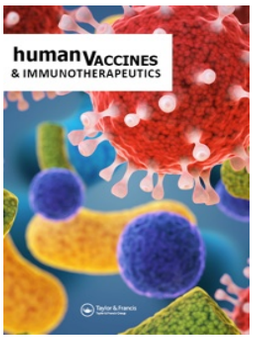

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Occupational HPV exposure and vaccination among healthcare workers: Implications for institutional vaccination strategies

Gurhan Guney[a,b], Evrim Erdemoglu[a,b], Selim Afsar[c], Gracie Haensgen[a,b], Sara Shihab[d], Ekin Erdemoglu[a,b], Kristina A. Butler[a,b], and Neal Boeder[e]

[a]Department of Medical and Surgical Gynecology, Mayo Clinic, Phoenix, AZ, USA; [b]Mayo Clinic Comprehensive Cancer Center, Mayo Clinic, Phoenix, AZ, USA; [c]Department of Obstetrics and Gynecology, Balikesir University Faculty of Medicine, Balikesir, Turkey; [d]Department of Internal Medicine, Women's Health Internal Medicine, Mayo Clinic, Phoenix, AZ, USA; [e]Department of General Internal Medicine, Mayo Clinic, Rochester, MN, USA

ABSTRACT

Healthcare workers may be exposed to HPV physically through occupational contact or while counseling patients with HPV conditions. Despite this exposure, HPV vaccination uptake among healthcare workers remains suboptimal. The relative contributions of demographic, cognitive, and occupational factors to vaccination behavior, risk perception, and vaccine advocacy in the context of institutional prevention strategies are not well defined. Our aim is to identify independent predictors of HPV vaccine uptake, perceived occupational HPV risk, and willingness to recommend HPV vaccination among healthcare workers, with the goal of informing institutional vaccination strategies. This cross-sectional survey study included healthcare workers from different specialties and evaluated HPV vaccine uptake, perceived occupational HPV risk, and willingness to recommend vaccination. We used predictors such as age, sex, clinical role, HPV knowledge, misconceptions, and vaccine safety beliefs then analyzing using multivariable logistic regression. Among 318 healthcare workers, 41.6% reported prior HPV vaccination. The majority (53.8%) worked in Internal Medicine. Vaccine uptake was strongly associated with age; those aged 27–45 had higher odds than those >45 y (aOR 7.03). Sex and HPV knowledge were not significant predictors. Perceived occupational HPV risk was linked to specialty, with dermatology showing higher risk perception (aOR 2.35), and inversely related to age (aOR 0.97 per year). Willingness to recommend HPV vaccination was high and driven mainly by confidence in vaccine safety (aOR 14.6). These findings suggest targeted, role-specific strategies beyond education to inform institutional HPV vaccination strategies

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Introduction

Human papillomavirus (HPV) is a common viral infection associated with substantial occupational exposure among healthcare workers, which may occur through direct physical contact during clinical care or through exposure while counseling patients with HPV conditions. Excisional procedures, laser ablation, and electrocauterization create a surgical plume containing HPV DNA, leading to inhalation and mucosal exposure and supporting the classification of healthcare workers as a population at increased risk.[1,2] Although healthcare workers are identified as a special occupational risk group, studies have shown limited awareness of national recommendations supporting HPV vaccination among healthcare personnel, with awareness affecting fewer than 25% of healthcare workers.[3,4] Despite this, healthcare workers have shown high interest in getting vaccinated, especially when their knowledge of HPV is high. Previous studies evaluating HPV vaccination among healthcare workers have reported highly variable but generally low uptake rates, ranging from 10–40% across different countries and clinical environments, indicating that even clinicians regularly managing HPV-related conditions remain under-vaccinated.[5–7] Multiple determinants of HPV vaccination influence have been described in the literature, including HPV behavior, knowledge, perceived susceptibility to occupational exposure, misconceptions about HPV-related cancers,

CONTACT Kristina A. Butler butler.kristina@mayo.edu Department of Medical and Surgical Gynecology, Mayo Clinic Hospital, 5777 E. Mayo Blvd., Phoenix, AZ, USA.

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and concerns regarding vaccine safety. However, associations between these determinants and actual vaccination behavior have been inconsistent across studies, with some reporting positive associations between knowledge and uptake, while others highlight the predominance of safety beliefs, perceived benefit, or provider recommendation practices as stronger drivers of vaccine acceptance. Most previous studies examining HPV vaccination in healthcare workers have consisted of descriptive analyses focusing on single outcomes such as HPV knowledge, risk perception, or self-reported vaccination behavior. In contrast, studies that simultaneously assess multiple behavioral outcomes in the same healthcare worker population are quite limited.[8–11] Importantly, the existing research has largely focused on descriptive assessments of awareness and prevention practices, with limited evaluation of how HPV knowledge, perceived occupational risk, and misconceptions independently influence vaccine uptake, risk perception, and willingness to recommend vaccination among healthcare workers. As this population is regularly offered vaccination, this highlights a convenient opportunity to offer HPV vaccination consistent with guideline- based updates and meeting age-appropriate criteria (age ≤45). Identifying these driving forces is crucial for designing targeted, institution-level interventions that go beyond education alone.[7,12–14] Based on this gap in the literature, this cross-sectional survey study aimed to identify behavioral determinants of HPV vaccination by evaluating occupational exposure awareness, HPV knowledge and misconceptions, vaccination behaviors, and willingness to recommend vaccination among tertiary healthcare personnel using multivariable modeling.[15]

Methods

Study design and participants

Data for the study were collected through a structured and anonymous online survey distributed electronically to healthcare workers across multiple clinical departments within a large tertiary academic healthcare system with locations in three U.S. states between June 3 and June 24, 2025. The survey invitation was sent through institutional communication channels and departmental mailing lists. A total of 328 healthcare workers participated in the survey. Participants were required to interact with patients and complete a minimum number of survey questions assessing HPV knowledge, perceptions, and vaccination behaviors. Because participation was voluntary and the survey link was shared through internal communication platforms, the exact number of individuals who received the invitation could not be determined, and a formal response rate could therefore not be calculated. Completion of the survey provided informed consent, and no financial incentives or compensation were offered for participation. Reminders were sent 3 times. REDCap, a secure web-based application designed to support data capture for research studies, was used for the survey in a de-identified manner, with reminders managed internally by the REDCap system to ensure anonymity. No linkage between responses and individual participants was available to the researchers.

Survey instrument and variable definitions

The survey design began with precise research questions. Some items were adapted from previously published surveys, while additional questions were developed by the study team. Constructs were grounded in established literature on HPV knowledge, vaccination behavior, and occupational exposure among healthcare professionals.[4] Expert panel review, including subject matter experts (NB, SA, KB, MH, EE), was used for content validation. Questions were refined based on feedback and an initial small sample pilot distribution. Formal cognitive interviews were not conducted prior to survey administration. A binary-response survey format was used to collect clear categorical data. The survey instrument included multiple domains comprising seven knowledge items, five perception items, and four behavior-related items.

In order to increase transparency and reproducibility, the full text of the questionnaire questions used in the study is presented in Supplementary Table S1. The survey included items assessing demographics, HPV transmission and vaccine knowledge, perceived occupational risk, awareness of vaccination guidelines, and personal vaccination practices. Demographic variables included age, sex, clinical role, department classification, and self-reported race. HPV knowledge was calculated by summing correct responses to seven binary survey items assessing knowledge of HPV-associated

malignancies. Correct identification of HPV-associated cancers (cervical, vulvar, vaginal, anal, penile, and oropharyngeal) and correct exclusion of non–HPV-associated cancers (breast or lung) contributed to the total score. Each item was coded dichotomously, and the total knowledge score was calculated, with higher scores indicating greater HPV knowledge.

Perceived occupational HPV exposure score was assessed using a single-item measure reflecting participants' self-reported awareness of occupational HPV exposure during clinical practice. In this study, occupational HPV exposure awareness refers to healthcare professionals' awareness of the likelihood of encountering HPV during clinical practice. This concept differs from risk perception, which reflects an individual's subjective assessment of the probability of developing an occupational infection. Responses were recorded on a four-level ordinal scale ranging from 0 (no awareness) to 3 (high awareness), with higher scores indicating greater perceived occupational exposure to HPV. Breast and lung cancer items served a dual purpose: correct exclusion of non–HPV-associated malignancies contributed to the HPV knowledge, whereas incorrect identification was used to define a separate binary HPV misconception variable, analyzed independently. HPV vaccination status was categorized as vaccinated or unvaccinated. Among unvaccinated participants, age was further described descriptively as ≤45 y or >45 y for reporting purposes only. Additional sections of the survey assessed attitudes toward vaccine safety, knowledge of national recommendations, and willingness to recommend the HPV vaccine to others. HPV preventive behavior score was calculated by summing responses to four binary items assessing HPV preventive practices, where higher scores indicated greater engagement in preventive behaviors.

Statistical analysis

Demographic characteristics, HPV knowledge scores, and vaccination status were summarized using descriptive statistics. Continuous variables were expressed as mean ± standard deviation or median (interquartile range), as appropriate, and categorical variables as frequencies and percentages. Given non-normal distributions, comparisons between two independent groups were performed using the Mann–Whitney test, and comparisons among three or more groups were conducted using the Kruskal–Wallis test, followed by pairwise Mann–Whitney U tests with Bonferroni-adjusted significance thresholds when appropriate. Bivariate analyses were performed to examine crude associations between participant characteristics and the three primary outcomes: HPV vaccine uptake, perceived occupational HPV risk, and willingness to recommend HPV vaccination. Variables were selected for multivariable logistic regression models based on clinical relevance and prior literature.[16] In addition, variables demonstrating a p value <.10 in univariate analyses were considered during model evaluation to avoid premature exclusion of potentially relevant factors and to minimize residual confounding. Three separate multivariable logistic regression models were constructed to identify independent predictors of each outcome. HPV knowledge score was included as a continuous variable. Age group was included as a covariate in the multivariable models to account for the age-dependent eligibility of HPV vaccination. Given the low proportion of participants (7.9%) unwilling to recommend vaccination, Firth penalized logistic regression was applied for this outcome. Results are reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs), and a two-sided p value <.05 was considered statistically significant. All descriptive and nonparametric analyses were conducted using SPSS version 28, while multivariable regression analyses were performed using R Studio (version 4.5.2). Multicollinearity among predictors was assessed using variance inflation factors (VIF), and model fit for standard logistic regression models was evaluated using the Hosmer–Lemeshow goodness-of-fit test. Exploratory factor analysis was conducted to evaluate whether survey items used to construct composite scores represented common underlying constructs. Sampling adequacy was assessed using the Kaiser–Meyer–Olkin (KMO) statistic and Bartlett's test of sphericity. Factor analysis was applied to the HPV knowledge items and preventive behavior items because these variables were derived from multiple conceptually related survey questions. In contrast, the HPV misconception score represents the count of incorrect responses to individual knowledge items rather than reflective indicators of a single latent construct; therefore, factor analysis was not considered appropriate for this variable. Similarly, perceived occupational HPV exposure awareness was assessed using a single binary survey item reflecting self-reported exposure awareness during clinical practice; therefore, exploratory factor analysis was not applicable for this variable.

Results

Participant characteristics

A total of 327 healthcare workers completed the survey. Following the exclusion of 9 respondents with missing or inappropriate data, the final analytic sample comprised 318 participants with a mean age of 45.12. The proportion of missing data was small (n = 9), thus imputation was not performed, and a complete-case analysis was used. Most participants were female with individuals aged 27–45 y representing the largest age group (158 participants, 52.8%). Internal medicine represented the largest clinical group, followed by family medicine and pediatrics; dermatology accounted for a smaller but distinct proportion of the cohort. Detailed demographic characteristics are presented in Table 1. Agreement with HPV-related statements across departments is shown in Figure 1.

HPV knowledge

HPV knowledge scores across participant characteristics are summarized in Table 2. Knowledge did not differ significantly between female and males ($p = .826$). Similarly, no significant difference in HPV knowledge was observed between vaccinated and unvaccinated healthcare workers ($p = .832$). Across clinical departments, HPV knowledge was also similar, with no significant differences observed among pediatrics, family medicine, internal medicine, dermatology, and other specialties ($p = .066$).

Perceived occupational HPV exposure

Perceived occupational HPV exposure risk is presented in Table 2. Exposure perception scores did not differ significantly between male and females ($p = .10$). In contrast, vaccinated participants demonstrated significantly higher occupational HPV exposure perception compared with unvaccinated participants ($p = .012$). No statistically significant differences in exposure perception were observed across professional

Table 1. Demographic and occupational characteristics of healthcare workers (n = 318).

Characteristic	n (%)[a]
Age (mean ± SD)	45.12 ± 12.7
Sex	
Female	217.0 (69.6%)
Male	95.0 (30.4%)
HPV Vaccination Status	
Vaccinated	129.0 (40.6%)
≤45 y	111 (86.0%)[b]
>45 y	14 (10.9%)[b]
Not Vaccinated	189.0 (59.4%)
Race	
White	255 (80.2)
Asian	31 (9.7)
Black/African American	9 (2.8)
Native American	8 (2.5)
Other/Mixed	25 (7.9)
Department	
Pediatrics	38.0 (11.9%)
Family Medicine	46.0 (14.5%)
Internal Medicine	171.0 (53.8%)
Dermatology	34.0 (10.7%)
Other	28.0 (8.8%)

[a]Data are presented as n (%) unless otherwise specified. Age is reported as mean ± standard deviation. HPV vaccination status reflects self-reported receipt of at least one dose of the HPV vaccine. Among unvaccinated participants, age distribution is shown descriptively (≤45 y vs >45 y). Percentages may not total 100% due to rounding.

[b]Age information was missing for 4 vaccinated participants.

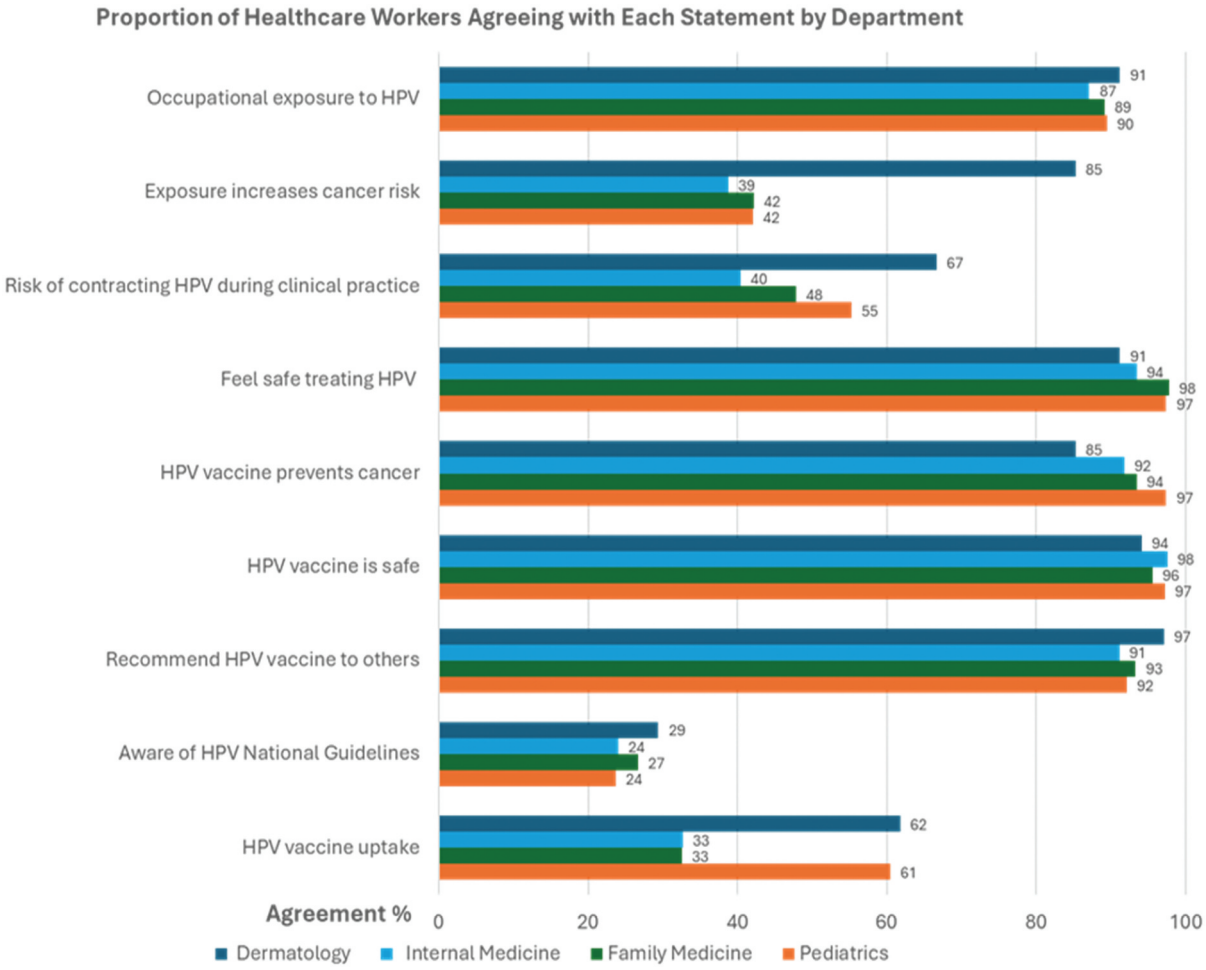

Figure 1. Proportion of healthcare workers agreeing with HPV-related statements by department. Bars represent the percentage of respondents within each specialty who agreed or strongly agreed with each statement. Dermatology, internal medicine, family medicine, and pediatrics are shown for comparison.

Table 2. Differences in HPV-related knowledge and occupational exposure perception scores by participant characteristics.

	HPV-related knowledge (0–7 score)				Occupational HPV exposure perception (0–4 score)			
	n	Mean	SD	*p* value	n	Mean	SD	*p* value
Gender								*p*: .103
Female	216	5.48	1.46	*p*: .826	215	1.73	1.03	
Male	95	5.48	1.48		94	1.94	1.06	
HPV vaccination								
Vaccinated	129	5.52	1.39	*p*: .832	128	1.95	1.04	***p*: .012***
Unvaccinated	188	5.45	1.55		187	1.66	1.03	
Profession								
Medical doctors	169	5.66	1.15	*p*: .072	166	1.89	1.02	*p*: .299
APP (NP/PA/CRNA	8	4.80	1.16		8	2.00	1.20	
Nursing/Allied Health	111	5.29	1.75		112	1.71	0.99	
Department								
Pediatrics	38	4.97	1.59	*p*: .066	38	1.87	1.07	***p*: .002***
Family Medicine	45	5.58	1.30		45	1.78	0.95	
Internal Medicine	171	5.56	1.41		170	1.6588	1.03	
Dermatology	34	5.82	1.22		33	2.42	0.97	
Other	28	5.0	2.07		28	1.68	1.06	

Continuous variables are presented as mean ± standard deviation. Comparisons between two independent groups were performed using the Mann–Whitney U test, and comparisons among three or more groups were conducted using the Kruskal–Wallis H test. When statistically significant, post-hoc pairwise comparisons were performed using Dunn's test with Bonferroni correction. *A two-sided *p* value <.05 was considered statistically significant.

Abbreviations: HPV, human papillomavirus; APP, advanced practice providers (nurse practitioners, physician assistants, certified registered nurse anesthetists).

groups, including medical doctors, advanced practice providers, and nursing or allied health professionals ($p = .299$). However, occupational HPV exposure perception differed significantly across clinical departments ($p = .002$). Healthcare workers in dermatology demonstrated higher HPV exposure perception compared with family medicine, internal medicine, and other specialties. Post-hoc pairwise comparisons using Mann–Whitney with Bonferroni correction ($\alpha = 0.01$) confirmed statistically significant differences for these comparisons, whereas no statistically significant difference was observed between dermatology and pediatrics.

HPV misconception

HPV misconception scores across participant characteristics are summarized in Table 3. Misconception did not differ significantly between female and male workers ($p = .79$). Similarly, no significant difference was observed between vaccinated and unvaccinated participants ($p = .328$). Misconception did not differ significantly across clinical departments ($p = .108$).

HPV preventive behavior

HPV preventive behavior scores are presented in Table 3. Preventive behavior did not differ significantly by sex ($p = .327$) or HPV vaccination status ($p = .914$). No statistically significant differences were observed across professional groups, including medical doctors, advanced practice providers, and allied health professionals ($p = .247$). In contrast, HPV preventive behavior differed significantly across clinical departments ($p = .002$). Dermatology healthcare workers demonstrated the highest preventive behavior. Post-hoc pairwise comparisons using Mann–Whitney with Bonferroni correction ($\alpha = 0.01$) revealed significantly higher scores in dermatology compared with pediatrics, family medicine, internal medicine and other specialties.

Multivariable analysis of HPV outcomes

The independent predictors of HPV vaccine uptake perceived occupational HPV risk, and willingness to recommend HPV vaccination identified in the multivariable models are summarized in Figure 2. In multivariable logistic regression analysis evaluating predictors of HPV vaccine uptake (Model 1), age group emerged as the strongest independent determinant. Healthcare workers aged 27–45 y had significantly higher odds of HPV vaccination compared with those aged over 45 y (adjusted odds ratio [aOR],

Table 3. Association between HPV-related misconceptions and preventive behaviors among healthcare workers.

	HPV-Related Misconceptions Score (0–3)				HPV Preventive Behavior Score (0–4)			
	n	Mean	SD	*p* value	n	Mean	SD	*p* value
Gender				*p*: .795				*p*: .327
Female	217	0.21	0.55		217	0.93	1.11	
Male	95	0.23	0.57		95	0.80	1.06	
HPV vaccination								
Vaccinated	129	0.20	0.56	*p*: .328	129	0.90	1.11	*p*: .914
Unvaccinated	189	0.24	0.59		189	0.87	1.08	
Profession								
Medical doctors	169	0.15	0.43	***p*: .046***	169	0.72	0.90	*p*: .247
APP (NP/PA/CRNA	8	.0000	.00000		8	0.75	0.89	
Nursing/Allied Health	112	0.33	0.70		112	1.04	1.26	
Department								
Pediatrics	38	0.19	0.56	*p*: .108	38	0.76	1.08	***p*: .002***
Family Medicine	46	0.20	0.50		46	0.83	1.10	
Internal Medicine	171	0.19	0.54		171	0.80	1.06	
Dermatology	34	0.44	0.79		34	1.56	1.08	
Other	28	0.29	0.60		28	0.86	1.11	

Continuous variables are presented as mean ± standard deviation. Comparisons between two independent groups were performed using the Mann–Whitney U test, and comparisons among three or more groups were conducted using the Kruskal–Wallis H test. When statistically significant, post-hoc pairwise comparisons were performed using Dunn's test with Bonferroni correction. *A two-sided *p* value <.05 was considered statistically significant.

Abbreviations: HPV, human papillomavirus; APP, advanced practice providers (nurse practitioners, physician assistants, certified registered nurse anesthetists).

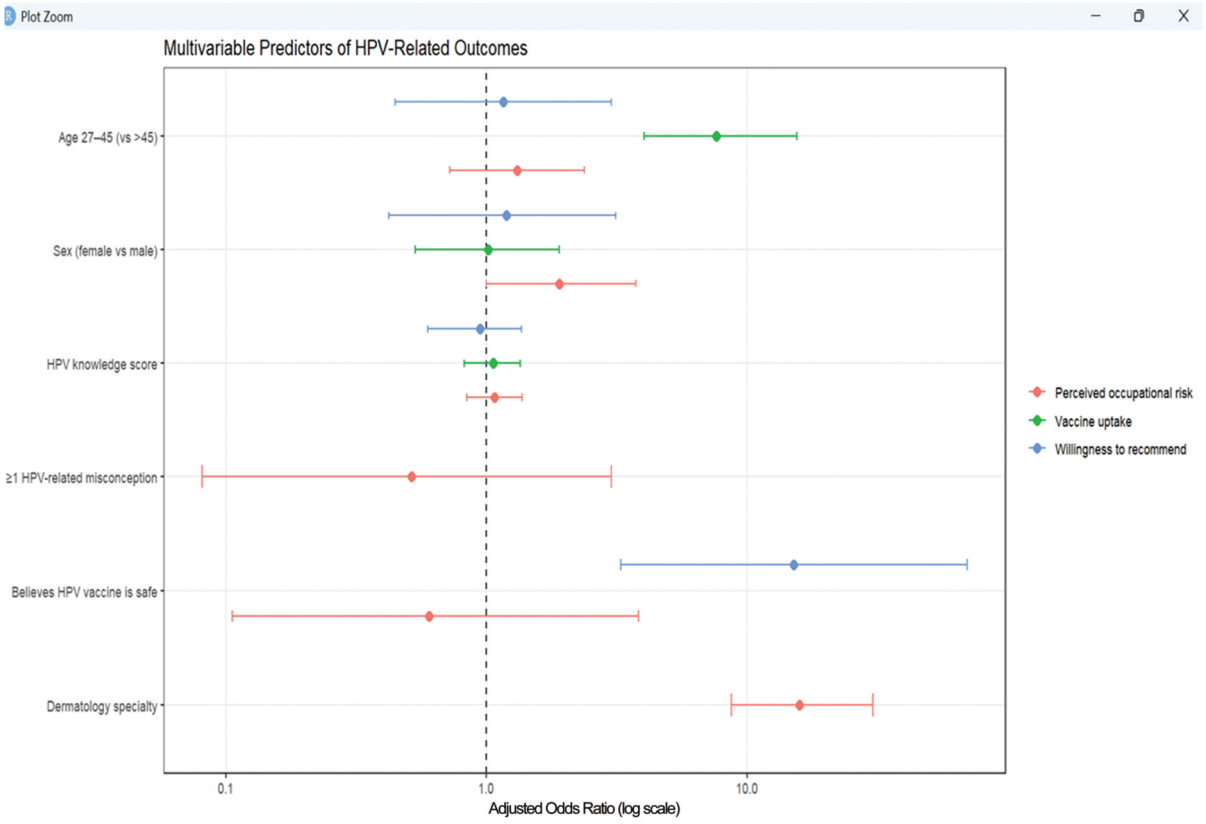

Figure 2. Multivariable predictors of HPV-related outcomes among healthcare workers. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) from three separate multivariable logistic regression models are shown for HPV vaccine uptake (green), perceived occupational HPV risk (red), and willingness to recommend HPV vaccination (blue). Odds ratios are displayed on a logarithmic scale, with the dashed vertical line indicating the null value (aOR = 1.0). Age group is shown as 27–45 y versus >45 y. Willingness to recommend HPV vaccination was analyzed using Firth penalized logistic regression due to outcome imbalance. Model fit for the multivariable logistic regression analyses was assessed using the Hosmer–Lemeshow goodness-of-fit test, and multicollinearity among predictors was evaluated using variance inflation factors (VIFs).

7.03; 95% CI, 3.72–14.16; $p < .001$). Sex was not independently associated with vaccine uptake after adjustment (aOR, 1.07; 95% CI, 0.57–2.00; $p = .83$). Similarly, HPV knowledge did not demonstrate an independent association with HPV vaccine uptake (aOR, 0.98 per unit increase; 95% CI, 0.78–1.23; $p = .87$). In the adjusted multivariable model examining perceived occupational HPV risk (Model 2), dermatology specialty was independently associated with higher perceived risk compared with other specialties (adjusted odds ratio [aOR], 2.35; 95% CI, 1.09–5.36; $p = .034$). Increasing age was inversely associated with perceived occupational HPV risk (aOR, 0.97 per year increase; 95% CI, 0.95–0.99; $p < .001$), indicating that younger participants were more likely to perceive themselves at occupational risk. Sex was not significantly associated with perceived occupational HPV risk (aOR, 0.89; 95% CI, 0.53–1.50; $p = .665$). Similarly, HPV knowledge did not demonstrate an independent association with perceived risk (aOR, 1.17; 95% CI, 0.96–1.43; $p = .119$). Belief in HPV vaccine safety was also not independently associated with perceived occupational HPV risk in the adjusted analysis (aOR, 0.92; 95% CI, 0.21–4.09; $p = .914$).

In Model 3, due to the low proportion of participants unwilling to recommend HPV vaccination (7.9%), Firth penalized logistic regression was applied. Belief in the safety of the HPV vaccine emerged as a strong independent predictor of willingness to recommend vaccination (adjusted OR 14.6, 95% CI 3.5–61.0). Department specialty, age, sex, and HPV knowledge were not significantly associated with willingness to recommend HPV vaccination. Multicollinearity among predictors in the regression models was assessed using variance inflation factors (VIF). VIF values across the models ranged between 1.00 and 1.02, indicating no evidence of multicollinearity. Model fit for the multivariable logistic regression models was evaluated using the Hosmer–Lemeshow goodness-of-fit test. The Hosmer–Lemeshow test did not indicate

lack of fit for the logistic regression models (Model 1: $\chi^2 = 5.87$, df = 3, $p = .118$; Model 2: $\chi^2 = 1.13$, df = 3, $p = .769$).

Discussion

This study identified strong and independent predictors of HPV behaviors among healthcare professionals. We observed that personal HPV vaccination uptake was driven primarily by age, with substantially higher uptake among individuals aged 27–45 y, independent of sex and HPV knowledge. The significantly lower HPV vaccination rate observed among healthcare workers over 45 y of age in our study likely reflects historical eligibility criteria for the HPV vaccine. When the HPV vaccine was first introduced, catch-up vaccination was only recommended up to age 26. In 2018, the FDA expanded the age range for HPV vaccination to 45, and subsequently, ACIP recommendations adopted an approach involving a joint clinical decision by physician and patient for adults aged 27–45. Therefore, many individuals currently over 45 may have fallen outside the recommended vaccination age range when the HPV vaccine was first introduced; this may partly explain the lower vaccination rate observed in this age group.[17] In contrast, perceived occupational HPV risk was shaped predominantly by specialty-specific clinical exposure, with dermatology professionals reporting significantly higher risk of perception. It should be noted that our study assessed perceived occupational HPV risk rather than objective exposure risk; therefore, these findings reflect healthcare workers' perceptions of occupational exposure rather than measured exposure levels. Additionally, increasing age was inversely associated with perceived occupational HPV risk, while HPV knowledge and belief in HPV vaccine safety were not independently associated with risk perception. Notably, willingness to recommend HPV vaccination was not influenced by age, sex, HPV knowledge or department specialty, but was overwhelmingly driven by confidence in vaccine safety. Although many previous studies have examined HPV knowledge, attitudes, and vaccination behaviors among healthcare professionals, most of these studies have focused on descriptive assessments of individual outcomes. Therefore, while some of our findings, such as those related to age and perceptions of vaccine safety, are consistent with the existing literature, our study contributes to the literature by simultaneously evaluating multiple behavioral determinants within the same healthcare professional population. Collectively, these multivariable modeling findings indicate that HPV behaviors among healthcare workers are shaped by different determinants, suggesting that institutional strategies may need to account for both occupational context and individual beliefs rather than relying solely on knowledge-based education.

In our study, an age-driven pattern persisted after adjustment for sex and HPV knowledge, neither of which independently influenced vaccine uptake in our cohort. Our results align with prior population-based and healthcare worker studies reporting an inverse relationship between age and adult HPV vaccination, particularly within the mid-adult age range.[18] In contrast to the literature, we did not observe a significant difference between genders in terms of vaccine uptake.[19] The absence of a gender difference in our study suggests that some commonly accepted assumptions regarding HPV vaccination such as traditional gender-based barriers may not be valid in all contexts. The perceptual, cultural, access-related factors proposed in the existing literature to explain lower vaccination rates in men may have a reduced effect in certain populations, as observed in our study.[20,21] These findings may provide preliminary insights into possible factors underlying disparities in HPV vaccination; however, given that the questionnaire-based scales used in this study have not been formally validated and the study was conducted within a single health system, the results should be interpreted cautiously and confirmed by future studies in different populations. Although HPV knowledge has frequently been reported as a positive determinant of vaccine uptake in many studies,[22] we did not observe an independent association between knowledge level and HPV vaccination in our study. In accordance with this heterogeneity, several studies have suggested that knowledge alone may be insufficient for vaccine uptake. For example, Thompson et al.[8] detected in their study that knowledge about HPV was more likely associated with asking questions to healthcare professionals about the vaccine, but that actual vaccine uptake was more strongly predicted by perceptions of the vaccine's effectiveness and the likelihood of benefiting from the vaccine. Similarly, a comprehensive study conducted in China[10] revealed that HPV knowledge and vaccination rates were concentrated in socioeconomically advantaged groups, suggesting that knowledge alone may be insufficient for vaccination and that broader

socioeconomic factors also play an important role. A large-scale, community-based study involving 11,678 mothers and their daughters aged 9–17 investigated the potential impact of factors such as perception of HPV, accessibility to the 9-valent HPV vaccine, satisfaction with government-provided health information materials, and exposure to HPV-related information on social media on HPV vaccination behavior. The study highlights that HPV vaccination rates among mothers are below the desired level and emphasizes the need to improve disease perception, facilitate access to the vaccine, develop effective health communication strategies, and utilize social media by health authorities to increase HPV vaccination.[23] In our study, the independent association we observed between dermatology specialization and perceived higher occupational HPV risk is most likely secondary to specialty-specific procedural practices. Dermatologists frequently treat HPV lesions using electrocautery or ablation, which explains the increased perceived exposure during clinical work; however, this does not indicate that occupational transmission has been definitively confirmed.

Another key finding of our study is the inverse association between age and perceived occupational HPV risk, suggesting that younger healthcare workers perceive occupational exposure to the infection as riskier. Like our study, a survey conducted by Lim et al.[24] on 1252 healthcare workers indicated that younger individuals had a higher perception of occupational risk, and that less work experience also increased this risk. Another interesting study showed, Polgar [25] nurses with more experience and greater comfort working with AIDS patients perceived a lower risk of contracting HIV. This pattern aligns with the concept of habituation and may contribute to the inverse relationship between increasing age and occupational risk identified in our research.

In our study, HPV knowledge was not found to be independently associated with perceived occupational risk, suggesting that knowledge alone may be insufficient to shape perceived occupational risk. The literature has shown that even though healthcare workers have a high level of knowledge and awareness regarding infectious diseases, their perception of occupational risk can vary significantly. This depends on the unit and clinical context in which they work, and that perception is influenced by factors beyond factual knowledge, such as procedural exposure and perceived protective measures.[26,27] Similarly, belief in the safety of the HPV vaccine was not found to be independently associated with perceived occupational HPV risk in our study. This finding suggests that perceptions of vaccine safety and assessments of occupational exposure risk are shaped through different cognitive processes. In the existing literature, beliefs about vaccine safety are mostly associated with vaccine acceptance or recommendation behaviors, and there are almost no studies that directly investigate the correlation between perceived occupational risk and vaccine safety beliefs.[28,29]

Finally, another important finding of our study was that willingness to recommend HPV vaccination was overwhelmingly driven by confidence in vaccine safety. In contrast age, sex, HPV knowledge and department specialty were not significantly associated with willingness to recommend HPV vaccination. Although shared clinical decision making (SCDM) was designed to support individualized adult HPV vaccination, accumulating evidence indicates that the current SCDM framework may inadvertently function as a structural barrier. Multiple studies show that primary care providers rarely initiate HPV vaccine conversations with adults including those aged 18–26 leaving nearly 70% of eligible individuals without any provider-driven recommendation.[11,30] This communication gap interacts with the ambiguity of SCDM guidance: as Wheldon and colleagues[31] note, only highly health-literate or empowered patients benefit, while 'last-chance' groups, particularly young men, show alarmingly low initiation rates (e.g., 8.2% in Adjei Boakye et al.[32]) In addition, even when providers do raise the topic, the quality of recommendations is often passive and non-directive, which further reduces uptake.[33] These barriers suggest a critical need to standardize how HPV vaccination discussions are initiated and delivered within the adult care workflow. Emerging system-level approaches such as pre-visit educational tools, nurse-driven workflow models, or AI-assisted conversation starters may help reduce provider hesitation, eliminate implicit bias, and ensure that the discussion is framed around cancer prevention rather than sexual activity. The association we observed between vaccine safety belief and willingness to recommend HPV vaccine is consistent with previous studies that emphasize the central role of vaccine safety confidence in shaping healthcare professionals' vaccine recommendation behaviors.[9,34] In a recent systematic review, Bakare et al.[9] observed that the main barriers to recommending the HPV vaccine among healthcare workers were concerns about the safety and effectiveness of the vaccine, but that vaccine recommendation behaviors varied depending on several factors, such as the geographical region studied and concerns about parental hesitancy. Therefore,

they emphasized that targeted educational and system-level support can strengthen vaccination recommendations by increasing confidence in vaccines. Similarly, a large-scale study by Farias et al.,[34] involving 36,827 patients and 134 pediatricians, found that physicians' concerns regarding vaccine safety, effectiveness, and cost negatively affected HPV vaccination initiation by reducing recommendation behavior.

Stigma around HPV being viewed a sexual infection instead of a virus that causes cancer negatively impacts provider willingness to recommend the vaccine.[35] HPV is not only sexually transmitted, hence 80–90% of adults contract HPV at some point in life.[36] Many, 6–20%, will not clear it.[37] Skin to skin contact can cause transmission as well as open mouth kissing.[38] Up to 8% of virgin girls in two different studies were found to have HPV.[39] The vaccine has been found to be beneficial even after exposure to the HPV virus by reducing the long-term consequences of not clearing the virus.[40] In 2018 the HPV vaccine was approved for adults through age 45. Despite this, only 34% of participants reported having prior HPV vaccine discussions with a clinician, receiving the vaccine was positively associated with prior HPV vaccine discussions.[11] Broadly speaking, most primary care providers do not initiate HPV vaccine discussions with adults over 18; however, when these conversations do occur, patients are often willing to receive the vaccine.[41,42] Adjusting counseling about HPV and presenting it as a risk factor for cancer would make it easier for care providers offering education. This study helps to facilitate communication about the vaccine in a nonsexual discussion. In addition, if healthcare workers want the vaccine many still require their care provider to order for the vaccine for them to be able to receive the vaccine.

Limitations

Our study has several limitations that should be considered when interpreting the findings. First, as this was a cross-sectional survey study, the observed associations do not allow causal inference. Second, vaccination status, occupational risk perception, and attitudes toward vaccine safety were self-reported and may be subject to recall. Third, some survey measures were relatively simplified. The survey instrument included multiple domains comprising seven knowledge items, five perception items, and four behavior-related items. HPV knowledge was assessed using a limited number of binary survey items, and perceived occupational HPV exposure was derived from self-reported survey responses rather than objective exposure measurements. These measures may not fully capture the complexity of these constructs and should therefore be interpreted as exploratory indicators rather than comprehensive assessments. Fourth, the study was conducted within a single tertiary academic healthcare system, therefore, generalizability to other institutional settings with different professions and vaccination policies may be limited. Fifth, the outcome assessing willingness to recommend HPV vaccination was highly imbalanced, with a small number of negative responses, requiring the use of Firth's penalized logistic regression to reduce small-sample bias. While this approach mitigates bias, wide confidence intervals remain for predictors with very low event counts (e.g., Black and Unknown/Multiple races). Sixth, the proportion of missing data was small; therefore, a complete-case analysis was performed without imputation. Finally, although the specialty-specific findings obtained among dermatology specialists were strong, the small number of participants may have limited the statistical power of the results. Additionally, the use of a non-validated survey instrument and the assessment of knowledge and occupational exposure using simplified measures represent significant limitations of this study. Although the survey was distributed to 3,965 unique e-mail addresses, there was no mechanism to ensure that all e-mail addresses were active or functional at the time of distribution. Therefore, the true denominator could not be reliably established, limiting our ability to determine an accurate response rate. While exploratory factor analysis was conducted to support the structure of selected variables, this approach does not fully establish construct validity. Consequently, given the existing limitations, the findings should be interpreted with caution.

Conclusions

In conclusion, our findings suggest that HPV influence among healthcare workers is associated with diverse and behavior-specific determinants rather than a single underlying factor. While HPV vaccination rates are primarily influenced by age, perceived occupational HPV risk is associated with specialty-specific clinical exposure, independent of HPV knowledge or perceptions of vaccine safety. In contrast, willingness to

recommend the HPV vaccine is associated with confidence in vaccine safety, rather than by demographic characteristics, knowledge level, or departmental specialization. The specialty specific patterns observed especially among dermatology specialists highlight the importance of clinical context and perceived exposure in shaping occupational risk perceptions. Additionally, our study includes healthcare professionals from different disciplines within Mayo Clinic sites in three states, as there is very little literature providing assessments specific to different areas of expertise. Moreover, we simultaneously evaluated HPV knowledge, perceived occupational risk, vaccination behavior, and recommendation practices to identify independent behavioral determinants. Identifying specialty-specific patterns, particularly among dermatology personnel, offers new perspectives on occupational HPV exposure and helps inform which specialties should be prioritized in terms of institutional training and prevention practices. Overall, these findings suggest that effective HPV prevention strategies among healthcare workers may require more than just increasing knowledge; future studies may help determine whether targeted, role-specific approaches that strengthen vaccine confidence and are supported by institutional policies could improve HPV prevention efforts.

Author contributions

CRediT: **Gurhan Guney:** Formal analysis, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Evrim Erdemoglu:** Data curation, Investigation, Methodology, Software; **Selim Afsar:** Supervision, Visualization; **Gracie Haensgen:** Data curation, Investigation, Resources; **Sara Shihab:** Conceptualization, Data curation, Methodology; **Ekin Erdemoglu:** Data curation, Investigation; **Kristina A. Butler:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Neal Boeder:** Methodology, Writing – review & editing.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Ethics

This survey study was conducted in accordance with the principles of the Declaration of Helsinki and was determined by the local Institutional Review Board (IRB) to be exempt from the requirement for IRB approval (IRB approval number: 23-002111). Because no protected health information was collected from participants, authorization under the Health Insurance Portability and Accountability Act (HIPAA) was not required in accordance with 45 CFR 160.103.

Informed consent statement

Informed consent was obtained from all participants of the study.

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