RESEARCH ARTICLE

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Using Structural Equation Modelling to Explore the Relationship Between Patient-Centered Communication, Human Papilloma (HPV)-related Knowledge, and Perceived Effectiveness of the HPV Vaccine

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Abstract

Background: Patient-centered communication has emerged as a potent strategy for increasing vaccine uptake. Drawing on evidence-based paths established from previous studies, our study examines the relationship between patient-centered communication, HPV knowledge and perceived HPV vaccine effectiveness. We also explored the sociodemographic factors impacting patient-centered communication, HPV knowledge and perceived HPV vaccine effectiveness. **Methods:** We analyzed data from the Health Information National Trends Survey (HINTS) 5, Cycle 1, ran Structural equation modeling (SEM) to test the pathways in our conceptual framework. **Results:** Our sample comprised 2522 adults aged 18-79 (mean age 47.98 years) who were predominantly Non-Hispanic White (67.65%), female (53.31%), and heterosexual (95.12%). The model fit statistics for the final structural model indicated a good fit [RMSEA= 0.039, CFI=0.99 TLI= 0.99, and SRMR =0.070]. The path linking patient-centered communication to HPV knowledge (β=0.011, $p<0.05$), and the knowledge-mediated path linking patient-centered communication to HPV vaccine effectiveness (β=0.007, $p<0.05$) were found to be statistically significant. **Conclusion:** HPV researchers must delve deeper into patient-centered communication practices to improve vaccine uptake. Tailoring conversations to individual needs and preferences is key to enhancing HPV knowledge, and ultimately improve perceptions of HPV vaccine effectiveness and increase its acceptability.

Keywords: HPV- patient-centered communication- HPV knowledge- vaccine effectiveness

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Introduction

The Human Papillomavirus (HPV) is the most prevalent sexually transmitted infection in the United States, affecting approximately 43 million individuals [1]. Left untreated, persistent high-risk HPV infections have the potential to stimulate oncogenic progression, eventually leading to HPV-associated cancers [2]. Launched in 2006, the HPV vaccine, the 9-valent Gardasil 9 currently offers protection against both high-risk (HPV 16, 18, 31, 33, 45, 52, 58), and low-risk (HPV 6 and 11) strains [3]. However, despite the proven benefits of HPV vaccination, initiation rates among U.S. adolescents remain unacceptably low, with only 65.5% having ≥ 1 dose coverage [4].

In the context of HPV vaccine uptake, quality patient-provider communication has been cited as a powerful influencer in improving vaccination uptake [5]. Notably, patient-provider communication has evolved significantly over time, transitioning from a paternalistic, provider-driven approach to an increasingly collaborative and patient-centered format [6]. Patient-centered communication plays a pivotal role in understanding and addressing the factors affecting HPV vaccine uptake [7], and focuses on respecting patients' preferences, needs, and values during medical visits and promoting their equal participation in decision-making [8, 9]. Additionally, it prioritizes patient decision-making autonomy, especially when healthcare options are complex and lack professional consensus [5].

Research has consistently supported the role of HPV knowledge in predicting HPV vaccine uptake [10, 11] Galbraith et al., 2016; [12]. Parents, who play a pivotal role in deciding on vaccines for their children, stand to gain valuable insights from understanding the potential consequences of untreated HPV infections (Wittenborn et al., 2022). Furthermore, comprehensive knowledge about HPV-related cancers becomes particularly vital for

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men who have sex with men, who have higher risk of developing HPV-associated anal cancers [13].

Perceived effectiveness of the HPV vaccine, which measures people's belief in the vaccine's ability to reduce HPV infection or prevent cervical cancer, is another important predictor of vaccine uptake. Higher perceived effectiveness of the HPV vaccine is associated with more favorable vaccination intentions for both vaccine-eligible women and parents/guardians of adolescent girls [14]. Perceived vaccine effectiveness is especially crucial among parents, who often prioritize it as the most important attribute of an acceptable sexually transmitted infection vaccine (Mays et al., 2011). In this paper, we have used the term "vaccine acceptability" interchangeably with the perceived effectiveness of the HPV vaccine.

To explore the relationship between patient-centered communication, HPV knowledge and perceived effectiveness of the HPV vaccine, we devised a conceptual framework grounded in evidence-based literature. The patient-centered component in our framework is based on Epstein and Street's. [15] model of patient-centered communication (Figure 1), which encompasses essential functions such as information exchange, emotion recognition, decision-making, patient self-management, the establishment of healing relationships, and the management of uncertainty, as illustrated in Figure 1.We also incorporated a cross-cutting function introduced by McCormack et al. [16], which focuses on the quality of communication interaction within a team care model. The literature supporting the pathways in our conceptual framework has been discussed below.

Patient-centered communication, as elucidated by Joseph et al. [17], plays a pivotal role in enhancing HPV knowledge, fostering a better understanding of the threat related to HPV and increasing their willingness to accept the HPV vaccine [18-20]. In their mediation analysis study, Niu et al. [21] reported a direct and positive association between patient-centered communication and HPV knowledge, as well as between HPV knowledge and perceived HPV vaccine effectiveness. Similarly, Joseph's et al. [17] client-centered motivational intervention significantly improved HPV knowledge among mothers of vaccine-eligible daughters; however, this heightened knowledge did not translate into increased acceptance of the HPV vaccine.

Building upon these findings, our study seeks to elucidate both the direct and indirect dynamics related to perceived effectiveness of the HPV vaccine, as depicted in Figure 1. Our model encompasses three primary constructs, and socio-demographic factors relevant to the three constructs. Developing a socio-demographically informed model will highlight existing health disparities and assist future researchers in designing interventions to bridge these gaps. Based on the existing literature, we propose the following associations: 1) a direct and positive link between patient-centered communication and HPV knowledge; 2) a direct relationship between HPV knowledge and HPV vaccine acceptability; 3) a direct and positive relationship between patient-centered communication and HPV vaccine acceptability. We also hypothesize an indirect, HPV knowledge-mediated association between patient-centered communication and perceived effectiveness of the HPV vaccine.

Overall, we aim to explore the direct and indirect relationships between patient-centered communication, HPV knowledge, and perceived effectiveness of the HPV vaccine. Our study will also explore sociodemographic predictors that are relevant to the three constructs.

Materials and Methods

Sample

We used the National Cancer Institute's (NCI) Health Information National Trends Survey (HINTS) 5, Cycle 1 data [22]. HINTS is a nationally representative survey that collects data on the American public's knowledge of, attitudes toward, and use of health-related information (HINTS, n.d.). The data for HINTS 5, Cycle 1 was collected between January 2017 and May 2017. The questionnaires were distributed exclusively via mail, with a $2 pre-paid monetary incentive to promote participation. With an overall response rate of 32.4%, 3,285 respondents completed the survey.

Only participants who reported visiting a doctor, nurse or other health professional at least once in the past year were directed to questions concerning patient-centered communication. Resultantly, our final sample for this study is restricted to N=2,522 participants aged 18-79 who had visited a health professional at least once in the past year.

Measures

Knowledge. The six HPV knowledge measures for our study have been extensively used to assess HPV knowledge in previous publications from the HINTS 5, Cycle 1 iteration [23]Lee et al., 2022; [24]. Survey respondents were first asked "Have you ever heard of HPV?". Those who responded "yes" were directed to the six HPV knowledge questions: (1-4) Do you think HPV can cause (cervical/penile/anal/oral) cancer? (5) Do you think HPV is a sexually transmitted disease (STD)? (6) Do you think HPV requires medical treatment or will it usually go away on its own without treatment? For the first five knowledge questions, yes/ no/ not sure were the three response options. The sixth HPV knowledge question was a binary variable with correct/ incorrect response options. For uniformity, we dichotomized the six knowledge questions to generate a binary response variable. Response options "no/ don't know/ not sure" were considered incorrect responses and coded as 0. Response option "yes" was coded as 1, denoting correct response. It must be noted that survey respondents who had not heard of HPV did not answer the subsequent HPV knowledge questions. Therefore, the six HPV knowledge questions were deemed incorrect and recoded as 0 for survey participants who responded "no" to "Have you ever heard of HPV" [24].

Patient-centered communication. The following seven questions capturing patient-centered communication in the HINTS 5, Cycle 1 questionnaire and corresponding functions of McCormack et al.'s [16] patient-centered communication framework (in parentheses): (1) give you the chance to ask all the health-related questions you

had? (exchanging information), (2) give the attention you needed to your feelings and emotions? (responding to emotions), (3) involve you in decisions about your health care as much as you wanted? (making decisions), (4) make sure you understood the things you needed to do to take care of your health? (enabling patient self-management), (5) explain things in a way you could understand? (fostering healing relationship), (6) spend enough time with you? (length of time with provider), (7) Help you deal with feelings of uncertainty about your health or health care? (managing uncertainty). The responses were measured on four-point Likert scale originally ranging from 1 (Always) to 4 (Never). We reverse-coded the items such that higher scores indicated better self-reported of quality of patient-centered communication (1= Never, 2= Sometimes, 3= usually, and 4= Always).

HPV vaccine effectiveness. The HINTS 5, cycle 1 survey measures perceived effectiveness of the HPV vaccine via the following question "In your opinion, how successful is the HPV vaccine at preventing cervical cancer?". The responses are measured on a scale of 1-5 (1= Not at all successful, 2=a little successful, 3= pretty successful, 4= Very successful, 5=Don't know). We dichotomized response options 1, 2 and 5 as 0, and response options 4 and 5 as 1.

Data analysis

We used Mplus Editor 8.8 [25] for modelling and Stata (version S.E. 17.0, College Station, Texas), for data cleaning, preparation, and descriptive analysis. We used structural equation modeling (SEM) to test our hypothesized conceptual model (Figure 1). SEM is a powerful, multi-step analytical technique that successfully investigates complex, multivariate direct/indirect causal relationships within theory-supported models [26, 27]. SEM combines factor analysis and multiple regression to analyze the structural relationships between measured variables and latent constructs [28]. Our model development involved two steps. First, we used confirmatory factor analysis (CFA) to examine the relationship between our latent constructs (knowledge and patient-centered communication) and their respective, underlying indicators [29]. Next, we constructed a full-scale structural model to check if our proposed model approximates/fits the data.

Given the categorical nature of our response variables, we implemented the weighted least squares (WLSMV) method to estimate the parameters [30, 31]. To accommodate the complex survey design and provide accurate representation of the U.S. population, we weighted data from HINTS 5, Cycle 1 as per the suggested analytical recommendations [32]. The weighting procedure comprised calculating household-level base weights, adjusting for household nonresponse, calculating person-level initial weights, and calibrating of person-level weights to population counts. The jackknife variance estimation technique was used to calculate replicate weights [33]. We used Stata (version S.E. 17.0, College Station, Texas) to obtain weighted proportions of our demographic variables; and accounted for weights in all our analyses [28]. We assessed the comparative fit index (CFI), Tucker–Lewis Index (TLI), root mean square error of approximation (RMSEA) and Standardized Root Mean Square Residual (SRMR) indices for the goodness of fit analysis. RMSEA values less than 0.08, CFI (Comparative Fit Index) and Tucker–Lewis Index (TLI) above 0.95, and Standardized Root Mean Square Residual (SRMR) values below 0.08 were used as reference to determine our model's fit [34-36].

Results

Descriptive Statistics

The study's sample characteristics are illustrated in Table 1. The study sample comprised N=2,522 participants aged 18-79, who visited a provider at least once in the past 12 months. We employed sample and replicate weights to derive weighted proportions, such that the estimates aptly represent the U.S population. Our sample is predominantly Non-Hispanic White (67.65%), females (53.31%), married (58.09%), heterosexual (95.12%); with at least college education (70.00%). The majority were employed (60.95%) and reported an income of $50,000 or more (58.83%). Corresponding with the recent Advisory Committee on Immunization Practices (ACIP) recommendation for HPV uptake, we categorized age into three groups: 18-26, 27-45, 46 and older. Briefly, in 2019 ACIP expanded its HPV vaccine guidelines to include routine vaccination for all adults aged 18-26, and at-risk individuals aged 27-45, upon shared and judicious decision-making with the provider [37]. With a mean age of 47.98 years and 89% participants aged 27-79, our sample represents a robust group HPV vaccine decision-makers for teens and pre-teens. Table 2 describes weighted characteristics for patient-centered, HPV knowledge and perceived HPV vaccine effectiveness. Participants elicited favorable perceptions of patient-centered communication. Majority of the participants indicated "always", with respect to the following patient-centered communication response options gave chance to ask questions (61.58%), addressed feelings (51.02%), involved in decisions (53.20%), understand next steps (63.17%), explained clearly (65.12%), spent enough time (48.72%), deal with uncertainty (45.28%). HPV knowledge was surprisingly low among our participants. The average proportion of participants who responded correctly to the HPV knowledge questions was 36.19%.

Confirmatory factor analysis

We evaluated the goodness of fit of the two latent constructs, HPV knowledge and patient-centered communication independently. Our initial results suggested acceptable fitness for both patient-centered communication (RMSEA= 0.08; SRMR=0.22; CFI=0.99, TLI=0.98) and HPV knowledge (RMSEA= 0.09; SRMR=0.10; CFI=0.98, TLI=0.98). Based on suggested modification indices for the latent variable patient-centered communication, we incorporated the paths denoted in Figures 2 and 3. Upon modifying the model by adding the recommending paths, our model fits for both patient-centered communication (RMSEA= 0.04; SRMR=0.020; CFI=0.98, TLI=0.99) and knowledge

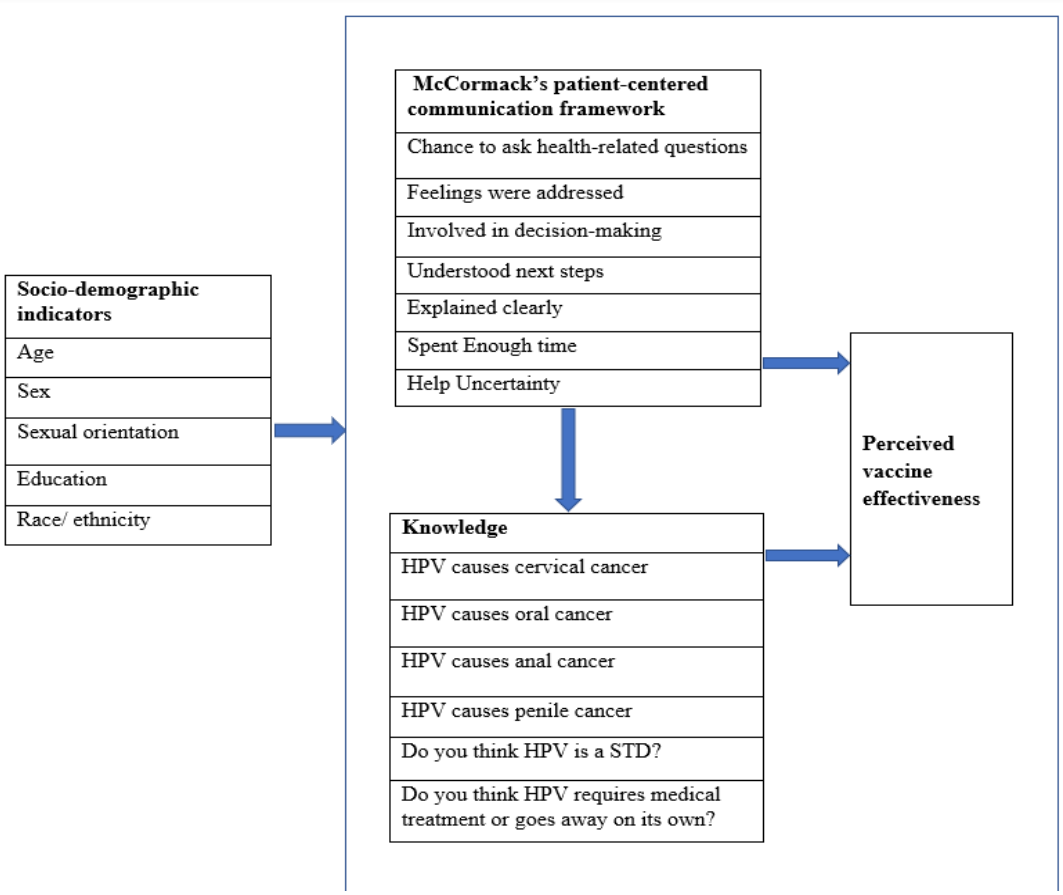

Figure 1. Conceptual Framework

(RMSEA= 0.05; SRMR=0.024; CFI=0.99, TLI=0.99) and improved dramatically. The model fit indices for patient-centered communication and HPV knowledge are presented in Table 3.

Figure 2 illustrates the one-factor model for patient-centered communication, with the latent variable (patient-centered communication) manifested by seven observed variables. The path coefficients between patient-centered communication and its underlying observed indicators show statistical significance at 0.05 or lower. With factor loadings ranging between β =0.86 and β =0.90, CFA results for patient-centered communication indicate a robust latent structure and a good fit with the data. All seven observed variables were positively

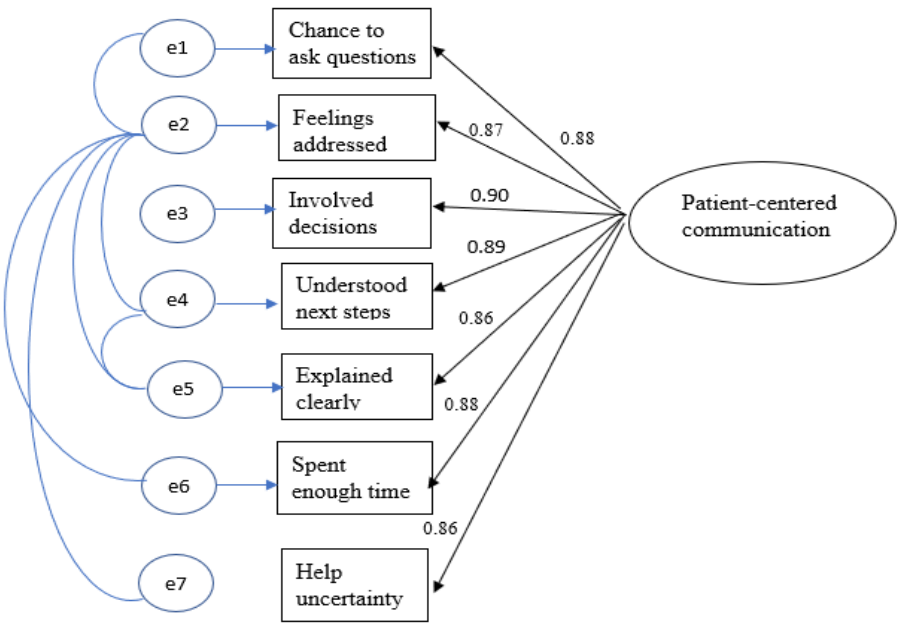

Figure 2. Confirmatory Factor Analysis for Patient-Centered Communication

Table 1. Sample Characteristics for Participants 79 or Younger Who Visited a Provider At Least Once in The Last Year; N= 2,522

Characteristic	N	Weighted proportion
Age [Mean: 47.98 (S.E. ± 0.40)]		
18-26	91	11.40%
27-45	568	30.60%
46-79	1,845	58.10%
Sex		
Female	1,468	53.30%
Male	956	46.70%
Sexual orientation		
Straight/ heterosexual	2,327	95.10%
Gay/Lesbian	61	3.50%
Bisexual	39	1.40%
Race/ ethnicity		
Non-Hispanic White	1,518	67.70%
Non-Hispanic Black	328	10.10%
Hispanic	308	14.50%
Non-Hispanic Asian	98	4.80%
Others	96	2.90%
Marital status		
Married	1,447	58.10%
Unmarried	1,050	41.90%
Education		
Less than high school	139	7.20%
High school	445	22.80%
Some college	750	33.10%
Bachelors	694	22.80%
Post bachelors	478	14.00%
Employment status		
Employed	1,322	60.90%
Unemployed	93	5.90%
Others (Student/ Retired/ Disabled/ Homemaker)	1,041	33.10%
Income		
Less than $35,000	764	28.30%
$35,000 - $49,000	297	12.80%
$50,000 - $75,000	461	20.00%
Above $75,000	983	38.90%

associated with patient-centered communication.

Figure 3 presents the one-factor model for HPV knowledge, with the latent variable (patient-centered communication) manifested by six observed variables. The path coefficients between HPV knowledge and its underlying indicators show statistical significance at 0.05 or lower. Like patient-centered communication, the factor loading values for HPV knowledge (β =0.67 to β =0.99) indicate adequate fitness with the data. All six observed variables were positively associated with the HPV knowledge latent variable.

Table 2. Weighted Characteristics for Patient-Centered, HPV Knowledge and Perceived HPV Vaccine Effectiveness; N= 2,522

Characteristic	N	Weighted proportion
Patient-centered communication		
Provider gave the chance to ask questions		
Always	1,597	61.60%
Usually	658	27.20%
Sometimes	222	10.40%
Never	29	0.80%
Provider addressed feelings		
Always	1,236	51.20%
Usually	770	30.00%
Sometimes	368	14.40%
Never	116	4.50%
Provider involved in decisions		
Always	1,361	53.20%
Usually	768	32.00%
Sometimes	312	12.90%
Never	53	1.80%
Provider helped understand next steps		
Always	1,567	62.60%
Usually	718	28.60%
Sometimes	199	7.90%
Never	19	0.80%
Provider explained clearly		
Always	1,618	65.10%
Usually	716	29.20%
Sometimes	146	5.10%
Never	15	0.60%
Provider spent enough time		
Always	1,246	48.70%
Usually	819	32.50%
Sometimes	353	16.10%
Never	77	2.60%
Provider helped deal with uncertainty		
Always	1,117	44.70%
Usually	803	32.10%
Sometimes	373	14.90%
Never	164	6.60%
HPV knowledge		
HPV causes cervical cancer		
Yes	1,359	56.30%
No	1,128	43.70%
HPV causes anal cancer		
Yes	485	19.20%
No	1,944	80.80%
HPV causes oral cancer		
Yes	547	21.30%
No	1,887	78.70%
HPV causes penile cancer		
Yes	544	21.40%
No	1,833	78.60%

Table 2. Continued

Characteristic	N	Weighted proportion
HPV requires medical treatment or will it usually go away on its own?		
Yes	1,496	62.60%
No	971	37.40%
HPV is a sexually transmitted disease?		
Yes	1,119	46.70%
No	1,371	53.30%
Perceived effectiveness of the HPV vaccine		
In your opinion, how successful is the HPV vaccine at preventing cervical cancer?		
Successful (Pretty successful/ very successful)	673	28.60%
Not successful (Don't know/ not at all successful/ a little successful)	1,807	71.40%

Structural model

Our final structural model was identified based on the t-rule [38]: total parameters estimated (n=100) was less than (22 × 22+1)/2=253, where 22 represents the total number of observed variables. The RMSEA [0.039; (95% C.I. 0.037 to 0.042)], CFI (0.99), TLI (0.99), and SRMR (0.070) statistics denote a good fit with the observed data. Table 4 describes the Goodness of Fit indices for the full-scale structural model. Socio-demographic factors affecting patient-centered and communication knowledge, perceived HPV vaccine effectiveness.

Results in Table 5 depict the relationship between the sociodemographic indicators and the three constructs. The significant relationships are illustrated in Figure 4. Briefly, HPV knowledge has a statistically significant, positive association with age group 18-45 (β = 0.201, p=0.000). Being a male (-0.193, p=0.000), straight (β = -0.070, p=0.001), Non-Hispanic Black relative to Non-Hispanic Whites (β = -0.074, p=0.004) and Hispanic relative to Non-Hispanic Whites (β = -0.064, p=0.014) negatively predict HPV knowledge. Patient-centered communication is statistically significant and negatively associated with age group 18-45 (β = -0.066, p=0.003), being Asian relative to Non-Hispanic Whites (β = -0.112, p=0.000) and being a minority group (Native Hawaiian/ Guamanian/ Samoan/Other Pacific Islander (β = -0.064, p=0.023). Interestingly, compared to previous theoretical evidence, we observed no other statistically significant relationship

Table 3. Goodness of fit CFA Results for the Latent Variables Patient-Centered Communication and HPV Knowledge

Statistic	Estimate
Patient-centered communication	
RMSEA	0.048
CFI	0.997
TLI	0.995
SRMR	0.021
HPV knowledge	
RMSEA	0.045
CFI	0.999
TLI	0.996
SRMR	0.024

Table 4. Goodness of fit CFA Results for the Full-Scale Structural Model

Statistic	Estimate
RMSEA	0.039
CFI	0.993
TLI	0.991
SRMR	0.071

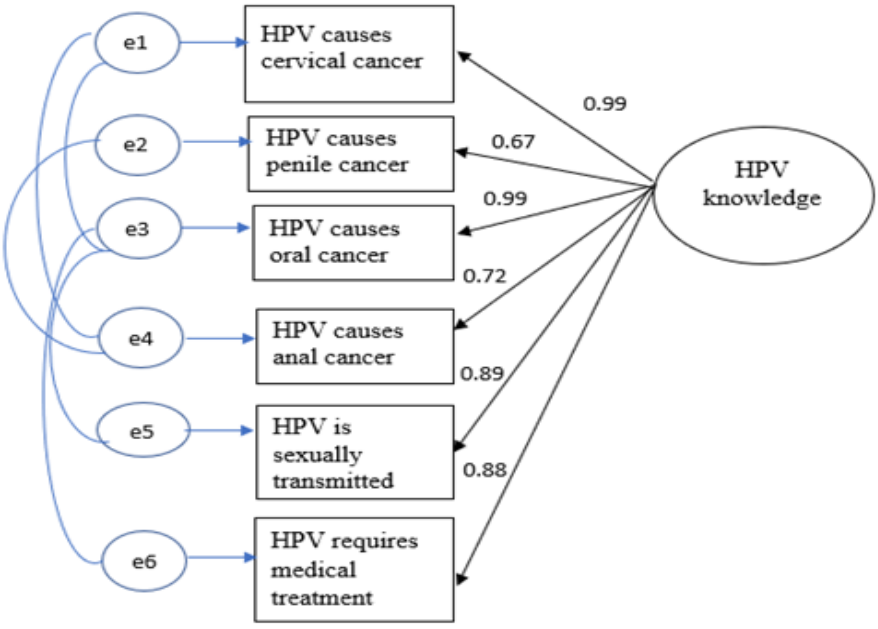

Figure 3. Confirmatory Factor Analysis for HPV Knowledge

Table 5. Standardized (β) Path Coefficients for HPV Knowledge, Patient-Centered Communication, and Perceived HPV Vaccine Effectiveness

Characteristic		β	S.E.	P-value
Age (18-45)	Patient-centered communication	-0.066	0.022	**0.003**
	HPV knowledge	0.201	0.02	**0.000**
	Perceived effectiveness of HPV vaccine	0.052	0.025	**0.038**
Sex (Male)	Patient-centered communication	0.02	0.023	**0.389**
	HPV knowledge	-0.193	0.022	**0.0000**
	Perceived effectiveness of HPV vaccine	-0.02	0.025	0.425
Sexual orientation (Straight/heterosexual)	Patient-centered communication	0.004	0.023	0.858
	HPV knowledge	-0.07	0.022	**0.001**
	Perceived effectiveness of HPV vaccine	-0.112	0.023	0.644
Race/ethnicity				
Non-Hispanic Black	Patient-centered communication	0.032	0.026	0.223
	HPV knowledge	-0.074	0.026	**0.004**
	Perceived effectiveness of HPV vaccine	-0.112	0.03	**0.0000**
Hispanic	Patient-centered communication	-0.024	0.025	0.345
	HPV knowledge	-0.064	0.026	**0.014**
	Perceived effectiveness of HPV vaccine	-0.05	0.026	0.219
Asian	Patient-centered communication	-0.112	0.029	**0.0000**
	HPV knowledge	-0.07	0.037	0.055
	Perceived effectiveness of HPV vaccine	-0.001	0.037	0.985
Others	Patient-centered communication	-0.064	0.028	**0.023**
	HPV knowledge	0.005	0.031	0.863
	Perceived effectiveness of HPV vaccine	-0.052	0.037	0.159
Education				
Some college or more	Patient-centered communication	0.006	0.022	0.785
	HPV knowledge	0.243	0.022	**0.0000**
	Perceived effectiveness of HPV vaccine	0.114	0.029	**0.0000**

between other socio-demographic indicators and patient-centered communication [39, 22]. Perceived effectiveness of the HPV vaccine is positively related to age 18-45 (β = 0.052, p=0.038), and attending some college at least (β=0.114, p=0.000). Relative to Non-Hispanic Whites, being Non- Hispanic Black (β=-0.112, p=0.000) is statistically significant and negatively associated with perceived effectiveness of the HPV vaccine.

Direct, indirect, and total effects

Table 6 presents the direct and indirect paths discussed in our study. Results support the hypothesis regarding the paths directly linking HPV Knowledge → HPV vaccine effectiveness (β=0.633; p=0.026), and patient-centered communication → HPV vaccine effectiveness (β=0.063; p=0.024). However, our model does not produce statistical significance in the direct path linking patient-centered communication to HPV knowledge (β=0.011; p=0.638), and the indirect path linking patient-centered communication and HPV vaccine effectiveness, mediated by HPV knowledge (β=0.007; p=0.637).

Discussion

This study explores the association between patient-centered communication, HPV knowledge and perceived

Table 6. Direct and Indirect Paths Discussed

Path	Standardized β	S.E.	P-value
Direct effect			
Patient-centered communication à HPV knowledge	0.011	0.024	0.638
Patient-centered communication àHPV vaccine effectiveness	0.063	0.029	**0.026**
HPV Knowledge à HPV vaccine effectiveness	0.633	0.022	**0.024**
Indirect effect			
Patient-centered communication à HPV knowledge àHPV vaccine effectiveness	0.007	0.015	0.637
Total effect	0.07	0.031	**0.023**

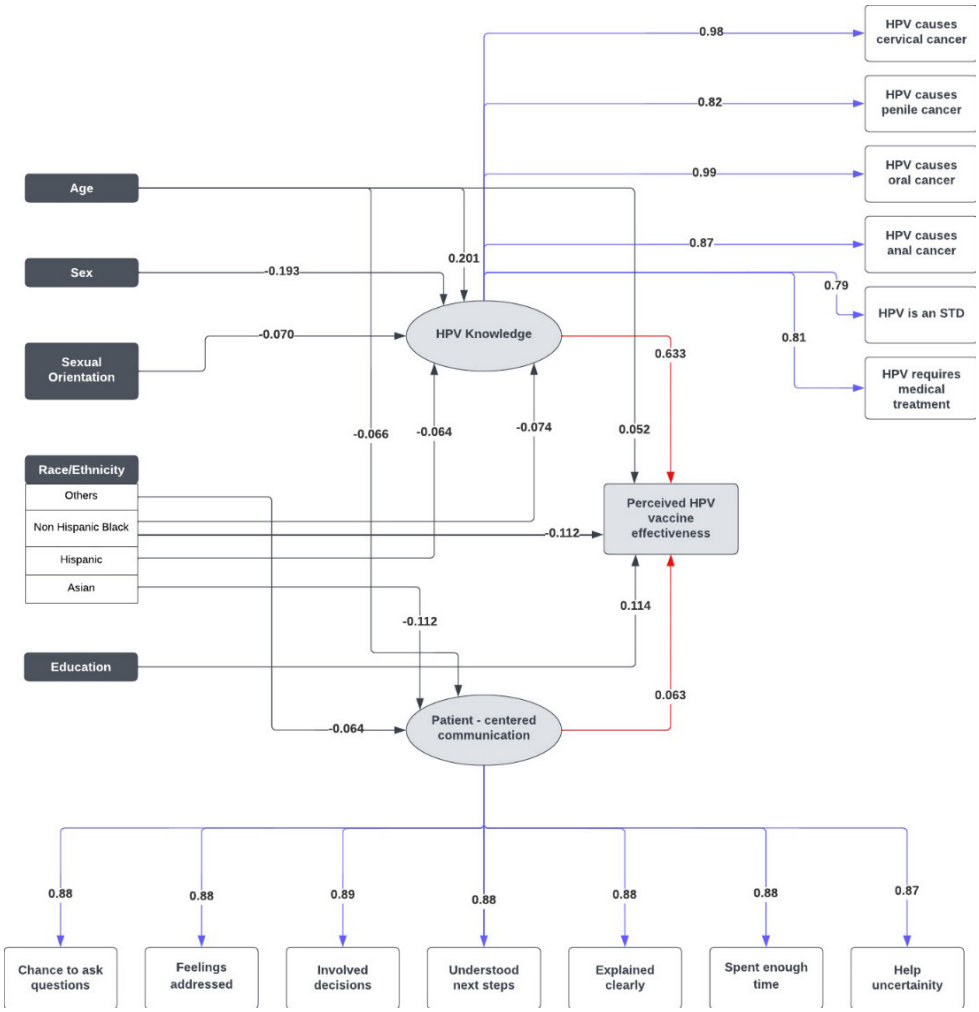

Figure 4. Statistically Significant Pathways Illustrating the Relationship between Sociodemographic Factors, Patient-Centered Communication, HPV Knowledge and Perceived HPV Vaccine Effectiveness

HPV vaccine effectiveness. Similar to findings from De Voe et al' [40], our study suggests that younger patients have a negative perception of patient centered communication. Younger patients display stronger negative emotions to diagnoses and do not respond well to reassurance and comfort from the providers [22]. Thus, they are likely hold a discontented view of their interaction with the provider and rate their patient-centered experience as subpar. Second, the degree of involvement with the healthcare system is another plausible explanation for age-oriented differences in patient-centered communication. As an instance, increased frequency of office visits due to age-related physical and cognitive health conditions demands greater engagement with the healthcare system. With increased experience interacting with providers, patients can adeptly navigate and partake in shared decision-making and exchanging information, and over time foster a good rapport with the provider. Therefore, relative to their younger counterparts, older patients garner a fulfilling patient-centered experience [40]. Like previous work, compared to Asians and other racial/ethnic minorities are less likely to report favorable patient-centered communication experiences [41, 39]. Inadequacies in cultural sensitivity and language discordance often lead to poorly perceived health care interactions. Therefore, patient- provider race-concordance plays a critical role in patient-provider experiences [42, 39].

Our findings also highlight racial/ethnic differences related to HPV knowledge and perceived vaccine effectiveness. Both constructs are negatively related with being Non-Hispanic Black and corroborate findings from previous studies [43, 44]. The findings are particularly alarming since Non-Hispanic Blacks pose much a higher risk to HPV illnesses, and often fail from seeking adequate preventive and prophylactic measures [45]. Efforts to reduce racial/ethnic disparities surrounding HPV illnesses are ongoing and extensively covered in literature [46, 47]. Unsurprisingly, aligning with previous studies, we observed a negative association between HPV knowledge and being Hispanic [48, 49]. This finding supports the need to continue delivering culturally tailored educational interventions for Hispanics. In our study, HPV knowledge is also negatively related to being heterosexual and female. Bearing relatively low HPV risk, heterosexuals [50, 51] may be lesser driven to engage in HPV-related knowledge/information seeking.

Our study also highlights a statistically significant, positive relationship with HPV knowledge among individuals aged 18–45-year-olds, compared to their older counterparts. Adults aged 18-45 constitute a robust

group of individuals, who may be vaccine eligible in the likelihood of missed opportunity. As existing and potential HPV vaccination decision makers, 18-45-year-olds ought to have a good understanding about HPV [43]. Our study also suggests that relative to adults aged 45 and older, younger adults demonstrate a statistically significant, positive association with HPV vaccine acceptability This finding aligns. with recent studies, suggesting better acceptability towards the HPV vaccine among younger adults, who are key current and potential HPV vaccine decision makers [52].

We also found sex-related disparity HPV knowledge. Like previous research, our study indicates significantly lower HPV knowledge among males, compared to females [53, 54]. This sex-oriented gap is attributed may be attributed to the understanding that to date, HPV is considered a predominantly female-only issue [55]; even though the vaccine has been routinely recommended for males since 2011 [37]. With that said, gender bias should be addressed as part of the routine education and training of health care providers [43]. Lastly, compared to participants with less than a college degree, those with at least some college education indicated a statistically positive, significant association with HPV vaccine acceptability, compared to those who had a high-school diploma or less. The rise in school/ college interventions promoting HPV vaccine uptake reasonable explains why those who attended a college/ university have better acceptability towards the HPV vaccine [56-58].

Congruous with Niu et al's. [21] HINTs data study, our study reports a significant relationship between HPV knowledge and perceived HPV vaccine effectiveness. Therefore, we infer that the role of HPV knowledge in bolstering HPV vaccine acceptability is indisputable [59, 52]. However, there are two noted dissimilarities. One, our study elicits a lack of statistical significance in the path linking patient-centered communication and HPV knowledge. Two, we found a statistically significant positive relationship between patient-centered communication and HPV vaccine effectiveness. Commensurate with previous studies, our study illustrates a direct, robust relationship between patient-centered communication and vaccine acceptability (Fenton et al., 2018; Francis et al., 2021). Finally, although the mediating role of HPV knowledge in improving HPV vaccine acceptability is not supported by our study results, we cannot dismiss the practicality involved in leveraging patient-centered communication to foster HPV-related knowledge, and consequently address people's apprehension and hesitancy related to HPV vaccine and promote acceptability. Moreover, the total effect of the channel linking patient-centered communication to HPV vaccine acceptability is significant and positive. Therefore, it is safe to ascertain that HPV knowledge does critically contribute to HPV vaccine acceptability.

Limitations

To the best of our knowledge, our study is the first to test a literature-supported, hypothesized model exploring the relationship between patient-centered communication, HPV knowledge and perceived HPV vaccine effectiveness. Using latent variables in our model helped us account for measurement error and strengthen our study's statistical appropriateness [38]. Although the relationships between patient-centered care and HPV knowledge with HPV vaccine acceptability have been independently explored, there is more scope for tapping into the simultaneous relationship between the three constructs [21]. Our study also highlights the direct and indirect paths leading up to perceived vaccine effectiveness and corroborates the previously established socio-demographic indicators influencing the three study constructs. Researchers may want to factor these variables in while designing future interventions.

We would also like to draw attention to the limitations we encountered. First, HINTS data is cross-sectional and collected at a given point; restricting our ability to draw causal inferences and temporal associations. Second, the self-reported HINTS data responses are susceptible to over-reporting and recall bias. Third, even though we employed weights for proper representation of the population, low response rates and incomplete questionnaires may have led to sample biases. Fourth, our sample heavily constituted adults aged 46 and above. Although potential decision makers, older adults may be less enthusiastic engaging in HPV conversations with their providers, especially if they do not have routine/catch-up vaccine-eligible adults in their immediate family; and their role in promoting HPV vaccine acceptability may not be as relevant. Fifth, only individuals who visited a provider at least once in the past twelve months answered questions related to patient-centered communication. While this reduces the possibility of recall bias, it reduces our sample size by almost one-fourth (2,522/3,285). Moreover, we cannot discount the hypothesis that participants who did not visit a provider in the past year refrained due to negative experiences with the provider. Consequently, the HINTS survey fails to capture potentially adverse patient-centered experiences, and the responses may disproportionally represent individuals who had positive patient-centered interactions with their providers. Sixth, the responses in HINTS are client-centered, and do on focus on providers' perspectives on patient-centered communication and HPV knowledge/ vaccine acceptability. Seventh, our analysis centers on a stable, unidirectional, and linear relationship between our study variables, and omits the possibility of a bi-directional relationship [60]. An interplay of both system and individual factors, our study explores individual HPV knowledge and vaccine acceptability nested withing a provider/systems level framework. Prospective researchers must account for these complexities while formulating interventions.

Implications for future research and practice

Altogether, our study suggests implications for health researchers interested in formulating vaccine campaigns and interventions. Providers often experience time constraints while discussing health issues in a patient-centered format and may want to strategically direct greater attention towards discussing effectiveness of the vaccine. Patient-centered communication has special

relevance during the ongoing SARS-coV-2 pandemic and has emerged as the preferred choice for patient-provider interaction [49]. The CDC recommends motivational interviewing, an evidence-based person-centered counselling approach, for resolving COVID-19 vaccine ambivalence and supporting self-efficacy [49]Zolezzi et al., 2022).

HPV vaccine rates are aberrantly low among certain socio-demographic groups. Sadly, despite the HPV vaccine's availability for almost two decades, these unfortunate trends continue to persist. The socio-demographic variations in our results yet again remind us of the prevalent disparities in health and health service utilization. A prominent taboo subject, sexual health discussions must be addressed with cultural appropriateness and sensitivity. HPV vaccine acceptability is a well-known predictor of HPV Vaccine uptake. Therefore, providers must unequivocally focus on addressing misinformation regarding the vaccine's safety and efficacy. Ultimately, in keeping with Healthy People 2030 goals to increase HPV vaccine uptake and reduce HPV infections ; researchers and practitioners must continue their collaborative efforts to promote HPV vaccination among adolescents and young adults still eligible for catch-up vaccination.

HPV vaccine decision makers often seek assurance regarding the vaccine's safety, and potential side effects, and prefer making shared clinical decisions with their providers. Therefore, practices must eventually consider adopting patient-centered communication as the standard form of patient-provider communication. Intervention/ protocol developers must also cater for socio-demographic disparities while formulating patient-centered strategies to boost HPV vaccine uptake. For example, our study reveals that mid/older adults aged 46 and above are less knowledgeable about HPV, relative to adults aged 18-26. Therefore, while interacting with older patients, practitioners must consider adopting evidence-based, patient-centered ways to make HPV conversations more geriatric-friendly. Regrettably, HPV-related health disparities continue to persist, and public health researchers must continue their endeavors to narrow these gaps. Lastly, our study offers a robust-evidence based conceptual framework that compares the direct and knowledge-mediated paths to improve acceptability towards the HPV vaccine. Future researchers may want to refer to this framework in the context of other vaccines.

In conclusion, Since the launch of the HPV vaccine, public health researchers have relentlessly been exploring and devising ways to improve vaccine uptake. The COVID-19 global pandemic has presented unprecedented public health challenges; driving health experts around the world to reform and revolutionize public health practices. The paradigm has universally shifted from a disease-centered to a patient-centered model, empowering patients more than ever. To keep up with the changing times, HPV researchers must delve deeper into patient-centered communication practices to improve vaccine uptake.

Author Contribution Statement

All authors contributed equally in this study.

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