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Determinants of HPV Vaccination Among Women in the United States: A Multilevel Socio-Ecological Analysis

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Abstract

Background: Cervical cancer remains a major public health concern in the United States despite being largely preventable through human papillomavirus (HPV) vaccination. Although HPV vaccines are highly effective and have led to substantial declines in HPV infections and precancerous lesions, national coverage continues to fall short of targets, with persistent disparities across socioeconomic, racial/ethnic, and insurance groups.

Objectives: To identify multilevel barriers to HPV vaccination (individual, interpersonal, and policy levels) among U.S. women, examining variation by education, race/ethnicity, income, and insurance coverage, and assessing how these factors collectively contribute to inequities in HPV vaccine uptake.

Methodology: This study applied the Socio-Ecological Model (SEM) to examine determinants of HPV vaccination using 2020–2023 Behavioral Risk Factor Surveillance System (BRFSS) data. Differences in vaccine uptake were assessed across individual-level (education), interpersonal/community-level (race and ethnicity), and structural-level (income and insurance) factors. Due to substantial missingness in the HPV vaccination module,

analyses used unweighted valid responses, which may limit population generalizability.

Results: Analytic samples ranged from 5,557 to 6,435 women with complete HPV vaccination data. Clear disparities were evident across all determinants. Vaccination prevalence increased with higher income and educational attainment, while uninsured women had the lowest coverage. Racial and ethnic inequities were also observed: Hispanic and Black women reported lower vaccination rates compared with White and Asian women. These patterns reflect the combined influence of socioeconomic disadvantage, limited healthcare access, and systemic inequities on HPV vaccination uptake.

Conclusion: Findings underscore the need for multilevel strategies—such as expanded insurance coverage, culturally tailored education, and strengthened provider recommendations—to improve vaccination equity. Addressing individual, interpersonal, and structural barriers is essential to reducing the long-term burden of HPV-associated cancers and advancing cervical cancer prevention nationwide.

Keywords: HPV Vaccination, Socio-Ecological Model, Behavioral Risk Factor Surveillance System (BRFSS), Women's Health, Socioeconomic Determinants, Health Disparities

Introduction

Human papillomavirus (HPV) vaccination is a cornerstone of cervical cancer prevention and has contributed to substantial reductions in precancerous lesions in the United States ^[1]. National impact data demonstrate the effectiveness of HPV vaccination and screening programs, supporting ongoing elimination efforts ^[1]. Despite this progress, persistent disparities in HPV vaccination coverage remain across sociodemographic groups, insurance status, and geographic regions ^[2, 3].

Barriers to HPV vaccination operate at multiple levels, including individual knowledge, interpersonal influences, and structural factors such as access to care, insurance coverage, and socioeconomic status ^[4, 5]. Recent population-based studies have shown that education, access to healthcare, and insurance coverage are strongly associated with HPV vaccine uptake among adults in the United States ^[4, 5]. Geographic variation further compounds these inequities, with significant differences observed across states and regions ^[5, 6].

Ecological and modeling studies suggest that increasing HPV vaccination coverage can significantly reduce cervical cancer incidence and accelerate national elimination goals ^[6]. However, state-level disparities in vaccination rates and cervical cancer

outcomes continue to present major public health challenges [6]. Surveillance data from the HPV Vaccine Impact Monitoring Project demonstrate an approximate 79 percent decline in high-grade cervical precancers (CIN2+) among young women between 2008 and 2022, providing strong real-world evidence of vaccine effectiveness [7].

Despite these advances, the benefits of HPV vaccination are not equally distributed. Analyses using National Health and Nutrition Examination Survey data have consistently reported lower HPV vaccination coverage among uninsured individuals, racial and ethnic minority populations, and foreign-born individuals [3]. These disparities reflect complex social and structural factors, including differences in healthcare access, provider communication, and trust in medical systems.

The socio-ecological model (SEM) provides a comprehensive framework to understand how multilevel factors influence HPV vaccination behavior. In this study, SEM is applied to examine disparities in HPV vaccine uptake among women in the United States, with a focus on education at the individual level, race and ethnicity at the interpersonal and community levels (operationalized using individual-level BRFSS categories), and insurance status and income at the structural level.

Educational attainment plays a critical role in shaping awareness of HPV, perceived susceptibility, and overall health literacy, all of which influence vaccination decisions. Evidence shows that higher educational levels are associated with greater HPV vaccine acceptability and uptake [8]. Racial and ethnic disparities in HPV vaccination remain persistent and are shaped by unequal access to care, historical and ongoing medical mistrust, and differences in provider communication [9, 10]. Insurance coverage and income further influence HPV vaccination by affecting access to preventive services, appointment availability, and completion of the multi-dose vaccine series [11]. Together, these findings reinforce the importance of multilevel social and structural conditions in shaping HPV vaccination behavior in the United States.

Although multiple studies have explored correlates of HPV vaccination, most examine socioeconomic and demographic factors independently rather than as interconnected, multilevel determinants. Few apply an SEM to understand how individual factors (e.g., education, knowledge), interpersonal factors (e.g., race/ethnicity, family and community influences), and societal factors (e.g., insurance, affordability, access) combine to shape vaccination behavior. As a result, there is limited population-level evidence that situates HPV vaccination disparities within an integrated multilevel framework, particularly using recent BRFSS data among adult women.

To address this gap, the present study applies the SEM as the guiding conceptual framework (Figure 1). In this model, education represents individual-level determinants linked to knowledge and awareness; race/ethnicity represents interpersonal and socially embedded influences; and income and insurance represent societal determinants tied to resource availability, structural access, and policy environments.

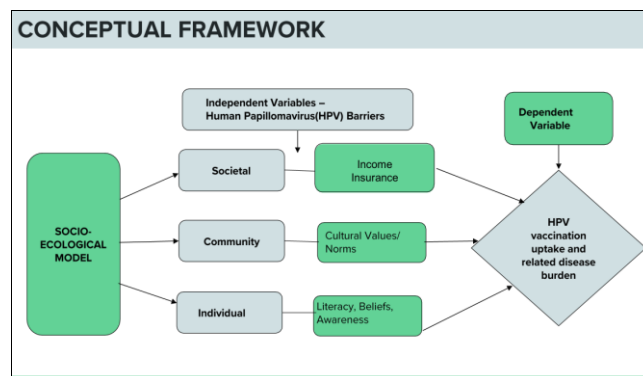


Fig 1: Socio-Ecological Model guiding the study and the conceptual framework for HPV vaccination determinants

Based on this framework, we advance two guiding assumptions:

Guiding Assumptions

Assumption 1: Based on prior research, women experiencing socioeconomic disadvantage (lower education, lower income, minority race/ethnicity, and lack of insurance) are expected to show lower HPV vaccination uptake.

Assumption 2: Structural-level factors, particularly income and insurance are expected to show the largest observable differences in vaccination coverage due to their direct role in shaping access to preventive healthcare.

Evidence from national surveys and behavioral research supports these assumptions. Lower educational attainment has been consistently associated with reduced HPV knowledge, weaker vaccine intentions, and lower uptake [12, 13]. Persistent racial and ethnic disparities have been documented, with non-Hispanic Black and Hispanic women exhibiting lower vaccination coverage attributable to structural inequities, differences in provider recommendations, and historical medical mistrust [14, 15]. Socioeconomic gradients further shape HPV vaccination patterns, as women in lower-income households face cost barriers, transportation challenges, and limited continuity of care [16, 17]. Insurance status is among the strongest predictors of adult vaccination, with uninsured women consistently showing substantially lower uptake than insured women [18, 19].

Guided by the SEM and these assumptions, the present study addresses the following research questions:

RQ1. How do education, race/ethnicity, income, and health insurance coverage influence HPV vaccination status among women in the United States?

Aim 1. To describe differences in HPV vaccination uptake across four key sociodemographic determinants education, race/ethnicity, income, and insurance status using national BRFSS data.

RQ2. To what extent does HPV vaccination status differ across groups of women in the United States based on education level, race/ethnicity, income category, and insurance status?

Aim 2. To examine group-level differences in HPV vaccination coverage by these determinants. This study provides a recent population-level assessment of multilevel determinants of HPV vaccination among adult women using nationally representative BRFSS data from 2020–2023. Although prior research has examined HPV vaccination disparities particularly among adolescents, far fewer studies focus on adult women or apply a socio-ecological framework to interpret disparities across individual, interpersonal, and structural levels. In a nationally representative sample (2019 NHIS, $n = 9,440$), only ~15.5% of adults aged 27–45 had received at least one dose of the HPV vaccine. By systematically comparing education, race/ethnicity, income, and insurance status, this study identifies the socioeconomic determinants most closely aligned with observed disparities and highlights the population groups most at risk for under-vaccination. These findings address critical gaps in the existing literature and offer actionable guidance for designing equity-focused public health interventions.

Background

Cervical cancer can be prevented, yet it continues to pose a significant public health challenge. HPV vaccination has the potential to substantially reduce cervical and other HPV-related cancers. To fully achieve this potential in the United States, it is essential to understand vaccination patterns, barriers to uptake, and gaps in existing research. This background section provides an overview of cervical cancer epidemiology, HPV vaccine efficacy, national vaccination trends, documented disparities, and limitations in prior research.

Cervical cancer remains a leading cause of cancer-related mortality among women worldwide, particularly in low- and middle-income countries [20]. Persistent infection with high-risk types of the human papillomavirus (HPV) is the causal agent for nearly all cervical cancers, as well as a substantial proportion of anogenital and oropharyngeal cancers [21]. Between 2018 and 2022, the age-adjusted incidence of cervical cancer in the United States was approximately 7.7 cases per 100,000 women per year. Vaccination coverage remains below national goals: in 2023, only 57.3% of adolescents aged 13–15 in underserved populations received the recommended HPV doses, well below the Healthy People 2030 target of 80% [22]. Among eligible adult women, only 19% had received at least one dose and just 12% had completed the full series [23]. An estimated 13,960 new cervical cancer cases and 4,360 deaths occur each year, with incidence and mortality highest among Hispanic, American Indian/Alaska Native, and Non-Hispanic Black women [24]. Prophylactic HPV vaccines target high-risk types such as HPV-16 and HPV-18, which together account for 70–90% of cervical cancers [25].

Clinical trials have consistently demonstrated strong efficacy, preventing nearly all persistent infections, CIN2/3 lesions, and adenocarcinoma in situ among HPV-naïve individuals [26]. Population-level evidence shows reductions in vaccine-type HPV prevalence, herd effects among unvaccinated groups, and substantial declines in high-grade precancers [27, 28]. Global health agencies continue to affirm the strong safety profile of HPV vaccines [29]. The Advisory Committee on Immunization Practices (ACIP) first recommended HPV vaccination for girls aged 11–12 in 2006 and expanded recommendations to boys in 2011 [30]. In

2019, ACIP introduced shared clinical decision-making for adults aged 27–45 [31]. Although vaccination coverage among adolescents has increased, rates remain below those of other routine adolescent vaccines such as Tdap and meningococcal conjugate vaccines [32].

Persistent disparities in HPV vaccine uptake have been documented across racial, ethnic, and socioeconomic groups [33, 34]. Contributing factors include low income, limited parental education, lack of insurance, weaker provider recommendations, and inconsistent healthcare access [35–37]. Provider recommendation strength is one of the most influential predictors of adolescent and adult HPV vaccination; however, individuals who lack regular healthcare or insurance often receive fewer or weaker recommendations [36]. Provider hesitancy, limited communication time, and misinformation can further reduce vaccine acceptance [37]. Despite this growing body of research, several limitations remain. Few studies systematically examine how individual, interpersonal, community, and structural factors interact to shape vaccination behavior through a socio-ecological lens [38]. Much of the existing research focuses on individual attitudes or knowledge but insufficiently addresses broader contextual factors such as healthcare system access, community norms, and state-level policy environments. This limits the identification of effective intervention points across multiple levels. Recent work has also highlighted gaps in vaccination research among specific underserved populations. For example, Arab American communities are not captured as a distinct racial/ethnic category in national immunization surveys, obscuring disparities in HPV vaccination and cervical cancer incidence [39]. Barriers identified in this population include limited provider recommendations, inadequate vaccine knowledge, cultural concerns about sexual health, and mistrust related to reproductive health procedures.

Similarly, studies among uninsured or low-income adults show that even when HPV vaccines are provided at no cost, vaccine completion remains low due to logistical challenges, hesitancy, and gaps in vaccine knowledge [40]. These findings underscore the importance of culturally informed, multilevel approaches to improving HPV vaccination coverage in underserved groups.

The current study examines how individual, interpersonal, and structural determinants shape HPV vaccination uptake among adult women in the United States, applying the Socio-Ecological Model to guide interpretation of multilevel influence.

Methods

This study employed a descriptive, cross-sectional epidemiologic design using nationally representative BRFSS data to identify multilevel determinants of HPV vaccination among adult women in the United States. The SEM served as the conceptual framework for organizing individual-, interpersonal-, and societal-level determinants that may shape vaccination uptake (see Figure 1). Consistent with the Introduction and Discussion, these determinants included education as an individual-level indicator of health literacy and awareness; race/ethnicity as an interpersonal and socially embedded factor, operationalized using individual-level BRFSS categories; and income and insurance as societal-level indicators of structural access to preventive healthcare.

Data were obtained from the Behavioral Risk Factor Surveillance System (BRFSS), a nationally representative, population-based survey administered annually by the Centers for Disease Control and Prevention (CDC). BRFSS employs a stratified, multistage probability sampling design using random-digit dialing methods to survey non-institutionalized U.S. adults. Survey years 2020–2023 were selected because HPV vaccination items were consistently included during this period, providing a coherent timeframe for assessing recent patterns in adult vaccination.

Although BRFSS provides sampling weights to account for nonresponse and design complexity, the HPV vaccination items are administered only to a subset of respondents and exhibit substantial item-level missingness. These conditions do not permit valid application of full BRFSS weights to joint distributions. Therefore, and consistent with established BRFSS methodological recommendations [41], analyses used unweighted, valid response frequencies to describe observed differences across sociodemographic groups. This approach aligns with the study's descriptive aims rather than producing weighted population estimates.

The study population included women aged 18 years and older who provided a valid response to the HPV vaccination item. Respondents were excluded if they answered “don't know/not sure,” refused, or had missing responses for the vaccination question. The primary outcome, HPV vaccination status, was defined as a binary indicator of whether respondents reported ever receiving an HPV vaccine.

Independent variables were selected based on theoretical relevance to the SEM and prior literature linking socioeconomic disadvantage to lower vaccination uptake. Education was categorized as less than high school, high school graduate, some college, and college graduate. Race/ethnicity included White non-Hispanic, Black non-Hispanic, Hispanic, Asian non-Hispanic, and Multiracial/Other. Household income was coded using standard BRFSS categories ranging from less than \$10,000 to \$200,000 or more. Insurance status was dichotomized as insured versus uninsured. Variable definitions and recording procedures followed CDC BRFSS documentation to ensure consistency and reproducibility.

The analytic strategy consisted of descriptive statistics and cross-tabulations to compare HPV vaccination status across categories of each determinant. For each cross-tabulation, frequencies and percentages were calculated separately for vaccinated and unvaccinated women, along with the number of valid cases available for analysis. Analyses were restricted to complete cases for each determinant; missing responses were not imputed due to the descriptive goals of the study and the substantial item-level missingness in the HPV vaccination module. Given these constraints, multivariable modeling was not conducted, and analyses intentionally remained descriptive. This analytic approach directly aligned with the study objectives: (1) to examine differences in HPV vaccination uptake across socioeconomic and demographic groups; (2) to identify determinants most strongly associated with vaccination disparities; and (3) to interpret these differences within the SEM framework, as articulated in the Introduction and further elaborated in the Discussion.

All analyses were conducted using IBM SPSS Statistics, Version 29 (Armonk, NY). BRFSS data are publicly available and fully de-identified; therefore, this study was

classified as non-human subjects research and deemed exempt from institutional review board oversight under federal regulation 45 CFR 46.

Results

A total of 445,132 respondents participated in BRFSS during the study period; however, only 1.2–1.4% had complete data on HPV vaccination status and the sociodemographic variable of interest. This reflects the modular structure of BRFSS, in which HPV vaccination items are administered only to a limited subsample. The final analytic samples for the income, education, race/ethnicity, and insurance crosstabulations ranged from 5,557 to 6,435 women.

Table 1 presents the sociodemographic characteristics of the analytic sample. Most respondents were insured, had at least some college education, and identified as White non-Hispanic. Income was broadly distributed, although the analytic subsample contained a higher proportion of middle-income respondents.

Table 1: Sociodemographic Characteristics of the Analytic Sample

Variable	Category	n (%)
Income	< \$10,000	211 (3.8)
	\$10,000–\$20,000	113 (2.0)
	\$20,000–\$30,000	175 (3.1)
	\$30,000–\$50,000	536 (9.6)
	\$50,000–\$75,000	852 (15.3)
	\$75,000–\$100,000	793 (14.3)
	\$100,000–\$150,000	937 (16.9)
	\$150,000–\$200,000	490 (8.8)
Education	≥ \$200,000	521 (9.4)
	< High school	206 (3.2)
	High school graduate	1,703 (26.5)
	Some college	1,544 (24.0)
Race/Ethnicity	College degree	2,860 (44.4)
	White, non-Hispanic	2,817 (44.8)
	Black, non-Hispanic	535 (8.5)
	Hispanic	1,086 (17.3)
	Asian, non-Hispanic	890 (14.1)
Insurance Status	Multiracial/Other	925 (15.3)
	Insured	5,688 (91.2)
	Uninsured	547 (8.8)

Clear sociodemographic disparities in HPV vaccination uptake were observed (Table 2). Vaccination rates increased steadily with higher income. Among women who reported ever receiving an HPV vaccination, relatively few were in income groups below \$30,000, whereas the largest proportions were in the \$50,000–\$75,000, \$75,000–\$100,000, and \$100,000–\$150,000 categories. In contrast, lower-income women represented a substantially larger share of the unvaccinated population.

Educational differences were similarly pronounced. One-half of vaccinated women were college graduates, and an additional quarter had completed some college. Fewer than 3% of vaccinated women had not completed high school. Unvaccinated women were more concentrated in the high-school-only category.

Racial and ethnic disparities were also evident. Hispanic and Black women were underrepresented among vaccinated women compared with White and Asian women. Insurance coverage demonstrated one of the strongest associations with HPV vaccination uptake. Vaccinated women were overwhelmingly insured (94.2%), whereas uninsured

women represented a disproportionately larger share of the unvaccinated population (9.8%).

Table 2: HPV Vaccination Status by Sociodemographic Characteristics

Variable	Category	Vaccinated (%)	Not Vaccinated (%)
Income Category	< \$10,000	2.5	4.2
	\$10,000–\$20,000	1.3	2.3
	\$20,000–\$30,000	2.2	3.4
	\$30,000–\$50,000	10.4–11.0	9.4–11.8
	\$50,000–\$75,000	17.9	14.4
	\$75,000–\$100,000	16.5	13.5
	\$100,000–\$150,000	16.3	17.0
	\$150,000–\$200,000	8.3	9.0
	≥ \$200,000	9.1	9.5
Education Level	< High school	2.0	3.6–5.9
	High school graduate	21.0	28.4
	Some college	26.0	23.3
	College graduate	50.2	42.3
Race/Ethnicity	White, non-Hispanic	43.9	45.0
	Black, non-Hispanic	9.2	8.3
	Hispanic	16.6	17.5
	Asian, non-Hispanic	14.4	14.1
	Multiracial/Other	15.9	15.1
Insurance Status	Insured	94.2	90.2
	Uninsured	5.8	9.8

Table 3 summarizes the disparities across income, education, race/ethnicity, and insurance status. Across all determinants, HPV vaccination coverage was highest among women with higher income, higher educational attainment, any health insurance, and among White and Asian women. The lowest coverage occurred among women with lower income, lower education, those uninsured, and Black and Hispanic women.

Table 3: Summary of Disparities in HPV Vaccination Uptake

Factor	Highest Coverage	Lowest Coverage	Interpretation
Income	\$50k–\$150k	< \$30k	Strong socioeconomic gradient
Education	College graduates	High school or less	Large knowledge/access gap
Race/Ethnicity	White & Asian women	Black & Hispanic women	Structural inequities
Insurance	Insured women	Uninsured women	Strongest structural barrier

To illustrate the magnitude of these gaps, Figure 2 shows a slope chart comparing the highest- and lowest-coverage subgroups for each determinant, highlighting steep socioeconomic and structural gradients in HPV vaccination uptake.

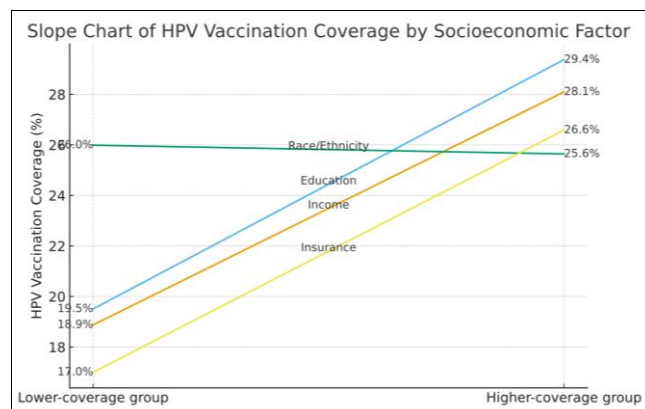


Fig 2: Slope chart of HPV vaccination coverage by socioeconomic factor

This figure compares HPV vaccination coverage (%) between lower-coverage and higher-coverage subgroups across four socioeconomic determinants: income, education, race/ethnicity, and insurance status. Each line represents the relative difference in coverage between the subgroup with the lowest uptake and the subgroup with the highest uptake for that factor. The steepest gradients appear for income, education, and insurance status, indicating substantial socioeconomic and structural disparities, whereas race/ethnicity shows comparatively smaller variation. These visual patterns align with the Socio-Ecological Model and support Assumptions 1 and 2.

Figure 3 below further visualizes the socio-ecological gradient of disparities across the four determinants, highlighting the substantially larger structural gap observed for uninsured women.

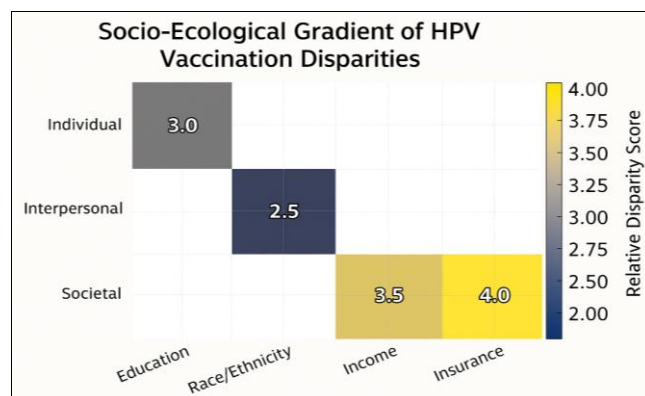


Fig 3: Socio-Ecological Gradient of HPV Vaccination Disparities

This figure illustrates relative disparities in HPV vaccination uptake across four determinants aligned with the Socio-Ecological Model (SEM). Each determinant income, education, race/ethnicity, and insurance coverage is displayed with a gradient scale representing the magnitude of disparity between the highest- and lowest-coverage

subgroups. Larger values indicate more pronounced inequities. Insurance coverage demonstrates the steepest gradient, followed by income and education, while race/ethnicity shows more modest differences. These patterns underscore how structural, interpersonal, and individual factors jointly contribute to vaccination gaps among U.S. women.

Discussion

This study examined socioeconomic and demographic differences in HPV vaccination status among women in the United States using a Socio-Ecological Model (SEM) framework. Consistent with Assumption 1, the findings indicate that women with lower educational attainment, lower income, racial/ethnic minority status, and lack of health insurance had substantially lower HPV vaccination uptake than their more advantaged counterparts. These patterns align with a well-documented literature showing the influence of socioeconomic constraints, structural inequities, and limited access to preventive care on HPV vaccination behaviors. The results also support Assumption 2, demonstrating marked variation in vaccination coverage across population groups, with the lowest uptake consistently concentrated among women with high school education or less, those in lower-income categories, uninsured women, and Black and Hispanic women.

Interpreting these findings through the SEM provides insight into the multilevel mechanisms that may contribute to persistent HPV vaccination disparities. At the individual level, lower education likely reflects differences in health literacy, vaccine awareness, and perceived susceptibility, all of which have been shown to reduce vaccine initiation. Women with fewer years of formal education may also face difficulties navigating healthcare systems or may be exposed to more misinformation regarding HPV vaccines. At the interpersonal level, the lower vaccination rates observed among Black and Hispanic women may reflect the effects of culturally mediated beliefs, historical mistrust of medical institutions, and reduced provider recommendation, a factor repeatedly identified in the literature as one of the strongest predictors of HPV vaccination. These patterns are consistent with prior qualitative and quantitative studies that highlight the roles of social norms, family beliefs, and community-level messaging in shaping HPV vaccine acceptance.

At the societal and structural level, income and health insurance emerged as strong correlates of vaccination status. Women in lower-income households had the lowest vaccination uptake, reinforcing the role of financial constraints, transportation and childcare barriers, and limited continuity of care. Insurance coverage displayed one of the strongest disparities: nearly all vaccinated women were insured, whereas uninsured women had markedly lower uptake. These results underscore how structural access to healthcare, not just individual preference, shapes preventive service use. Although programs such as Vaccines for Children (VFC) have reduced cost barriers for adolescents, comparable structural support for adult women remains limited, contributing to persistent inequities across the adult population.

An important methodological consideration is that only approximately 1.2-1.4% of BRFSS respondents had complete HPV vaccination and sociodemographic data. This limited analytic subsample may not fully represent the broader population and could introduce selection bias,

requiring cautious interpretation of the findings.

Collectively, however, these findings illustrate that HPV vaccination disparities follow predictable socioeconomic gradients. They further suggest that interventions must address multiple SEM levels simultaneously to be effective. Educational campaigns alone are unlikely to eliminate uptake gaps if women lack insurance coverage or access to a consistent medical home. Similarly, structural solutions such as expanded insurance coverage or community-based vaccination programs may have limited impact without tailored messaging that addresses cultural concerns, mistrust, or limited awareness in marginalized communities. The study's findings also provide actionable evidence to guide targeted interventions that address the multilevel factors contributing to low HPV vaccination uptake among underserved women. Because lower education, lower income, racial and ethnic minority status, and lack of insurance were associated with the lowest vaccination rates, effective strategies should combine health literacy-appropriate education, culturally tailored outreach for Black and Hispanic women, and stronger provider recommendations during clinical encounters. Community-based approaches, such as pop-up clinics, mobile vaccination units, and integration of vaccination into WIC, community health centers, and Title X programs, may help reach women with limited access to preventive care.

At the structural level, expanding insurance coverage, reducing cost barriers, and strengthening policies that support adult vaccination can further reduce disparities. Together, these interventions directly align with the multilevel determinants identified in this study and offer practical pathways to improving HPV vaccination coverage in underserved populations. However, these recommendations should be interpreted as plausible extensions supported by prior research rather than causal conclusions drawn from the present descriptive analysis.

This study's descriptive design, based on the BRFSS HPV vaccination module, contributes new population-level evidence but also presents limitations. First, substantial item-level missingness restricted analyses to available cases and precluded multivariable modeling. Because the design is cross-sectional, temporal ordering cannot be established, and associations should not be interpreted as causal. Second, vaccination status was based on self-report and may be subject to recall error, particularly among adult women who received doses many years earlier; the direction and magnitude of this bias remain uncertain and could lead to either underreporting or overreporting. Third, BRFSS data do not allow examination of series completion, provider recommendation, or contextual factors such as geographic access to clinics. Finally, BRFSS excludes institutionalized populations, slightly limiting generalizability. Despite these limitations, the findings provide a valuable snapshot of HPV vaccination inequities among U.S. women and highlight priority populations for intervention.

Future work should build on these descriptive disparities by integrating longitudinal data, provider-level variables, and structural measures of healthcare access. Linking BRFSS data with contextual indicators or medical claims records may also clarify pathways through which socioeconomic disadvantage translates into reduced vaccination uptake. Additionally, intervention research grounded in SEM is needed to evaluate multilevel strategies that simultaneously address awareness, provider engagement, and structural

barriers.

The study's findings reaffirm Assumption 1 and Assumption 2 by demonstrating that HPV vaccination disparities are patterned along socioeconomic and demographic lines and reflect multilevel determinants described within the SEM. Targeted interventions grounded in the SEM may help improve HPV vaccination uptake among the most underserved female populations, ultimately reducing the burden of HPV-associated cancers across the lifespan.

Conclusion

This study demonstrates that HPV vaccination among U.S. women remains significantly below national goals and is shaped by clear socioeconomic and demographic disparities. Guided by the Socio-Ecological Model, the findings reaffirm both study assumptions, showing that women with lower educational attainment, lower income, racial and ethnic minority backgrounds, and those without insurance have markedly lower vaccination uptake. These disparities reflect the combined influence of individual health literacy, interpersonal dynamics such as provider recommendation and cultural beliefs, and structural barriers including financial constraints and limited access to preventive care. By identifying which population groups experience the lowest vaccination coverage, this study contributes important evidence to the literature and provides updated population-level data from a national survey module rarely examined in adult women with this level of detail. Improving HPV vaccination rates will require coordinated efforts across SEM levels, including culturally tailored education, stronger provider engagement, expanded insurance coverage, and community-embedded vaccination opportunities. Addressing these multilevel barriers is essential for advancing equity and reducing the long-term burden of HPV-associated cancers among underserved women. Continued research and policy attention are needed to ensure that preventive strategies reach the populations most at risk and fulfill the potential of HPV vaccination to reduce cervical cancer and other HPV-related diseases.

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