	1.48 (0.83–2.64)	0.18	0.86 (0.45–1.64)	0.65	1.24 (0.45–3.44)	0.68
Some college or above	4.41 (1.86–10.45)	<0.001***	2.18 (0.89–5.35)	0.09	2.47 (0.80–7.68)	0.12
Health insurance type						
No health insurance (Ref)	1.00		1.00		1.00	
Private/other plan	2.71 (1.70–4.30)	<0.0001****	0.74 (0.57–0.97)	0.03*	0.92 (0.41–2.05)	0.84
Public plan	1.57 (1.15–2.15)	0.005**	0.88 (0.67–1.17)	0.38	0.90 (0.71–1.15)	0.41
Poverty						
Above poverty level (Ref)	1.00		1.00		1.00	
Below poverty level	0.48 (0.25–0.90)	0.02*	0.54 (0.27–1.10)	0.09	0.67 (0.43–1.03)	0.07
Homelessness						
Never homeless (Ref)	1.00		—	—	—	—
Currently homeless	1.30 (0.72–2.33)	0.39	—	—	—	—
Has been, but not currently homeless	0.46 (0.08–2.84)	0.41	—	—	—	—
Incarceration						
Never incarcerated (Ref)	1.00		1.00		1.00	
Incarcerated, but not within past 12 months	0.51 (0.33–0.80)	<0.01**	0.97 (0.63–1.49)	0.88	1.35 (0.68–2.70)	0.39
Incarcerated within past 12 months	0.78 (0.36–1.66)	0.52	1.37 (1.10–1.70)	0.005**	1.74 (1.07–2.83)	0.03*
Source of healthcare						
No usual source of healthcare (Ref)	1.00		1.00		1.00	
Clinic or health care center	3.25 (1.06–9.99)	0.04*	2.19 (1.08–4.43)	0.03*	2.49 (1.16–5.37)	0.02*
Doctor's office or HMO	6.94 (3.24–14.86)	<0.0001****	5.69 (3.42–9.47)	<0.0001****	3.84 (1.83–8.04)	0.0004***
Healthcare provider visit						
Within past year (Ref)	1.00		1.00		1.00	
1–2 years ago	0.73 (0.22–2.42)	0.61	0.89 (0.24–3.37)	0.87	0.93 (0.50–1.71)	0.81
2 + years ago	0.12 (0.07–0.23)	<0.0001****	0.41 (0.18–0.98)	0.04*	0.75 (0.27–2.03)	0.57

aPR, adjusted prevalence ratio; CI, confidence interval; PR, prevalence ratio.

^a Model adjusted with RDS-weights.

^b Model not adjusted with RDS-weights.

Boldface indicates statistical significance (**p* < 0.05, ***p* < 0.01, ****p* < 0.001, *****p* < 0.0001).

exacerbated HPV-related cancer health disparities (Budhwani and De, 2017; Kobetz et al., 2010; Korngiebel et al., 2015; Holland and Palaniappan, 2012).

CRedit authorship contribution statement

Trisha L. Amboree: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Jane R. Montealegre:** Conceptualization, Supervision, Writing – review & editing. **Paige Padgett Wermuth:** Methodology, Writing – review & editing. **Osaro Mgbere:** Conceptualization, Writing – review & editing. **Kayo Fujimoto:** Methodology, Writing – review & editing. **Charles Darkoh:** Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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