Journal of Cancer Policy 47 (2026) 100675

Contents lists available at ScienceDirect

Journal of Cancer Policy

journal homepage: www.elsevier.com/locate/jcpo

Economic evaluation of the one-dose HPV vaccination program in Nigeria

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ARTICLE INFO

Keywords:
Economic evaluation
HPV vaccination
Nigeria

ABSTRACT

Background: This study retrospectively examines the cost-effectiveness of the national HPV vaccination program using the program cost and coverage data in Nigeria.
Methods: We conducted a cost-effectiveness analysis of the HPV vaccination program compared with no vaccination in Nigeria, adopting both health system and societal perspectives. A static Markov model simulating HPV infection and cervical cancer outcomes was developed for a cohort of girls aged 9–14 years, followed until age 100. The model comprised primarily the following health states: susceptible, cervical cancer, and death. It further incorporated three additional pathways for patients with cervical cancer, including those with successful treatment, with treatment failure, and with no treatment.
Results: The incremental cost-effectiveness ratio (ICER) was estimated at $268.67 per quality-adjusted life year (QALY) gained from the health system perspective and $217.85 per QALY gained from the societal perspective. Both ICERs were well below the cost-effectiveness threshold of one-time GDP per capita in Nigeria ($806.95). Key drivers of cost-effectiveness included vaccine cost, treatment success rate, cervical cancer treatment coverage, and cervical cancer utility values.
Discussion: The single-dose HPV vaccination program is highly cost-effective in Nigeria, compared to the status quo of no vaccination. To ensure long-term sustainability, the Nigerian government should strengthen financing mechanisms and the healthcare system to support the program.
Policy Summary: Single dose HPV vaccination is cost-effective in Nigeria. It is crucial to obtain sustainable vaccine financing and improve treatment to maintain the program impact.

1. Introduction

Nigeria encounters great health challenges triggered by HPV infection and cervical cancer. The incidence rate of cervical cancer was estimated at 11.9 per 100,000 women in 2020, ranking it as the second most common cancer among women between 15 and 44 in the country [1]. To mitigate the burden caused by HPV infections, the Nigerian government has introduced and scaled up HPV vaccine programs. In October 2023, Nigeria introduced the single-dose quadrivalent HPV vaccine (Gardasil-4) into its national routine immunization schedule. The school-based rollout was planned in two phases, which target girls aged 9–14 years, with the first phase (2023–2024) covering girls in 15 states and Abuja and second phase covering the remaining 21 states [2]. After two years of implementation (2023–2025), around 71 % of girls in the 9–14 age group in Nigeria have been vaccinated [3].

Prior studies have demonstrated the cost-effectiveness of HPV vaccination in Nigeria, with a wide range of the incremental cost-effectiveness ratios (ICERs), ranging from I$100 to $7930 per disability-adjusted life year (DALY) averted or quality-adjusted life year (QALY) gained [4–6]. However, none of these studies has examined the cost-effectiveness of the single-dose HPV vaccine currently adopted in Nigeria. Additionally, the previous studies largely relied on hypothetical

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https://doi.org/10.1016/j.jcpo.2025.100675
Received 9 November 2025; Accepted 2 December 2025
Available online 6 December 2025

assumptions on various cost information to perform the cost-effectiveness analysis and did not incorporate real-world implementation data. To fill in this gap, the study leverages the real-world costing data from Nigeria's national routine immunization program [7], aiming to model the cost-effectiveness of the ongoing national one-dose HPV vaccination program targeting girls aged 9–14 years, in comparison with a scenario without a vaccination program.

2. Methods

We conducted a cost-effectiveness analysis of HPV vaccination from both the health system and societal perspectives, according to the recommendation proposed by the Second Panel on Cost-effectiveness in Health and Medicine. We compared two scenarios: (1) the intervention with the one-dose HPV vaccination program; and (2) the status quo without a vaccination program for girls aged 9–14 in Nigeria. TreeAge Pro Healthcare 2025 was used to construct the model.

2.1. Model construction

A Markov model was constructed to assess the health effects of HPV vaccination for girls aged 9–14. The model started with a hypothetical cohort of 100,000 girls aged 9–14, who were followed through to 100 years old. As shown in Appendix Fig. A1, the model was primarily composed of the following health states: (1) susceptible, (2) cervical cancer, and (3) death. For those with cervical cancer, further pathways were incorporated, including those with successful treatment and recovery, with unsuccessful treatment and no recovery, and with no treatment. Thus, there were a total of six health states in the model. The detail explanation of the model and its structure is shown in Appendix A.

2.2. Cost assessment

We analyzed the costs considering both the health system and societal perspectives. In this study, health system costs of the HPV vaccination program included the HPV vaccine cost, service delivery cost, cost of vaccine wastage, cost incurred by other HPV vaccination introduction program activities, and direct medical costs due to cervical cancer. Other program activities refer to (1) microplanning, (2) national review meeting, (3) social mobilization, (4) commodities, data tools, vaccine transport and logistics, (5) administrative charges and technical support, as well as (6) supervision, monitoring, and evaluation.

Specifically, the vaccine cost was based on the fixed Gavi price of $4.50 per dose for Gardasil [8]. We assume the vaccine wastage rate at 5 %. The costs of service delivery and other program activities were obtained from the estimates based on the national program in Nigeria [7]. Furthermore, we searched the articles related to cervical cancer treatment cost per year, and we took the average of the costs in two studies [9,10]. By using the purchasing power parity converter and the exchange rate, we converted the costs to US dollars (USD) in the original year of the cost.

From the societal perspective, besides the costs incurred by the health system, we considered household-level expenses, such as direct non-medical costs (travel and meal costs) for cervical cancer treatment, and the indirect cost due to the productivity loss of caretakers. While direct non-medical costs were directly derived from the literature, the indirect cost was calculated based on the length of care and the minimum wage in Nigeria. A detailed breakdown of all costs is provided in Table 1. All costs were converted to 2024 USD by adjusting for inflation using the consumer price index, and future costs were discounted at a rate of 3 % annually.

2.3. Effectiveness assessment

We modeled the effectiveness of HPV vaccination using a Markov model. The key parameters include: (1) coverage of HPV vaccination; and (2) transition probabilities among the six health states specified in Appendix Fig. A1, under the two scenarios that contain HPV vaccination or not.

In the no vaccination scenario, we assumed that coverage of HPV vaccination was zero. The transition probabilities among the six health states were obtained from the literature. For example, from susceptible to cervical cancer, we obtained age-specific incidence of cervical cancer from the Institute for Health Metrics and Evaluation (IHME), which was applied to the individuals as they went through different ages during the Markov simulation. Similarly, we applied age-specific natural death rates and death rates due to cervical cancer over individuals' life cycles. Similarly, age-specific natural mortality and cervical cancer–specific fatality rates were also sourced from IHME [11]. Details of other transition probabilities are presented in Table 1.

Table 1
Key model inputs.

Parameters	Value	Range	Distribution	Source
Population and epidemiology parameters				
Population size (9–14)	100,000	-	-	Assumption
Cervical cancer due to HPV 16 and 18	70.00 %	65.00 %-77.00 %	Beta	[12]
Efficacy of HPV vaccination	97.50 %	92.60 %-99.50 %	Beta	[13]
Incidence of cervical cancer	11.90 %	7.24 %-16.56 %	Beta	[1]
Efficacy of vaccine against cervical cancer incidence overall	68.25 %	41.50 %-95.00 %	Beta	[12][13],
Treatment coverage	71.20 %	64.00 %-75.00 %	Beta	[14]
Failure rate	8.00 %	4.00 %-18.00 %	Beta	[15]
Successful treatment rate	92.00 %	82.00 %-96.00 %	Beta	[15]
Vaccine coverage in Nigeria	76.00 %	74.00 %-78.00 %	Beta	[7]
Vaccine wastage rate	5.00 %	4.00 %-6.00 %	Beta	[16]
Share of hysterectomy in all cervical cancer treatments	12.91 %	7.85 %-17.98 %	Beta	[17]
Cost parameters				
Cost of vaccine (per dose)	$4.50	$3.00-$6.00	Gama	[8]
Cost of service delivery (per vaccinated)	$0.23	$0.14-$0.32	Gama	[7]
Cost of other program activities (per person)	$0.81	$0.80-$0.82	Gama	[7]
Family cost (transportation) for cancer treatment per year	$113.26	$68.86-$157.66	Gama	[18]
Family cost (meal) for cancer treatment per year	$92.77	$56.40-$129.14	Gama	[19]
Cost of caretakers per year	$173.37	$105.41-$241.33	Gama	[20]
Treatment cost per year	$213.22	$129.64-$296.80	Gama	[10,21]
Utility parameters and others				
Susceptible	1	-	-	
Cervical cancer	68.00 %	48.00 %-84.00 %	Beta	[22]
Successful treatment and recovery	89.00 %	85.00 %-94.00 %	Beta	[23]
Unsuccessful treatment and no recovery	68.00 %	48.00 %-84.00 %	Beta	[22]
No treatment	68.00 %	48.00 %-84.00 %	Beta	[22]
Death	0	-	-	
Discount rate	3.00 %	-	-	

In the vaccination scenario, we assumed 76 % coverage of HPV vaccination [7], with lifelong protection from the HPV vaccine. Vaccine efficacy against cervical cancer in Nigeria was estimated at 68.25 %, reflecting the high efficacy of HPV vaccines (97.5 %) against types 16 and 18, which account for roughly 70 % of cervical cancer cases [12]. Thus, overall cervical cancer incidence was modeled to be reduced by 68.25 % among vaccinated individuals.

Using the Markov model, we estimated the differences in the number of cervical cancer cases and deaths between the two scenarios. To translate these outcomes into QALYs for cost-effectiveness analysis, we assigned utility weights to each of the six health states. Future effectiveness gains (e.g., QALYs) were discounted at an annual rate of 3 %. Table 1 presents all the parameters of costs and effectiveness used in our analysis.

2.4. Estimates of the incremental cost-effectiveness ratio

The ICERs for the HPV vaccination program, relative to the base scenario of no vaccination program, were assessed from both the health system and societal perspectives. ICER is defined as the incremental costs divided by QALYs gained from one-dose vaccination programs compared with no vaccination, which is calculated using the following formula:

$$ICER = \frac{Cost_{intervention\ arm} - Cost_{control\ arm}}{QALYs_{intervention\ arm} - QALYs_{control\ arm}}$$

Despite ongoing debates on the cost-effectiveness thresholds, we classified the intervention as highly cost-effective when the ICER was below the one-time per capita gross domestic product (GDP) of Nigeria (US$ 806.95) in 2024 and as cost-effective when the ICER was between one and three times the per capita GDP of Nigeria (US$ 806.95-$2420.85) according to the recommendations from WHO [24]. These GDP-based thresholds remain used widely in recent cost-effectiveness studies [25].

2.5. Sensitivity analysis

We conducted univariate sensitivity analyses by altering key parameters individually. The key parameters used included: (1) the efficacy of the HPV vaccine, (2) vaccine coverage, (3) vaccine cost, (4) cervical cancer treatment coverage, (5) cancer treatment success rate, (6) cervical cancer treatment cost, and (7) utility of cervical cancer. A tornado diagram was generated to illustrate the sensitivity of the parameters to the cost-effectiveness of the vaccine strategy.

Additionally, a probability sensitivity analysis was also performed in the study. We used and derived the standard deviations of some parameters from the literature. For parameters without reported standard deviations, we assumed a value equal to 20 % of the mean [26]. Beta distributions were applied to parameters constrained between 0 and 1, such as the HPV vaccine efficacy and cervical cancer treatment coverage, while gamma distributions were used for positive continuous parameters, like cervical cancer treatment costs. Monte Carlo simulations with 10,000 iterations were conducted to estimate the mean ICERs along with their 95 % confidence intervals (CIs) and generate a cost-effectiveness acceptability curve.

2.6. Ethics approval

This is not a human subjects study and used secondary data for the analysis; Institution review board approval was not required.

3. Results

Table 2 presents the cost estimates for the one-dose HPV vaccination program compared to the status quo (no vaccination) for a cohort of 100,000 girls. Under the status quo, the health system incurred only the direct medical cost of cervical cancer treatment, totaling $84,863. In contrast, the vaccination program resulted in a total health system cost of $498,475, comprising $359,100 for the vaccine with wastage (72.04 %), $17,480 for service delivery (3.51 %), $81,000 for other program activities (16.25 %), and $40,895 for cervical cancer treatment (8.20 %). The total cost of the vaccination program was $413, 612 higher than the status quo.

From the societal perspective, direct non-medical and indirect costs were considered, leading to higher costs of $151,005 under the status quo and $72,767 under the vaccination program, respectively. Under the status quo, direct non-medical and indirect costs were $82,002 and $69,003, respectively, for a total societal cost of $235,868. By contrast, for the HPV vaccination program, direct non-medical costs amounted to $39,516 and indirect costs to $33,251, yielding a total societal cost of $571,242. Overall, the cost difference between the vaccination program and the status quo was $335,374.

Table 3 shows the number of cervical cancer cases and deaths under two scenarios. In the absence of a HPV vaccination program, the model projected 1,820 (95 %CI: 1,784–1,953) cervical cancer cases among girls over their lifetime, up to age 100, compared to 896 (95 %CI: 846–963) cases under the vaccination scenario. This indicates that the vaccination program could prevent 924 (95 %CI: 849–999) cervical cancer cases. In terms of mortality, the simulation estimated 603 (95 % CI: 594–693) cervical cancer deaths without the vaccination program and 316 (95 %CI: 280–349) deaths with the program, averting 287 (95 %CI: 243–530) deaths. In total, 1,539 (95 %CI: 1,216–1,907) QALYs were gained by the vaccination program.

Table 2
Impact of HPV vaccination on the costs by category in US$.

Perspective	Cost component	Status quo	Vaccination program
Health system related cost	Vaccine cost including wastage	0	359,100 (358,233–360,732)
	Service delivery cost in the program	0	17,480 (17,466–17,587)
	Other program activity cost	0	81,000 (80,000–82,000)
	Direct medical cost	84,863 (81,119–91,485)	40,895 (38,256–45,403)
Subtotal (health system cost)		84,863 (81,119–91,485)	498,475 (493,802 – 501,173)
Additional cost from society perspective	Direct non-medical cost	82,002 (78,838–89,046)	39,516 (36,557–43,582)
	Indirect cost	69,003 (64,981–73,339)	33,251 (29,394–35,169)
Subtotal (additional cost)		151,005 (142,274–160,768)	72,767 (67,126–80,067)
Total (Social cost)		235,868 (216,172–244,403)	571,242 (566,006–586,525)

Table 3
The impact of HPV vaccination on cervical cancer cases and deaths.

	Status quo (1)	Vaccination program (2)	Differences ((1)-(2))
Cervical cancer cases	1,820 (1,784–1,953)	896 (846–963)	924 (849–999)
Cervical cancer deaths	603 (594–693)	316 (280–349)	287 (243–530)
QALYs	2,643,439 (2,640,621 – 2,646,372)	2,644,979 (2,642,250 – 2,647,994)	1,539 (1,216–1,907)

Table 4 presents the results of the cost-effectiveness analysis. From the health system perspective, an ICER of $268.67 per QALY gained was estimated, with 95 % CI of $183.76 – $385.53 per QALY gained. From the societal perspective, an ICER of $217.85 per QALY gained was estimated with a 95 % CI of $136.99 – $328.02 per QALY gained. By comparison, the ICER from the societal perspective was $50.82 per QALY gained, lower than that from the health system perspective.

Fig. 1 presents a one-way sensitivity analysis conducted for seven key parameters in the tornado diagram. The cost of the HPV vaccine was the parameter that affected the ICER the most, followed by treatment success rate, treatment coverage of cervical cancer, utility of cervical cancer, treatment cost of cervical cancer, vaccine efficacy, and vaccine coverage. For example, when the vaccine price was reduced to $3.00 per dose, the ICER decreased to $140.09 per QALY gained, whereas an increase to $6.00 per dose raised the ICER to $295.60 per QALY gained, holding all other parameters constant. Similarly, lowering the treatment success rate to 0.82 reduced the ICER to $184.01 per QALY gained, while raising it to 0.96 increased the ICER to $235.16 per QALY gained. In all cases, the ICER remained below Nigeria's 2024 one-time GDP per capita threshold (US$806.95). The acceptability curve from the probabilistic sensitivity analysis is presented in Appendix B.

4. Discussion

The results of our analysis prove that the one-dose HPV vaccination is a highly cost-effective intervention in reducing cervical cancer mortality for a cohort of girls aged 9–14 in Nigeria. Concerning the effectiveness, the vaccination program would avert 924 cervical cancer cases and 287 deaths due to cervical cancer, leading to 1,539 QALYs gained compared to the status quo. These generate ICERs of $268.67 and $217.85 per QALY gained from the health system and societal perspective, respectively. Both values are below the one-time GDP per capita ($806.95) in Nigeria. Additionally, the one-way sensitivity analysis suggests that the ICER is most sensitive to the change in the HPV vaccine cost, followed by treatment success rate and treatment coverage of cervical cancer.

This study shows that the HPV vaccination program is highly cost-effective in Nigeria. This finding is consistent with findings from other studies conducted in the country [4–6]. Our ICER estimate is comparable to that of Goldie and Kim [4,5], but lower than Ekwunife's assessment ($7,930-$32,167 per DALY averted) of the two-dose HPV vaccination program [6]. The key difference between our estimate and Ekwunife's is primarily due to the difference in dosage. The two-dose regime in Ekwunife's study had higher vaccine costs compared with the one-dose regime used in our model. As shown from the one-way sensitivity analysis, the vaccine cost is the major driver of the cost-effectiveness results.

Using a one-dose vaccination strategy is financially more affordable for low- and middle-income countries (LMICs) to initiate and scale up HPV vaccine programs, with several benefits. First, the one-dose vaccine is less costly yet offers comparable effectiveness to multiple doses [27]. An empirical study shows that one dose of the HPV vaccine has similar efficacy (95.4 %) in preventing persistent HPV infection, in comparison with two or three doses of the vaccine (93.1 % and 93.3 % for two and three doses, respectively) [28]. Given the restrained resources in LMICs, using one-dose HPV vaccine would significantly increase the country's affordability for such a program. Therefore, WHO updated its HPV vaccine guidance in 2022 to endorse a one-dose schedule as an alternative to the two-dose regimen [29]. Second, the single-dose regimen is administratively more operational with higher adherence. It was estimated that the dropout rates for the second dose have averaged 18 % in LMICs, with wide variation ranging from 1 % to 69 % [30]. The dropout would compromise the efficacy of the vaccine. In contrast, the one-dose strategy mitigates the dropout concern and would lower not only the vaccine program cost from donors or the government, but also the household cost derived from the vaccination (e.g., travel cost). Therefore, one dose of HPV vaccine provides a more financially feasible approach for initiating and scaling up a national HPV immunization program.

The results suggest that vaccine cost is a major determinant of the cost-effectiveness of the one-dose HPV vaccination program. Vaccine prices vary substantially [31]. If the price rose to $25, the ICER in our study would increase to $1,280.47 per QALY gained. This issue is particularly relevant for Nigeria, which is currently in the accelerated transition phase. A country will lose Gavi's financial support eight years after it enters the accelerated transition phase. Nigeria is expected to graduate from Gavi in 2028, and the HPV price is expected to increase, which would significantly challenge the long-term sustainability of the vaccination program. As many LMICS are expected to graduate from Gavi, it is important for these countries to collaborate in securing affordable HPV vaccine prices. This requires them to engage in partnerships with both public and private organizations to negotiate HPV prices with producers to ensure a reasonable price to maintain the program impact in the long run. For example, countries in Latin America leveraged the Pan American Health Organization's Revolving Fund to negotiate HPV price, resulting in $10.48 per dose in 2025 for the quadrivalent HPV vaccine [32]. Such mechanism provides Nigeria and other LMICs opportunities to maintain the HPV vaccination program sustainably in the future.

Furthermore, the treatment success rate has also impacted the cost-effectiveness of the HPV vaccination program. In this study, treatment success rates are assumed to be between 0.82 and 0.96, with ICERs ranging from $184.01 to $235.16 per QALY gained. This suggests that in countries where the quality of care is a concern, with a low treatment success rate, the HPV vaccine is more important in addressing cervical cancer. Once an individual develops cervical cancer, it is critical to improve the treatment success rate to reduce the mortality rate and improve the quality of life of patients. To do so, the potential strategies include but are not limited to: (1) early detection through screening. For example, it was reported that HPV testing and screening every five years without triage showed effectiveness in reducing cervical cancer incidence rate by 57 % and mortality rate by 67 % among women aged 30–50 [33]. ; (2) expanding access to specialized facilities. It was estimated that patients treated at designated cancer centers experienced a 20 % lower risk of cervical cancer–specific death compared to those treated in other facilities [34], as cancer treatment is highly specialized; (3) training of healthcare professionals on cervical cancer treatment [35]. Additionally, it is critical to strengthen patient follow-up to improve treatment adherence.

The study is subject to several limitations. First, the Markov model did not incorporate the costs related to detecting or treating precancerous lesions. Since we did not include the screening in the model and the screening in Nigeria is opportunistic [36], the chance to detect precancerous lesions is slim. Thus, the cost associated with detecting or treating precancerous lesions would be minimal. Second, we did not capture the herd immunity of the HPV vaccine. Herd immunity of the HPV vaccine has been documented, with a wide variation [37]. The omission of the herd immunity may result in an underestimation of the potential impact of HPV vaccination. Third, we assumed an immediate increase in the coverage of HPV vaccination to 76 %, which is unrealistic. In Nigeria, the national HPV program took about two years to reach

Table 4
Result of cost-effectiveness analysis for HPV vaccination program versus no vaccination.

Perspective	Cost difference	QALY difference	ICER (95 % CI)
Health system perspective	$413,611	1,539	268.67 (183.76–385.53)
Societal perspective	$335,374	1,539	217.85 (136.99–328.02)

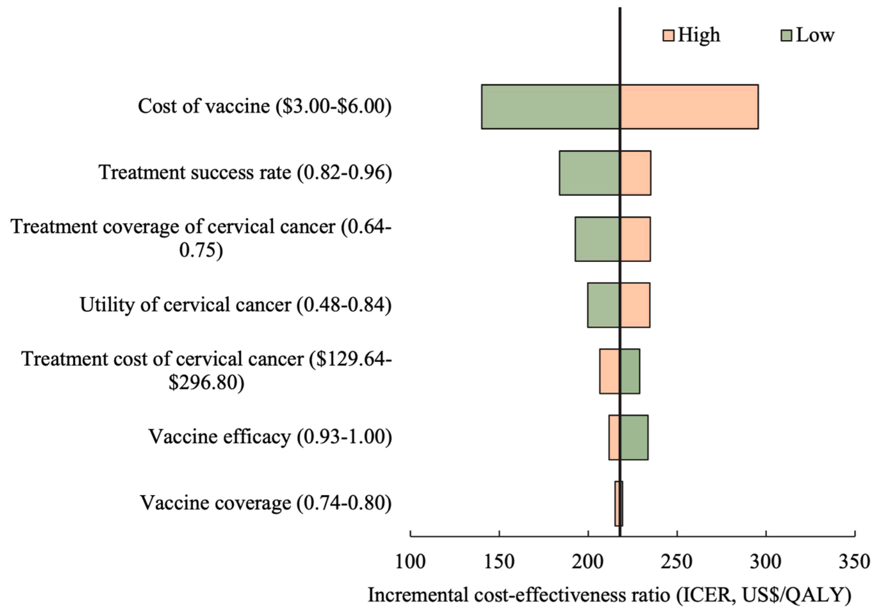

Fig. 1. Tornado diagram for the univariate sensitivity analysis.

the level we specified in the model. However, this limitation would not significantly affect the analysis results, given that the cost associated with the HPV program is proportionate to the HPV coverage.

5. Conclusions

The single-dose quadrivalent HPV vaccination program for girls aged 9–14 is very cost-effective in Nigeria, compared to no vaccination. The inclusion of a one-dose HPV vaccine strategy into the national vaccine program could substantially reduce the cervical cancer burden at reasonable costs from both health system and societal perspectives. As Nigeria progresses towards graduation from Gavi support, ensuring long-term sustainability will require deliberate strategies to strengthen domestic financing, integrate HPV vaccination into broader immunization planning, and safeguard the gains already achieved.

Ethical consideration

Not applicable because the study uses secondary data to perform the analysis

Funding

No funding.

CRediT authorship contribution statement

Xiaohui Hou: Investigation, Writing – review & editing. **Linda Mobula:** Investigation, Writing – review & editing. **Sohail Agha:** Investigation, Writing – review & editing. **Marwa Farag:** Investigation, Methodology, Writing – review & editing. **Guohong Li:** Investigation, Methodology, Writing – review & editing. **Tianjiao Gao:** Formal analysis, Investigation, Writing – original draft. **Wu Zeng:** Conceptualization, Data curation, Project administration, Supervision, Writing – original draft, Writing – review & editing, Methodology.

Declaration of Competing Interest

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

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jcpo.2025.100675.

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Glossary

CI: Confidence interval
DALY: Disability-adjusted life years
GDP: Gross domestic product
HPV: Human papillomavirus
ICER: Incremental cost effectiveness ratio
IHME: Institute for Health Metrics and Evaluation
LMICs: low- and middle-income countries
QALY: Quality-adjusted life years
WHO: World Health Organization