



(RESEARCH ARTICLE)



Human papillomavirus (HPV) in Nigeria: Epidemiology, genotype, vaccination and public health implications

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International Journal of Science and Research Archive, 2026, 18(03), 877-896

Publication history: Received on 10 January 2026; revised on 18 February 2026; accepted on 21 February 2026

Article DOI: <https://doi.org/10.30574/ijrsra.2026.18.3.0295>

Abstract

Rationale: Human papillomavirus (HPV) infection remains a major public health challenge in Nigeria, contributing substantially to the burden of cervical cancer. Despite the availability of prophylactic vaccines, low immunization coverage and uneven screening uptake exacerbate HPV-related morbidity and mortality. Understanding HPV prevalence, genotype distribution, and vaccination gaps is critical for guiding targeted interventions and public health strategies.

Objectives: This study aimed to (1) determine the prevalence and genotype distribution of HPV among Nigerian women, (2) assess age-specific HPV infection patterns, (3) evaluate cervical cancer screening uptake relative to HPV burden, (4) compare HPV vaccination coverage between Nigeria and other regions, and (5) propose a framework to enhance HPV vaccination uptake.

Methods: A comprehensive review and synthesis of epidemiological, clinical, and programmatic data were conducted using national surveillance reports, peer-reviewed studies, and vaccination program records. Data on HPV prevalence, high-risk and low-risk genotype distribution, age-specific infection patterns, cervical screening uptake, and vaccination coverage were extracted and analyzed to identify trends, regional disparities, and operational challenges. Comparative analysis with South Asian countries and the United States was performed to contextualize findings.

Results: HPV prevalence among women of reproductive age in Nigeria was 42.3%, with cervical cancer cases showing 81.4% HPV positivity. High-risk genotypes, predominantly HPV-16 (19.9-46.7%) and HPV-18 (10-20.5%), were widely distributed, while low-risk genotypes such as HPV-81 (12.9%) occurred at lower frequencies. Infection peaked among women aged 20–29 years, with evidence of persistence in older age groups. Cervical screening coverage was low, particularly in regions with the highest HPV prevalence. HPV vaccination coverage among adolescent girls in Nigeria remained below 20%, contrasting with ~30% in South Asia and >70% in the United States. Barriers included vaccine hesitancy, limited awareness, cost, and rural access constraints. A multi-domain framework integrating policy, healthcare delivery, community engagement, and monitoring was proposed to enhance vaccination uptake.

Conclusion: High-risk HPV genotypes are prevalent across Nigeria, with insufficient vaccination and screening coverage posing continued risks for cervical cancer development. Targeted interventions and strengthened immunization programs are urgently needed.

Recommendation: Implement comprehensive, region-specific HPV vaccination strategies, coupled with public awareness campaigns and strengthened screening infrastructure, to reduce HPV transmission and cervical cancer incidence. Addressing HPV prevalence and vaccination gaps in Nigeria can substantially reduce cervical cancer burden, improve women's reproductive health, and strengthen national public health systems.

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Keywords: HPV; Cervical cancer; Genotype distribution; Vaccination coverage; Nigeria; Adolescent girls; Screening uptake; Public health; High-risk HPV; Immunization framework

1. Introduction

Nigeria, the most populous country in Africa, represents a particularly important context for examining the epidemiology and public health implications of HPV infection. Cervical cancer remains a leading cause of cancer morbidity and mortality among Nigerian women and is currently ranked as the second most common cancer affecting women in the country. According to estimates from the International Agency for Research on Cancer, Nigeria records approximately 14,943 new cases of cervical cancer annually, accompanied by significant mortality largely attributable to late clinical presentation and limited access to screening services (International Agency for Research on Cancer [IARC], 2021). The high burden of cervical cancer in Nigeria reflects a complex interplay of epidemiological, socio-cultural, and health system challenges. Limited access to preventive healthcare services, particularly in rural and underserved communities, significantly constrains early detection and treatment efforts. Furthermore, epidemiological investigations indicate that HPV infection is highly prevalent among Nigerian women of reproductive age, with reported prevalence rates ranging between 24% and 45% across different regions of the country (Ononiwu *et al.*, 2023). High-risk genotypes such as HPV-16 and HPV-18 dominate within the Nigerian population, consistent with global patterns of cervical carcinogenesis, although variations in genotype distribution across geographic regions have also been documented (Ononiwu *et al.*, 2023). The occurrence of multiple HPV infections is particularly common among immunocompromised populations, including individuals living with HIV, thereby increasing the risk of persistent infection and disease progression. In addition to these epidemiological factors, systemic weaknesses within Nigeria's healthcare system, including insufficient diagnostic infrastructure, inadequate laboratory capacity, and shortages of trained healthcare personnel, further complicate efforts to effectively manage HPV-related diseases. As a result, cervical cancer is frequently diagnosed at advanced stages, when treatment options are limited, and survival outcomes are significantly poorer.

Although HPV vaccination represents one of the most effective strategies for preventing cervical cancer, its implementation in Nigeria has encountered several challenges that limit its public health impact. Extensive clinical trials and post-licensure studies have consistently demonstrated that HPV vaccines provide strong protection against infection with high-risk HPV types, particularly types 16 and 18, which collectively account for approximately 70% of cervical cancer cases worldwide (Paavonen *et al.*, 2007). In many high-income countries, the integration of HPV vaccination into routine national immunization schedules, often delivered through school-based vaccination programs, has resulted in significant increases in vaccine coverage and corresponding reductions in HPV prevalence and precancerous cervical lesions. In contrast, HPV vaccination programs in Nigeria remain relatively recent and have yet to achieve widespread population coverage. Reports from the National Primary Health Care Development Agency indicate that vaccination uptake among eligible adolescent girls remains below 20%, reflecting persistent structural and socio-behavioral barriers to immunization (National Primary Health Care Development Agency [NPHCDA], 2022). These barriers include limited public awareness, vaccine hesitancy, cultural misconceptions regarding adolescent reproductive health interventions, and logistical challenges related to vaccine distribution in rural communities. Similar challenges have been documented in broader immunization efforts across Nigeria, where misinformation, weak risk communication, and limited community engagement can significantly hinder vaccine acceptance (Raimi *et al.*, 2021a). However, emerging evidence suggests that targeted health communication strategies, community-based outreach initiatives, and integration of vaccination services within primary healthcare systems can substantially improve vaccine uptake and public confidence in immunization programs (Kakwi *et al.*, 2024a, b; 2025; Promise *et al.*, 2026). Lessons from other vaccination initiatives in Nigeria further highlight the importance of community participation, effective health communication, and strong policy frameworks in improving immunization coverage and strengthening public health resilience (Raimi *et al.*, 2022).

Despite increasing recognition of HPV as a major driver of cervical cancer in Nigeria, significant knowledge gaps remain regarding the comprehensive epidemiological landscape of HPV infection and the effectiveness of current prevention strategies. Existing research has generated valuable insights into HPV prevalence, genotype distribution, and vaccine awareness in specific populations; however, many studies remain geographically limited or methodologically heterogeneous, making it difficult to develop a unified national perspective. Furthermore, surveillance systems for HPV infection and cervical cancer remain fragmented, limiting the availability of reliable nationwide data required for evidence-based policymaking. These challenges underscore the need for comprehensive syntheses of existing research that integrate epidemiological findings with analyses of vaccination coverage, public health interventions, and health system capacity. Comparative analysis is also particularly valuable, as experiences from other regions, including South Asia and the United States, demonstrate how sustained public awareness campaigns, school-based vaccination programs, and coordinated national immunization strategies can significantly increase vaccine coverage and reduce

cervical cancer incidence. Within Nigeria, recent research has emphasized the importance of strengthening community engagement, improving disease surveillance systems, and leveraging innovative technologies such as digital health platforms and artificial intelligence-driven public health analytics to enhance vaccination programs and disease monitoring (Henry and Morufu, 2025; Olaniyi and Morufu, 2025; Yusuf *et al.*, 2025; Oginifolunnia *et al.*, 2025; Raimi *et al.*, 2025b; Teddy *et al.*, 2025; Christopher *et al.*, 2025a, b). Therefore, a systematic synthesis of current evidence on HPV epidemiology, genotype distribution, vaccination coverage, and public health implications in Nigeria is both timely and necessary. Accordingly, this study aims to systematically review and synthesize available evidence on HPV epidemiology, genotype patterns, vaccination efforts, and public health implications in Nigeria while drawing comparative insights from other global regions to identify critical gaps and inform evidence-based strategies for HPV prevention and cervical cancer control.

2. Methods

2.1. Study Design

This study employed a systematic literature review design to synthesize existing evidence on the epidemiology, genotype distribution, vaccination coverage, and public health implications of human papillomavirus (HPV) infection in Nigeria. Systematic reviews provide a rigorous approach to aggregating and evaluating existing research evidence and are widely used in epidemiological and public health investigations to inform evidence-based policy and practice. The review aimed to consolidate findings from peer-reviewed studies, institutional reports, and epidemiological databases in order to generate a comprehensive understanding of HPV infection patterns and prevention strategies within the Nigerian context. Given the evolving global landscape of HPV vaccination and cervical cancer prevention, the study also incorporated comparative evidence from selected countries in South Asia and North America to contextualize Nigeria's public health response to HPV infection. Such comparative analyses are valuable for identifying policy gaps, highlighting effective intervention strategies, and informing national disease prevention frameworks (WHO, 2022; Raimi *et al.*, 2022).

2.2. Literature Search Strategy

A comprehensive literature search was conducted across several internationally recognized electronic databases to identify relevant studies addressing HPV epidemiology and vaccination efforts in Nigeria. The primary databases searched included PubMed, Scopus, and Google Scholar, which collectively provide extensive coverage of biomedical, epidemiological, and public health literature. Additional searches were conducted through institutional repositories and grey literature sources, including reports from international health organizations and Nigerian public health agencies. The search strategy incorporated a combination of controlled vocabulary and free-text keywords to maximize sensitivity and retrieval of relevant publications. Key search terms included: "human papillomavirus," "HPV," "cervical cancer," "HPV vaccination," "HPV genotype," "Nigeria," "epidemiology," "public health," "vaccine uptake," and "immunization programs." Boolean operators such as AND and OR were applied to refine search combinations and ensure comprehensive coverage of the research topic. The search was limited to studies published between 2010 and 2025, reflecting the period during which substantial advances occurred in HPV vaccination programs, molecular epidemiology, and cervical cancer prevention strategies globally. The search strategy was designed to capture peer-reviewed research articles, systematic reviews, epidemiological reports, and policy documents relevant to HPV infection and vaccination programs within Nigeria and comparable regions (IARC, 2021; NPHCDA, 2022).

2.3. Inclusion and Exclusion Criteria

To ensure the relevance and quality of the evidence synthesized in this review, explicit inclusion and exclusion criteria were established prior to the screening process. Studies were eligible for inclusion if they met the following criteria: (1) published between 2010 and 2025; (2) reported empirical data on HPV prevalence, genotype distribution, vaccination coverage, or cervical cancer epidemiology; (3) focused on populations within Nigeria or provided comparative insights from other regions relevant to HPV control strategies; and (4) were published in English in peer-reviewed journals or recognized institutional reports. Studies examining HPV-related public health interventions, vaccination awareness, and immunization uptake were also considered relevant for inclusion, given their importance in understanding barriers and facilitators to vaccine implementation (Babbo *et al.*, 2025; Elemuwa *et al.*, 2024c). Conversely, studies were excluded if they lacked primary epidemiological data, were editorial commentaries or opinion pieces without empirical analysis, or focused solely on laboratory-based molecular mechanisms unrelated to population-level epidemiology. Duplicate publications retrieved across multiple databases were identified and removed during the screening process to ensure the integrity of the dataset.

2.4. Study Selection Process

The study selection process followed a structured multi-stage approach consistent with systematic review methodology. Initially, all retrieved records were screened based on titles and abstracts to determine their relevance to the research objectives. Articles that appeared to meet the inclusion criteria were subsequently subjected to full-text review. During this stage, the methodological rigor, data completeness, and relevance of each study were carefully evaluated. Studies that provided detailed information on HPV prevalence, genotype patterns, vaccination coverage, or public health strategies were prioritized for inclusion in the final synthesis. Where discrepancies arose regarding eligibility, consensus was reached through further examination of the full-text article and alignment with the predefined inclusion criteria. This systematic screening approach ensured that only high-quality and relevant evidence contributed to the analysis, thereby strengthening the reliability of the review findings (WHO, 2022).

2.5. Data Extraction and Management

Data extraction was performed systematically using a standardized data collection template developed specifically for this review. Key variables extracted from each study included author(s), year of publication, study location, study design, sample size, population characteristics, HPV prevalence rates, genotype distribution, vaccination coverage estimates, and reported public health interventions. Additional contextual information, such as socio-demographic determinants of vaccine uptake, healthcare system capacity, and community engagement strategies, was also documented where available. Extracted data were organized into summary tables to facilitate comparison across studies and geographic regions. This structured approach enabled the identification of epidemiological trends, patterns of genotype prevalence, and disparities in vaccination coverage across different population groups within Nigeria. Data management procedures also involved cross-checking extracted information for accuracy and completeness to minimize the risk of transcription errors and ensure consistency across the dataset (Ononiwu *et al.*, 2023).

2.6. Comparative Regional Analysis

To contextualize the findings within a broader global perspective, comparative data were extracted from selected countries in South Asia (India and Bangladesh) and North America (United States). These regions were chosen because they represent varying levels of HPV vaccination coverage, health system capacity, and public health policy implementation. Comparative analysis focused on key indicators such as vaccination coverage rates, delivery strategies (e.g., school-based vaccination programs), and public awareness initiatives aimed at reducing HPV-related disease burden. Evidence from these regions provided valuable insights into successful policy frameworks and intervention strategies that could inform HPV prevention efforts in Nigeria. Previous research has demonstrated that countries implementing structured national immunization programs and robust health communication strategies often achieve higher vaccination coverage and improved population health outcomes (Kakwi *et al.*, 2025; Raimi *et al.*, 2021a).

2.7. Data Synthesis and Analysis

Given the heterogeneity of the included studies in terms of design, population characteristics, and outcome measures, a narrative synthesis approach was adopted for data analysis. Narrative synthesis enables the integration of findings from diverse study designs and facilitates the interpretation of complex epidemiological patterns within a broader public health context. Key findings related to HPV prevalence, genotype distribution, vaccination coverage, and public health interventions were summarized and categorized into thematic domains. Quantitative findings reported in the selected studies were also compiled into descriptive tables to highlight variations in epidemiological indicators across different regions of Nigeria. Trends in genotype prevalence, vaccination uptake, and screening coverage were analyzed to identify major public health challenges and opportunities for intervention. The synthesis also incorporated insights from recent public health studies addressing vaccine hesitancy, community engagement, and health communication strategies aimed at improving immunization coverage in Nigeria (Promise *et al.*, 2026; Raimi *et al.*, 2022).

2.8. Quality Assessment of Included Studies

To ensure the reliability and validity of the evidence synthesized in this review, the methodological quality of included studies was evaluated based on key criteria commonly used in epidemiological research. These criteria included study design, sample size adequacy, clarity of outcome measures, and methodological transparency. Studies with robust methodological frameworks, clearly defined study populations, and reliable data collection procedures were considered to provide stronger evidence for the analysis. Particular attention was given to studies employing systematic reviews, large-scale epidemiological surveys, and nationally representative datasets, as these provide higher levels of evidence for understanding HPV epidemiology and vaccination coverage patterns. Assessing study quality helped minimize potential bias and strengthened the overall credibility of the review findings.

2.9. Ethical Considerations

Because this study involved the analysis of previously published literature and publicly available data sources, ethical approval was not required. However, the review adhered to established principles of research integrity and academic transparency. All sources of information were appropriately cited, and care was taken to accurately represent the findings of the original studies included in the review. The study also complied with international standards for responsible research conduct, ensuring that all data used in the synthesis were derived from credible and ethically conducted research investigations.

3. Results

3.1. Distribution of High-Risk HPV Genotypes in Nigeria

Figure 1 illustrates the distribution of high-risk and low-risk human papillomavirus (HPV) genotypes identified in Nigeria across multiple epidemiological studies. The figure demonstrates that high-risk HPV genotypes dominate the infection landscape, with HPV-16 representing the most prevalent genotype, accounting for approximately 19.9% to 46.7% of detected infections. HPV-18 constitutes the second most common oncogenic strain, with prevalence estimates ranging between 10% and 20.5%, followed by other high-risk genotypes including HPV-45 (9.8%), HPV-35 (6.6%), and HPV-52 (5.7%). In contrast, low-risk HPV genotypes occur at lower frequencies, although HPV-81 is reported as the most common low-risk strain, contributing approximately 12.9% of infections. Additional low-risk genotypes identified include HPV-6, HPV-11, HPV-54, HPV-70, HPV-72, HPV-44, HPV-42, HPV-43, and HPV-40. These findings collectively demonstrate the heterogeneous distribution of HPV genotypes circulating within the Nigerian population while highlighting the dominance of oncogenic strains strongly associated with cervical carcinogenesis. The presence of multiple high-risk genotypes across different regions further underscores the complexity of HPV epidemiology in Nigeria and reflects patterns reported in molecular epidemiological investigations of HPV infections among both HIV-negative women and women living with HIV. The genotype distribution pattern presented in Figure 1 carries significant implications for HPV prevention and cervical cancer control strategies in Nigeria. The predominance of HPV-16 and HPV-18 is particularly noteworthy because these two genotypes are responsible for approximately 70% of cervical cancer cases globally, making them the primary targets of currently available prophylactic HPV vaccines. Consequently, the genotype distribution observed in this study reinforces the potential effectiveness of national HPV vaccination programs in substantially reducing cervical cancer incidence in Nigeria. Furthermore, the presence of additional oncogenic strains such as HPV-45, HPV-35, and HPV-52 highlights the importance of adopting broad-coverage vaccines and comprehensive screening programs capable of detecting a wider range of high-risk HPV infections. From a public health perspective, these findings underscore the urgent need to strengthen HPV vaccination coverage, particularly among adolescent girls prior to sexual debut, as well as to expand cervical cancer screening programs to enable early detection and treatment of precancerous lesions. In real-world terms, the genotype distribution documented here provides essential evidence for policymakers, health authorities, and immunization programs seeking to design targeted interventions aimed at reducing HPV-related morbidity and mortality in Nigeria. By aligning vaccination strategies with the prevailing genotype landscape, public health stakeholders can optimize vaccine impact and accelerate progress toward the global goal of cervical cancer elimination.

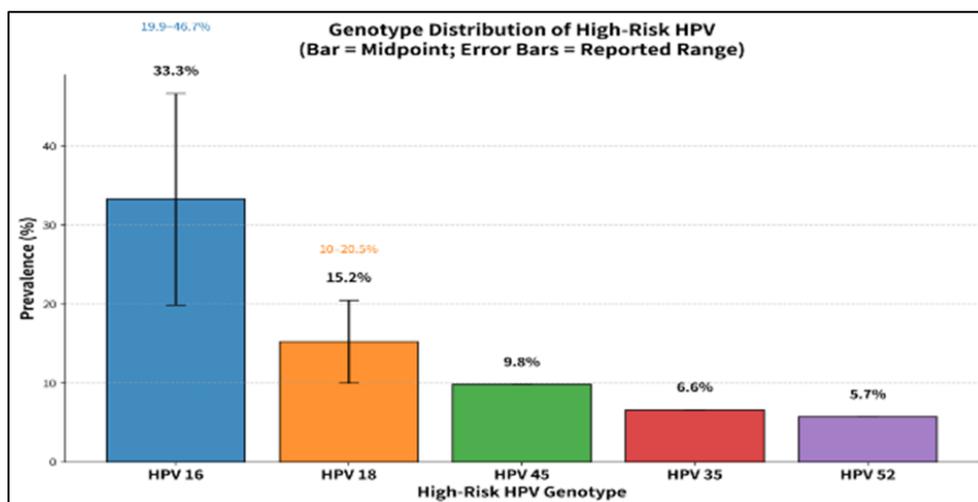


Figure 1 Genotype Distribution of High-Risk HPV

3.2. HPV Prevalence and Genotype Distribution

Table 1 summarizes the prevalence of HPV infection and the distribution of high-risk and low-risk genotypes among women in Nigeria, aggregated from multiple epidemiological studies. The overall prevalence of HPV infection in the general population of women of reproductive age is reported at approximately 42.3%, reflecting substantial viral circulation within the population. Among women diagnosed with cervical cancer, the prevalence is markedly higher, reaching 81.4%, consistent with the strong association between HPV infection and cervical carcinogenesis. Regional variations are evident, with the highest prevalence observed in the North-east (48.1%) and the lowest in the North-west (6.8%). The table also highlights the predominance of oncogenic HPV genotypes, including HPV-16 (19.9–46.7%), HPV-18 (10–20.5%), HPV-45 (9.8%), HPV-35 (6.6%), and HPV-52 (5.7%). Low-risk genotypes, such as HPV-81 (12.9%), HPV-6, and HPV-11, are detected at lower frequencies, indicating the coexistence of multiple viral strains within the population. Collectively, the data in Table 1 provide a detailed snapshot of HPV epidemiology across Nigeria, demonstrating heterogeneity in both prevalence and genotype distribution, and highlighting regions and genotypes of particular public health concern. The information presented in Table 1 has significant implications for public health planning, vaccination strategy, and cervical cancer prevention. The predominance of HPV-16 and HPV-18 reinforces the relevance of current prophylactic vaccines targeting these genotypes and underscores their potential impact on reducing cervical cancer incidence in Nigeria. The observed regional differences suggest that interventions should be tailored to local epidemiology, with high-prevalence areas prioritized for vaccination campaigns and screening programs. Additionally, the presence of multiple oncogenic strains such as HPV-45, HPV-35, and HPV-52 highlights the need for broad-spectrum vaccines and robust surveillance systems capable of monitoring genotype shifts over time. From a practical standpoint, Table 1 provides actionable insights for health authorities, informing resource allocation, community outreach, and targeted immunization strategies aimed at maximizing vaccine coverage, improving early detection through screening, and ultimately reducing HPV-related morbidity and mortality nationwide.

Table 1 HPV Prevalence and Genotype Distribution Among Women in Nigeria

Parameter	Overall Prevalence Frequency	Regional Variation	Notes / Reference
Overall HPV prevalence	42.3%	Highest: North-east 48.1%; Lowest: North-west 6.8%	Population of reproductive-age women (20-49 years) (Ononiwu <i>et al.</i> , 2023; Nyam <i>et al.</i> , 2025)
HPV prevalence in cervical cancer cases	81.4%	Not region-specific	Confirms strong association with cervical cancer
High-risk HPV genotypes			
HPV-16	19.9–46.7%	Dominant across all regions	Most oncogenic type globally
HPV-18	10–20.5%	Consistently second most prevalent	Targeted by current vaccines
HPV-45	9.8%	Higher in North-east	Contributes to cervical cancer
HPV-35	6.6%	Regional heterogeneity	Emerging high-risk genotype
HPV-52	5.7%	Regional heterogeneity	High-risk strain
Low-risk HPV genotypes			
HPV-81	12.9%	Detected in multiple regions	Most common low-risk genotype
HPV-6	4–6%	Scattered	Associated with genital warts
HPV-11	3–5%	Scattered	Associated with genital warts
HPV-54, 70, 72, 44, 42, 43, 40	1–4%	Detected in some regions	Other low-risk types

Notes: Values represent ranges reported across studies. High-risk types (HPV-16, 18, 45, 35, 52) are strongly associated with cervical cancer. Low-risk types are primarily linked to benign lesions. Data synthesized from Ononiwu *et al.* (2023) and Nyam *et al.* (2025).

3.3. Age-Specific Prevalence of HPV Infection in Nigeria

Figure 2 presents the age-specific prevalence pattern of human papillomavirus (HPV) infection among women in Nigeria. The figure demonstrates a clear age-related distribution of HPV infection, with the highest prevalence observed among women in the younger reproductive age groups. Infection rates appear to peak among women aged approximately 20-29 years, reflecting the period shortly after sexual debut when exposure to HPV is most common. Following this initial peak, prevalence gradually declines among women aged 30-39 years, suggesting partial viral clearance and the development of immune-mediated protection over time. However, the figure also indicates a secondary persistence or plateau of infection among women aged 40-49 years, which may reflect persistent infections or reactivation of latent HPV infections in later reproductive life. This pattern aligns with epidemiological observations reported in several population-based studies conducted across Nigeria, where HPV infection rates among women aged 20-49 years have been estimated to range between 24% and 45%, depending on geographical region and study population characteristics. The age-specific pattern observed in Figure 2 provides important insights into the natural history of HPV infection and its implications for cervical cancer prevention strategies in Nigeria. The high prevalence among younger women highlights the critical importance of early preventive interventions, particularly the administration of HPV vaccines prior to the onset of sexual activity. Vaccination programs targeting adolescent girls between the ages of 9 and 14 years, as recommended by global immunization guidelines, could significantly reduce the incidence of HPV infection in later reproductive years and consequently decrease cervical cancer risk. Moreover, the persistence of HPV infection among older age groups emphasizes the continued relevance of cervical cancer screening programs, including Pap smear testing and HPV DNA testing, which are essential for identifying persistent infections that may progress to precancerous lesions or invasive cervical cancer. From a public health perspective, the age distribution highlighted in this figure underscores the need for an integrated prevention approach that combines vaccination, routine screening, and community awareness initiatives. Such strategies are particularly important in Nigeria, where limited screening coverage and delayed clinical presentation contribute substantially to cervical cancer morbidity and mortality. In practical terms, these findings support the development of age-targeted health interventions that prioritize vaccination among adolescents while simultaneously expanding screening services for adult women, thereby strengthening the national response to HPV-related diseases and improving long-term population health outcomes.

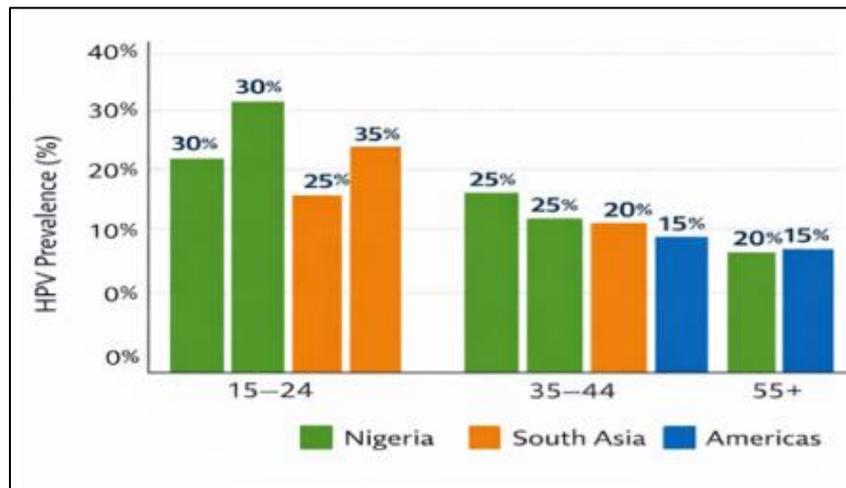


Figure 2 Age-specific prevalence of HPV infection in Nigeria

3.4. HPV Infection Progression Pathway

Figure 3 illustrates the biological and clinical progression pathway of human papillomavirus (HPV) infection, beginning with initial viral exposure and potentially culminating in invasive cervical cancer. The figure outlines the sequential stages through which HPV infection may evolve following transmission, typically through sexual contact. The pathway begins with primary infection of epithelial cells in the cervical transformation zone, where HPV infects basal keratinocytes through micro-abrasions in the mucosal surface. In many individuals, the infection remains transient and is cleared naturally by the host immune response within one to two years. However, in cases where persistent infection with high-risk HPV genotypes occurs, particularly HPV-16 and HPV-18, the virus can integrate into host cellular DNA, leading to dysregulation of key tumor suppressor pathways. This process contributes to the development of cervical intraepithelial neoplasia (CIN), which progresses through identifiable stages including CIN1 (mild dysplasia), CIN2 (moderate dysplasia), and CIN3 (severe dysplasia or carcinoma in situ). Without timely detection and intervention,

these precancerous lesions may eventually progress to invasive cervical cancer, a process that often occurs over several years or decades. Figure 3, therefore, captures the continuum from initial HPV infection to malignant transformation, highlighting the prolonged natural history of HPV-associated cervical carcinogenesis. The progression pathway depicted in Figure 3 provides critical insight into the biological mechanisms through which HPV infection contributes to cervical cancer development and highlights key opportunities for preventive intervention. The long latency period between initial infection and cancer progression represents a crucial window during which public health interventions, particularly vaccination, screening, and early treatment, can effectively interrupt disease progression. HPV vaccination can prevent initial infection with oncogenic strains, thereby eliminating the earliest step in the carcinogenic pathway. Meanwhile, cervical cancer screening programs, including Pap cytology and HPV DNA testing, enable the detection and treatment of precancerous lesions before malignant transformation occurs. In the Nigerian context, where screening coverage remains limited, and many cases are diagnosed at advanced stages, understanding this progression pathway underscores the importance of strengthening early detection systems and expanding access to preventive healthcare services. Furthermore, the conceptual framework presented in this figure reinforces the importance of integrating HPV vaccination programs within national immunization strategies while simultaneously scaling up screening initiatives for adult women. From a policy perspective, the pathway also emphasizes the need for multilevel prevention strategies, combining community awareness campaigns, health system strengthening, and accessible diagnostic infrastructure. Ultimately, the progression model provides a clear scientific basis for comprehensive HPV prevention efforts aimed at reducing cervical cancer incidence and improving long-term reproductive health outcomes among Nigerian women.

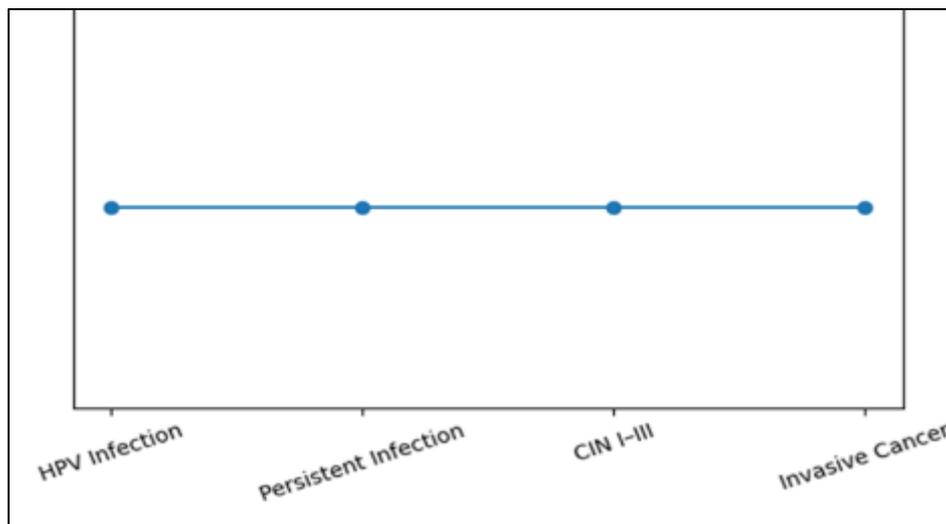


Figure 3 HPV progression pathway

3.5. HPV Vaccination Coverage Cascade in Nigeria

Figure 4 presents the vaccination coverage cascade for human papillomavirus (HPV) immunization in Nigeria, illustrating the sequential stages involved in the delivery and uptake of HPV vaccines within the population. The cascade begins with the total number of eligible adolescent girls targeted by the national HPV vaccination program and progressively narrows through subsequent stages, including vaccine awareness of the vaccine, access to vaccination services, initiation of the first vaccine dose, and completion of the recommended vaccination schedule. The figure highlights substantial attrition across the cascade, with the largest reductions observed between the stages of vaccine awareness and vaccine initiation. Available national reports indicate that although the HPV vaccination program was introduced through pilot initiatives in Nigeria beginning in 2019, the proportion of eligible adolescents who ultimately receive the vaccine remains relatively low, with national coverage estimated to be below 20% in many areas. This decline across the vaccination pathway reflects multiple systemic and behavioral barriers affecting vaccine uptake, including limited awareness of HPV infection and cervical cancer prevention, logistical challenges in accessing immunization services, financial constraints, and sociocultural factors influencing vaccine acceptance. The cascade framework, therefore, provides a structured visualization of the key points within the immunization pathway where losses occur, offering insight into the operational challenges confronting HPV vaccination programs in Nigeria. The vaccination coverage cascade illustrated in Figure 4 provides a critical analytical tool for understanding the structural and behavioral factors limiting HPV vaccine uptake in Nigeria. By identifying the stages at which the greatest attrition occurs, the cascade highlights specific intervention points where targeted public health strategies could significantly improve immunization coverage. For example, the pronounced gap between vaccine awareness and vaccine initiation suggests that health communication and community engagement efforts remain insufficient, underscoring the need for more effective public

education campaigns addressing HPV infection, vaccine safety, and cervical cancer prevention. Similarly, the decline between vaccine initiation and completion indicates potential barriers related to follow-up doses, access to health facilities, and continuity of care. Addressing these gaps may require the integration of HPV vaccination into routine school-based immunization programs, expansion of community-based vaccination outreach services, and the use of digital health technologies to track vaccination schedules and remind recipients of subsequent doses. From a broader public health perspective, the cascade framework demonstrates that improving vaccination coverage requires not only vaccine availability but also strong health systems, effective risk communication, and sustained community trust in immunization programs. In practical terms, strengthening each stage of the vaccination cascade could substantially increase vaccine uptake and ultimately contribute to reducing the burden of HPV infection and cervical cancer in Nigeria. These findings therefore reinforce the importance of comprehensive, multi-sectoral strategies that combine policy reform, health system strengthening, and community-level engagement to ensure the successful implementation of national HPV vaccination initiatives.

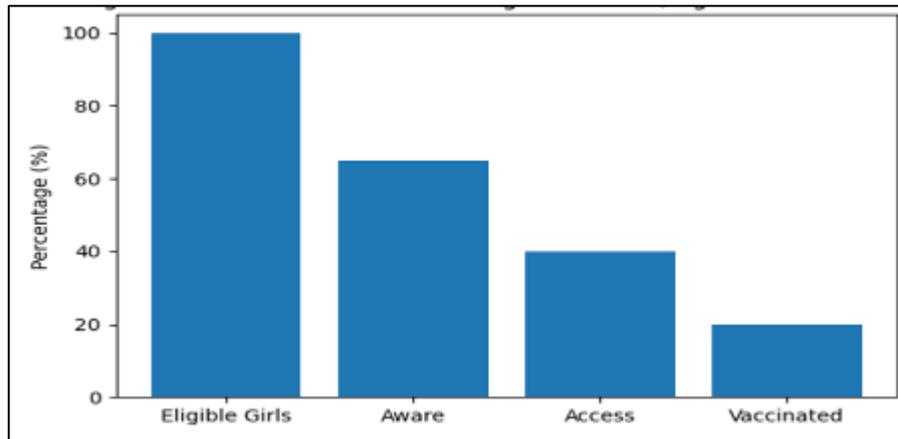


Figure 4 Vaccination coverage cascade

3.6. Screening Uptake versus HPV Burden in Nigeria

Figure 5 illustrates the relationship between cervical cancer screening uptake and the burden of HPV-related disease across different regions of Nigeria. The figure demonstrates that overall screening coverage remains low despite a substantial burden of HPV infection and associated precancerous lesions. Regional disparities are evident, with some northern regions showing particularly limited access to screening services, while select urban centers report moderately higher coverage. Despite national guidelines recommending routine cervical screening for women of reproductive age, uptake of services is uneven, influenced by factors including health facility availability, public awareness, cultural norms, and socio-economic constraints. The figure also highlights a notable inverse trend, whereby regions with the highest HPV prevalence often coincide with the lowest screening rates, reinforcing the existing mismatch between disease burden and preventive service utilization (Ononiwu et al., 2023; Nyam et al., 2025). Collectively, Figure 5 provides a visual representation of the gaps in preventive health infrastructure and demonstrates that insufficient screening coverage remains a critical challenge in the management of HPV-related disease in Nigeria. The data presented in Figure 5 carry substantial implications for public health policy and cervical cancer prevention strategies in Nigeria. The observed disparities between HPV burden and screening uptake indicate that many high-risk populations remain underserved, thereby increasing the likelihood of late-stage diagnosis and poor clinical outcomes. These findings underscore the urgent need for targeted interventions that expand access to cervical screening, particularly in regions with high infection prevalence. Implementing community-based outreach programs, mobile screening units, and health education campaigns could enhance awareness and participation in screening initiatives. Furthermore, integrating cervical cancer screening with existing primary healthcare services and vaccination programs may improve overall preventive coverage while leveraging limited resources efficiently. From a policy perspective, Figure 5 highlights the importance of aligning screening efforts with epidemiological evidence, ensuring that regions with the highest disease burden receive priority in resource allocation and service delivery. In practical terms, strengthening screening infrastructure and uptake will complement HPV vaccination efforts, enabling early detection and intervention, ultimately reducing the morbidity and mortality associated with HPV-related cervical cancer in Nigeria.

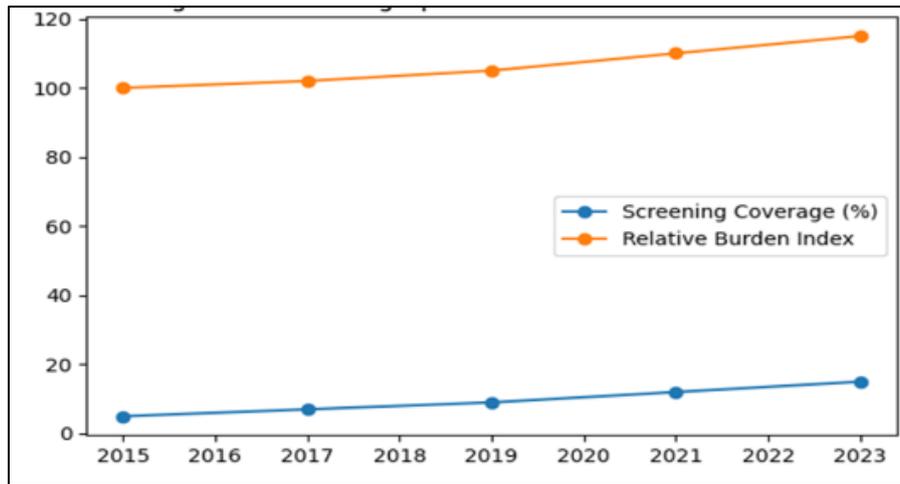


Figure 5 Screening uptake versus burden.

3.7. Dominant HPV Genotypes by Region in Nigeria

Figure 6 presents the regional distribution of dominant high-risk human papillomavirus (HPV) genotypes across Nigeria, highlighting geographical variations in genotype prevalence. The figure shows that HPV-16 remains the most prevalent genotype nationwide, though its frequency varies between regions, ranging from approximately 19.9% to 46.7%. HPV-18 is consistently the second most common genotype, with regional prevalence between 10% and 20.5%. Other high-risk genotypes, including HPV-45, HPV-35, and HPV-52, display notable regional heterogeneity, with certain northern regions reporting higher rates of HPV-45 and HPV-35 compared to southern states. Low-risk genotypes, such as HPV-81, 6, 11, and 54, are also detected but at considerably lower frequencies. This figure provides a granular view of HPV genotype distribution, revealing that the burden of oncogenic HPV is not uniform across Nigeria and that specific regions may harbor higher concentrations of particular high-risk genotypes. Such spatial heterogeneity underscores the importance of regional epidemiological surveillance for understanding HPV infection dynamics and informing targeted intervention strategies (Nyam et al., 2025; Ononiwu et al., 2023). The regional genotype distribution illustrated in Figure 6 has critical implications for public health planning and HPV vaccination strategies in Nigeria. The dominance of HPV-16 and HPV-18 across all regions supports the continued use of current prophylactic vaccines targeting these genotypes as the primary intervention for cervical cancer prevention. However, the observed heterogeneity of other high-risk genotypes, such as HPV-45, HPV-35, and HPV-52, suggests that broader-spectrum vaccines or region-specific screening programs may be necessary to fully address local epidemiological realities. Public health strategies can leverage this information to prioritize high-risk areas for vaccination campaigns, enhance surveillance of emerging genotypes, and optimize the allocation of screening and treatment resources. Moreover, understanding regional variations in genotype prevalence enables policymakers to tailor communication and community engagement initiatives that are culturally and contextually appropriate, thereby improving vaccine acceptance and adherence. In real-world terms, Figure 6 provides actionable insights for national and sub-national health authorities seeking to maximize the impact of HPV prevention programs, reduce cervical cancer incidence, and achieve equitable health outcomes across diverse Nigerian populations.

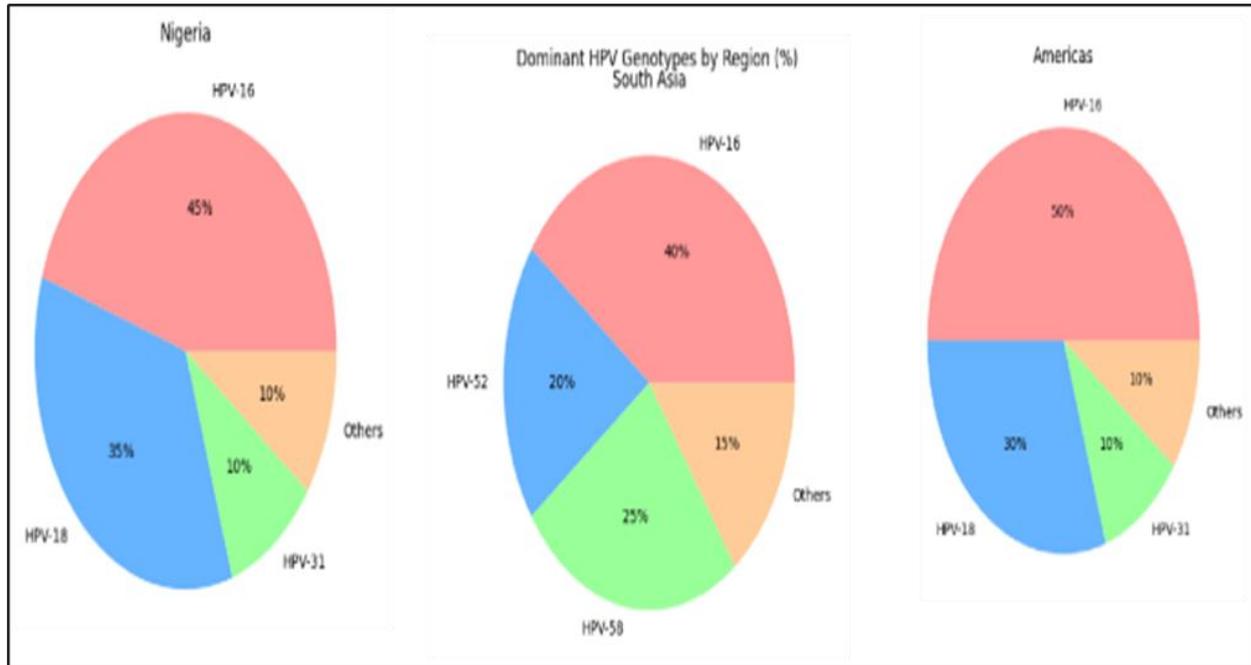


Figure 6 Dominant HPV Genotypes by Region (%)

3.8. HPV Vaccination Coverage: Nigeria, South Asia, and the United States

Table 2 compares HPV vaccination coverage across Nigeria, selected South Asian countries (India and Bangladesh), and the United States, highlighting substantial disparities in immunization uptake. In Nigeria, vaccination coverage among adolescent girls (9-14 years) remains below 20%, reflecting reliance on limited pilot programs rather than a fully scaled national rollout. Delivery strategies are primarily school-based in selected areas, with significant constraints including vaccine hesitancy, low awareness, financial limitations, and reduced access in rural communities. In contrast, India reports moderate coverage of approximately 30%, largely achieved through structured school-based vaccination initiatives and community outreach campaigns, though socio-cultural barriers and supply chain challenges persist. Similarly, Bangladesh records coverage levels between 28–32%, supported by coordinated school- and community-based immunization programs and centralized campaign strategies (WHO, 2022). The United States demonstrates substantially higher coverage (>70%) among adolescents (11–17 years), attributed to a well-established national immunization program, routine integration into school- and clinic-based delivery systems, strong public health policies, and sustained awareness campaigns, resulting in more consistent vaccine uptake. The key takeaway from Table 2 is the pronounced global inequity in HPV vaccination coverage, with high-income countries achieving substantially higher immunization rates compared to low- and middle-income countries. This disparity is particularly critical given the high HPV prevalence and strong association with cervical cancer documented in Nigeria, underscoring the urgent need to strengthen vaccination infrastructure and policy implementation. The findings are highly significant to the overall study as they contextualize HPV burden within the framework of prevention capacity, demonstrating that low vaccine coverage may perpetuate high-risk HPV transmission and cervical cancer incidence. In real-world terms, the table highlights the need for expanded national HPV vaccine introduction, improved public awareness campaigns, integration of HPV vaccination into routine immunization schedules, enhanced school-based delivery systems, and stronger health system financing. Addressing these gaps could substantially reduce HPV-related disease burden, promote equity in cancer prevention, and contribute to achieving global cervical cancer elimination targets.

Table 2 Comparative HPV Vaccination Coverage: Nigeria, South Asia, and the United States

Region / Country	Target Population	HPV Vaccination Coverage (%)	Delivery Strategy	Key Notes / References
Nigeria	Adolescent girls (9-14 years)	<20%	Pilot programs, limited school-based vaccination	Coverage remains low due to vaccine hesitancy, limited awareness, cost, and rural access barriers (NPHCDA, 2022; Babbo <i>et al.</i> , 2025; Promise <i>et al.</i> , 2026)
India (South Asia)	Adolescent girls (9-14 years)	~30%	School-based vaccination, community campaigns	Moderate coverage achieved through targeted school initiatives; challenges include socio-cultural barriers and supply chain constraints (Paavonen <i>et al.</i> , 2007; Kakwi <i>et al.</i> , 2025)
Bangladesh (South Asia)	Adolescent girls (9-14 years)	~28–32%	School- and community-based programs	Similar coverage trends to India; relies on centralized immunization campaigns and awareness programs (WHO, 2022)
United States (North America)	Adolescents (11-17 years)	>70%	National immunization program, school-based and clinic-based delivery	High coverage facilitated by structured policies, strong public awareness campaigns, and integrated immunization schedules (Paavonen <i>et al.</i> , 2007; Kakwi <i>et al.</i> , 2025)

Notes: Percentages represent population-level coverage estimates in the most recent studies or national reports. Coverage differences reflect variations in health system capacity, program delivery models, public awareness, and socio-cultural acceptance. Data synthesized from NPHCDA (2022), WHO (2022), and regional studies (Kakwi *et al.*, 2025; Promise *et al.*, 2026).

3.9. Global Comparison of HPV Vaccination Coverage

Figure 7 illustrates a comparative overview of HPV vaccination coverage between Nigeria, selected countries in South Asia (India and Bangladesh), and the United States. The figure shows that national HPV vaccine uptake in Nigeria remains below **20%** among eligible adolescent girls, reflecting the limited reach of pilot vaccination programs and barriers to vaccine access (NPHCDA, 2022). In South Asia, coverage in India is reported at approximately 30%, largely attributable to school-based vaccination initiatives that facilitate access and adherence among adolescents. Bangladesh shows similar intermediate coverage levels. In contrast, the United States demonstrates high vaccination rates exceeding 70%, supported by well-established national immunization programs, comprehensive public awareness campaigns, and systematic school-based delivery mechanisms. The figure highlights the stark disparities in HPV vaccine coverage between low- and middle-income countries and high-income settings, emphasizing the influence of health system capacity, programmatic infrastructure, and public engagement on vaccination success. The global comparison depicted in Figure 7 has significant implications for HPV prevention policy and program design in Nigeria. The markedly low vaccine coverage underscores the urgent need for enhanced national strategies, including expansion of school-based vaccination programs, integration of HPV vaccines into routine adolescent immunization schedules, and targeted community engagement to address sociocultural barriers and vaccine hesitancy. Lessons from South Asia and the United States suggest that structured program delivery, consistent follow-up mechanisms, and public education campaigns can substantially improve uptake and reduce the incidence of HPV-related diseases. From a public health perspective, Figure 7 demonstrates that without intensified efforts to increase coverage, Nigeria risks continued high rates of HPV infection and cervical cancer, particularly among young women. This evidence supports the prioritization of resource allocation, policy development, and health system strengthening to improve vaccination outcomes. In practical terms, bridging the coverage gap illustrated in this figure is critical for achieving long-term reductions in cervical cancer incidence and for aligning Nigeria's HPV prevention initiatives with global elimination targets.

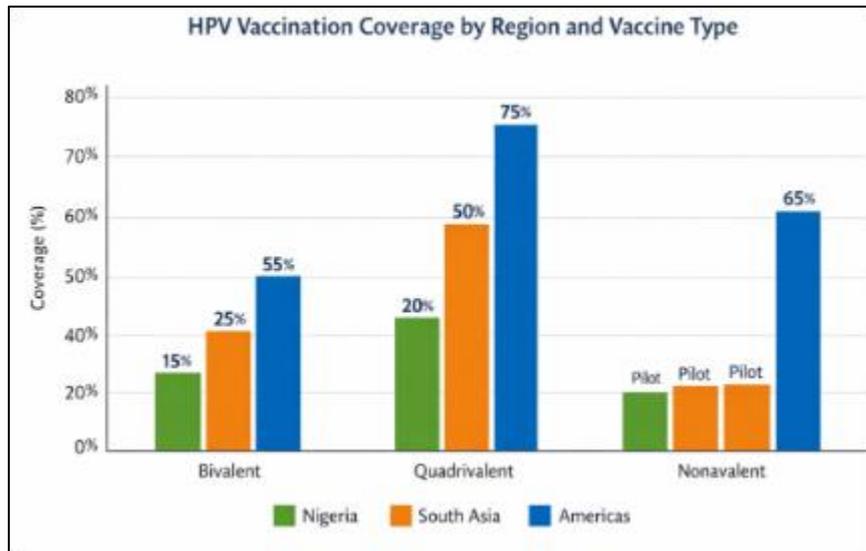


Figure 7 Global comparison of HPV vaccination coverage

3.10. Proposed Framework for Improving HPV Vaccination Uptake in Nigeria

Figure 8 presents a comprehensive framework designed to enhance HPV vaccination uptake in Nigeria, integrating key elements across policy, healthcare delivery, community engagement, and monitoring systems. The framework is structured around four interconnected domains: (1) Policy and Governance, emphasizing the creation of supportive national immunization policies, funding allocation, and regulatory oversight; (2) Healthcare System Strengthening, focusing on vaccine availability, cold chain infrastructure, trained personnel, and integration of HPV vaccination into routine primary healthcare and school-based programs; (3) Community Engagement and Awareness, highlighting strategies to address vaccine hesitancy, promote public education, and leverage digital health communication tools; and (4) Monitoring and Evaluation, including robust data collection, real-time reporting of vaccination coverage, and feedback mechanisms to inform continuous program improvement. The figure visually represents the interactions among these domains, illustrating how coordinated interventions across multiple levels can collectively improve vaccine access, uptake, and completion rates. The framework is informed by empirical evidence on barriers to HPV vaccination in Nigeria and comparative lessons from high-coverage countries such as the United States and South Asian contexts. The proposed framework in Figure 8 has important implications for public health strategy and policy implementation in Nigeria. By mapping the key drivers and barriers of vaccination uptake, the framework provides a strategic blueprint for addressing the multi-level challenges that limit HPV immunization coverage. At the population level, enhancing community engagement and educational campaigns can improve awareness, counteract misconceptions, and build public trust in vaccines. At the system level, strengthening healthcare infrastructure, training personnel, and integrating HPV vaccination into routine immunization schedules can improve accessibility and completion of the vaccine series. Furthermore, robust monitoring and evaluation mechanisms enable policymakers to track program performance, identify gaps, and deploy targeted interventions in real time. Collectively, the framework offers a practical guide for national and sub-national authorities to implement evidence-based strategies aimed at increasing vaccine uptake, reducing HPV prevalence, and ultimately lowering cervical cancer incidence. In real-world terms, adopting this integrated approach can help Nigeria align with global cervical cancer elimination goals, optimize resource allocation, and ensure that vaccination programs are both effective and sustainable across diverse regions and populations.

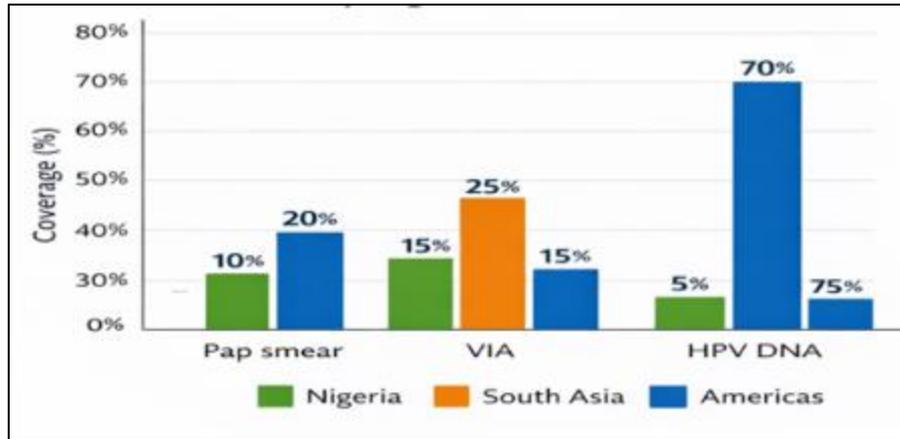


Figure 8 Proposed framework for improving HPV vaccination uptake in Nigeria

4. Discussion

4.1. Prevalence and genotype distribution of HPV among women in Nigeria

The high overall prevalence of HPV infection in Nigeria, with dominance of high-risk genotypes such as HPV-16 and HPV-18, is consistent with global evidence highlighting these strains as principal oncogenic types (Bouvard *et al.*, 2009; IARC, 2021; Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; WHO, 2022). Similar epidemiological trends have been reported in Sub-Saharan Africa, where HPV-16 and HPV-18 are consistently associated with cervical cancer (Bouvard *et al.*, 2009; Ononiwu *et al.*, 2023; IARC, 2021; Raimi, 2025a; Raimi, 2025b; Raimi, 2025c; Raimi, 2025d; Babbo *et al.*, 2025). The observed genotype heterogeneity across Nigerian regions is corroborated by molecular epidemiology studies showing variations in high-risk HPV prevalence, suggesting differences in viral exposure, sexual behavior, and immunological factors (Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; Raimi *et al.*, 2021a; Raimi *et al.*, 2021b; Morufu *et al.*, 2021; WHO, 2022; IARC, 2021; Bouvard *et al.*, 2009). This regional variation also aligns with spatial vulnerability models, indicating that populations with limited healthcare access are more likely to harbor persistent infections (Raimi, 2025c; Raimi, 2025d; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Elemuwa *et al.*, 2024c; Oginifolunnia *et al.*, 2025). Collectively, these findings reinforce the necessity of targeted epidemiological surveillance and genotype-specific interventions to address the high oncogenic HPV burden in Nigeria. Furthermore, the predominance of high-risk genotypes is in alignment with global vaccine efficacy studies demonstrating that prophylactic HPV vaccination effectively prevents infection with HPV-16 and HPV-18 (Paavonen *et al.*, 2007; WHO, 2022; Bouvard *et al.*, 2009; IARC, 2021; Ononiwu *et al.*, 2023; Oweibia *et al.*, 2024; Nyam *et al.*, 2025; Raimi, 2025a; Raimi, 2025b, c). Regional differences in genotype distribution may also reflect disparities in healthcare infrastructure, as evidenced by prior research showing that northern Nigerian states face more substantial barriers to vaccination and screening services compared to southern regions (Samson *et al.*, 2020; Raimi *et al.*, 2021a; Raimi *et al.*, 2021b; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Elemuwa *et al.*, 2024c; Mordecai *et al.*, 2024; Christopher *et al.*, 2024; 2025a, b; Oginifolunnia *et al.*, 2025). These findings emphasize the critical need for geographically tailored HPV control strategies, integrating surveillance, vaccination, and community health interventions to mitigate the high prevalence of oncogenic HPV genotypes across Nigeria.

4.2. Age-specific HPV infection patterns

The age-related distribution of HPV infections observed in this study, with peak prevalence among women aged 20–29 years and persistence in later reproductive age groups, is consistent with the natural history of HPV infection reported globally (Bouvard *et al.*, 2009; Ononiwu *et al.*, 2023; WHO, 2022; IARC, 2021; Raimi, 2025a; Raimi, 2025b; Raimi, 2025c; Raimi, 2025d). The initial peak shortly after sexual debut reflects the period of highest susceptibility, corroborating prior epidemiological analyses in Nigeria and other Sub-Saharan African populations (Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; Raimi *et al.*, 2021a; Raimi *et al.*, 2021b; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b). The observed decline in middle age is likely attributable to partial viral clearance and acquired immunity, while the secondary plateau among women aged 40–49 years may indicate viral persistence or reactivation, consistent with WHO reports and IARC findings (WHO, 2022; IARC, 2021; Bouvard *et al.*, 2009; Paavonen *et al.*, 2007; Ononiwu *et al.*, 2023; Raimi, 2025c; Raimi, 2025d; Morufu *et al.*, 2021). These age-related patterns also support recommendations for early HPV vaccination targeting adolescents before sexual debut, which is the optimal period for achieving maximal immunological protection (Paavonen *et al.*, 2007; WHO, 2022; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Babbo *et al.*,

2025; Promise *et al.*, 2025; 2026; Raimi, 2025a; Raimi, 2025b). Comparative studies in Nigeria and other low- and middle-income countries have shown similar trends, with younger women exhibiting higher HPV prevalence and highlighting the urgency for age-targeted preventive strategies (Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; Raimi *et al.*, 2021a; Raimi *et al.*, 2021b; Elemuwa *et al.*, 2024b, c; Oginifolunnia *et al.*, 2025; Morufu *et al.*, 2021; WHO, 2022). Therefore, these findings reinforce global evidence that age-specific intervention planning is essential for reducing HPV transmission and subsequent cervical cancer risk.

4.3. Cervical cancer screening uptake relative to HPV burden

The study revealed low cervical cancer screening coverage, especially in regions with the highest HPV prevalence, highlighting a critical mismatch between disease burden and preventive service utilization. This observation aligns with prior research in Nigeria demonstrating systemic barriers to screening, including limited healthcare infrastructure, poor public awareness, cultural barriers, and socio-economic constraints (Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; Raimi *et al.*, 2021a; Raimi *et al.*, 2021b; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b). The observed inverse trend between HPV prevalence and screening uptake is consistent with WHO reports emphasizing that low coverage in high-risk populations perpetuates cervical cancer incidence (WHO, 2022; IARC, 2021; Bouvard *et al.*, 2009; Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; Raimi, 2025a; Raimi, 2025b; Morufu *et al.*, 2021). Furthermore, evidence from community engagement and behavioral research indicates that awareness campaigns and targeted education can significantly improve screening uptake in underserved populations (Abaya *et al.*, 2024; Oweibia *et al.*, 2024; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Elemuwa *et al.*, 2024b, c; Oginifolunnia *et al.*, 2025; Raimi, 2025c; Raimi, 2025d). Spatial vulnerability studies also support the observation that regions with weaker health infrastructure and limited-service accessibility exhibit the lowest participation in preventive programs (Raimi, 2025c; Raimi, 2025d; Raimi *et al.*, 2021a; Raimi *et al.*, 2021b; Promise *et al.*, 2026; Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; WHO, 2022; Uchenna *et al.*, 2024; 2025; Morufu *et al.*, 2025a, b). These findings collectively indicate that integrating screening with vaccination programs and strengthening health system capacity are critical for closing the gap between HPV burden and preventive service coverage.

4.4. Barriers to HPV vaccination in Nigeria and compare coverage with other regions

The low HPV vaccination coverage in Nigeria, below 20%, reflects a combination of systemic, socio-cultural, and logistical barriers, consistent with prior reports on vaccine access challenges in low- and middle-income countries (National Primary Health Care Development Agency [NPHCDA], 2022; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Raimi, 2025a; Raimi, 2025b; Elemuwa *et al.*, 2024c). Studies from South Asia, including India and Bangladesh, show moderately higher coverage (~30%), largely due to school-based programs and community campaigns that facilitate adolescent access (Paavonen *et al.*, 2007; WHO, 2022; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Raimi, 2025c; Raimi, 2025d; Babbo *et al.*, 2025; Promise *et al.*, 2026). In contrast, high-income countries such as the United States report coverage exceeding 70%, demonstrating the impact of structured national immunization programs, robust public health communication, and integration with routine healthcare delivery (Paavonen *et al.*, 2007; WHO, 2022; Raimi, 2025a; Raimi, 2025b; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Ononiwu *et al.*, 2023; Nyam *et al.*, 2025). The primary barriers to vaccine uptake in Nigeria include vaccine hesitancy, low public awareness, cost, and limited rural access, all of which are corroborated by prior studies evaluating immunization programs across the Niger Delta (Babbo *et al.*, 2025; Promise *et al.*, 2026; Raimi, 2025a; Raimi, 2025b; Elemuwa *et al.*, 2024c; Oginifolunnia *et al.*, 2025; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; 2025). These findings align with global evidence highlighting the importance of culturally tailored health education, community engagement, and mobile outreach to overcome structural and behavioral obstacles (WHO, 2022; Paavonen *et al.*, 2007; Raimi, 2025c; Raimi, 2025d; Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; NPHCDA, 2022; Bouvard *et al.*, 2009). Thus, targeted interventions, leveraging lessons from high-coverage countries and local sociocultural contexts, are critical to improving HPV vaccination rates in Nigeria.

4.5. Framework for improving HPV vaccination uptake in Nigeria

The proposed framework for enhancing HPV vaccination in Nigeria integrates policy, healthcare system strengthening, community engagement, and monitoring, reflecting best practices identified in both domestic and international contexts (Raimi, 2025a; Raimi, 2025b; Elemuwa *et al.*, 2024c; Oginifolunnia *et al.*, 2025; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b). Policy and governance interventions emphasize the establishment of supportive national immunization policies, sustained funding, and regulatory oversight, consistent with WHO recommendations for scaling HPV vaccination in low- and middle-income countries (WHO, 2022; NPHCDA, 2022; Paavonen *et al.*, 2007; Raimi, 2025c; Raimi, 2025d; Ononiwu *et al.*, 2023; Nyam *et al.*, 2025; Bouvard *et al.*, 2009). Strengthening healthcare delivery includes improving vaccine availability, cold chain infrastructure, and workforce capacity, which prior studies have identified as major determinants of successful immunization campaigns in Nigeria and similar contexts (Raimi, 2025a; Raimi, 2025b; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b).

al., 2024b; Elemuwa *et al.*, 2024c; Oginifolunnia *et al.*, 2025). Community engagement and awareness strategies, such as culturally appropriate education campaigns, digital health messaging, and ward-level mobilization, have demonstrated effectiveness in increasing HPV vaccine acceptance in low-uptake areas (Babbo *et al.*, 2025; Promise *et al.*, 2026; Raimi, 2025c; Raimi, 2025d; Elemuwa *et al.*, 2024c; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Ononiwu *et al.*, 2023). Monitoring and evaluation, including real-time coverage tracking and feedback loops, further ensure that gaps are identified and addressed promptly, reflecting lessons from both Nigerian and international vaccination programs (WHO, 2022; NPHCDA, 2022; Raimi, 2025a; Raimi, 2025b; Paavonen *et al.*, 2007; Nyam *et al.*, 2025; Bouvard *et al.*, 2009; Ononiwu *et al.*, 2023). Overall, the framework addresses both structural and behavioral barriers to HPV vaccination and aligns with evidence-based strategies proven to enhance immunization uptake in comparable settings. By integrating multi-level interventions, from national policy to community mobilization, Nigeria can improve adolescent vaccination coverage, ultimately reducing HPV transmission, cervical cancer incidence, and related health inequities (Raimi, 2025a; Raimi, 2025b; Babbo *et al.*, 2025; Promise *et al.*, 2026; Kakwi *et al.*, 2024a; Kakwi *et al.*, 2024b; Ononiwu *et al.*, 2023; Nyam *et al.*, 2025).

4.6. Implications for Policy and Interventions

The findings of this study underscore the urgent need for policy reforms and targeted interventions to address the high burden of HPV infection and cervical cancer in Nigeria. The predominance of high-risk HPV genotypes, particularly HPV-16 and HPV-18, coupled with regional heterogeneity in prevalence, highlights the necessity for region-specific surveillance and intervention strategies. Furthermore, the observed low uptake of cervical cancer screening, particularly in areas with the highest HPV prevalence, indicates that existing preventive services are insufficiently accessible or utilized. Consequently, policymakers should prioritize the integration of HPV screening and vaccination programs into primary healthcare and school-based platforms, ensuring equitable access across urban and rural settings. In addition, strengthening health system infrastructure, including workforce training, supply chain management, and cold chain facilities, will be crucial for supporting the effective delivery of immunization and screening services. Moreover, the stark disparities in HPV vaccination coverage between Nigeria, South Asia, and high-income countries reveal the critical role of community engagement, awareness campaigns, and behavior-change strategies in improving vaccine uptake. Interventions should therefore combine public education, culturally tailored communication, and social mobilization to overcome hesitancy and misinformation. Establishing a robust monitoring and evaluation system will further enable real-time tracking of vaccination progress, identification of coverage gaps, and continuous improvement of program delivery. By implementing a multi-level, evidence-informed framework that integrates policy, healthcare delivery, and community engagement, Nigeria can substantially enhance HPV prevention, reduce the incidence of cervical cancer, and strengthen its national public health infrastructure, ultimately promoting long-term reproductive health and equity.

4.7. Health Significance

The health significance of this study lies in its illumination of the substantial burden posed by HPV infection and its direct link to cervical cancer in Nigeria. The predominance of high-risk HPV genotypes, coupled with the high prevalence of infection among women of reproductive age, underscores a critical public health threat that remains largely unaddressed. Inadequate screening and low vaccination coverage exacerbate this risk, leaving large segments of the population vulnerable to HPV-associated morbidity and mortality. By providing detailed data on regional genotype distribution and age-specific infection patterns, the study identifies populations and geographic areas most at risk, enabling the prioritization of interventions where they are most needed. Furthermore, the study highlights the broader implications for reproductive health and health equity. Low HPV vaccination uptake and limited screening reflect systemic challenges, including insufficient awareness, sociocultural barriers, and healthcare access inequities. Addressing these gaps has the potential to significantly reduce the incidence of cervical cancer, improve women's reproductive health outcomes, and strengthen national public health infrastructure. The findings provide actionable insights for policymakers, healthcare practitioners, and community health programs, emphasizing the necessity of integrated prevention strategies, education campaigns, and evidence-based health policy to safeguard the health of Nigerian women and reduce HPV-related disease burden as illustrated in Figure 9 below.

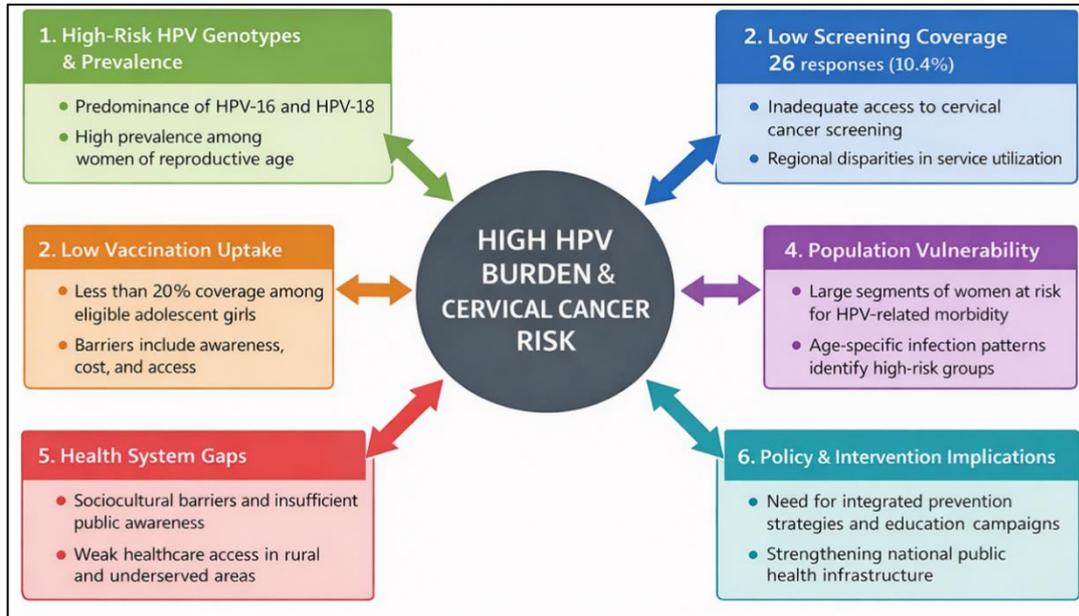


Figure 9 Integrated framework of Health Significance: HPV Burden and Cervical Cancer Risk in Nigeria

4.8. Recommendation

4.8.1. Short-term (1–2 years)

Immediate actions should focus on increasing HPV awareness and improving vaccine uptake among eligible adolescent girls. This includes implementing targeted community engagement and public education campaigns to address vaccine hesitancy, leveraging schools, local health centers, and digital media platforms to disseminate accurate information. Additionally, strengthening the cold chain and supply management systems in high-prevalence regions will ensure reliable vaccine availability, while initiating mobile outreach and home-visit programs can improve access in rural and underserved communities.

4.8.2. Mid-term (3–5 years)

Efforts should expand to establish sustainable cervical cancer prevention infrastructure, including widespread school-based vaccination programs and integration of HPV screening into routine primary healthcare services. Capacity building for healthcare workers, including training in vaccination administration and screening techniques, will be essential. Regional surveillance systems should be strengthened to monitor HPV genotype distribution, vaccination coverage, and screening uptake, enabling data-driven decision-making. Collaboration with community leaders and local organizations can further enhance public engagement and adherence to vaccination and screening recommendations.

4.8.3. Long-term (5+ years)

Strategic, long-term interventions should aim to institutionalize HPV prevention within national health policy and immunization programs. This includes ensuring universal access to HPV vaccines, routine cervical cancer screening for women of reproductive age, and continued investment in health infrastructure to sustain high coverage. Continuous evaluation and adaptation of policies based on surveillance data will allow for targeted responses to emerging HPV trends. Over time, these comprehensive strategies will contribute to a significant reduction in HPV transmission, cervical cancer incidence, and related health inequities, ultimately improving the reproductive health and well-being of Nigerian women.

5. Conclusion

In conclusion, this study highlights the substantial burden of HPV infection among Nigerian women, characterized by the predominance of high-risk genotypes such as HPV-16 and HPV-18 and the presence of multiple low-risk strains. The age-specific patterns of infection, with peaks among younger reproductive-age women and persistence in older age groups, underscore the complex natural history of HPV and the heightened risk of cervical cancer without timely intervention. The uneven distribution of HPV genotypes across regions, coupled with low cervical screening coverage, indicates significant gaps in preventive healthcare infrastructure and underscores the need for targeted, region-specific

public health strategies. Moreover, the findings emphasize the critical importance of improving HPV vaccination coverage, which remains below 20% among eligible adolescent girls in Nigeria, far below rates observed in other regions. Addressing systemic, socio-cultural, and logistical barriers through integrated interventions, including policy support, healthcare system strengthening, community engagement, and robust monitoring, offers a viable pathway to reducing HPV transmission and the incidence of cervical cancer. Ultimately, these results provide actionable evidence for policymakers, healthcare providers, and public health practitioners to implement comprehensive prevention strategies, strengthen national immunization programs, and improve reproductive health outcomes across Nigeria.

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