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HPV vaccination and cervical cancer control in Georgia: evidence and projections

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Abstract

Introduction Human Papillomavirus (HPV) is the primary cause of cervical cancer. In Georgia, cervical cancer is the fifth leading cause of cancer-related deaths among women, with approximately 330 new cases and 200 deaths annually. Although HPV vaccines are included in the national immunization programme, coverage remains suboptimal. This study aimed to assess national trends in HPV vaccination, cervical cancer screening, and incidence in Georgia, and to project the potential impact of improved vaccination coverage.

Materials and methods National data from 2016–2022 were analysed using descriptive statistics, chi-square tests, and linear regression. Cumulative risk and age-standardized rates were calculated using WHO-recommended methods. Scenario-based simulation models projected reductions in cervical cancer incidence assuming vaccination coverage of 60%, 80%, and 90% through 2032.

Results In 2022, only 38% of eligible adolescents received the first HPV vaccine dose and 26% completed the second. Regional variation was substantial (83% in Adjara vs. 14% in Shida-Kartli), with consistently lower uptake in rural than urban areas. Screening participation declined from 26,348 women in 2016 (4.4% of eligible) to 13,890 in 2022 (2.3%). Regression analysis showed an inverse but non-significant association between vaccination coverage and cervical cancer incidence ($\beta = -0.12$, 95% CI −0.32 to 0.08, $p = 0.18$). Simulation models projected that 90% coverage could prevent up to 276 cases over the next decade.

Conclusion HPV vaccination coverage in Georgia remains insufficient, with regional disparities and declining screening participation. Scaling up vaccination to ≥ 80% and integrating it with screening could substantially reduce cervical cancer burden and accelerate progress toward WHO elimination targets.

Keywords Human papillomavirus (HPV), Cervical cancer, Screening, HPV vaccination

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Introduction

Cervical cancer remains a leading cause of cancer-related mortality among women worldwide, despite being largely preventable through HPV vaccination and screening [1–4]. In Georgia, cervical cancer is the fifth most common cause of cancer-related deaths among women. In 2022, an estimated 327 new cases were diagnosed (15.7 per 100,000 women; age-standardized rate 10.6 per 100,000), resulting in 204 deaths (9.5 per 100,000) [5]. These figures correspond to approximately 5.8% of all female cancer cases nationally and underscore the substantial burden of disease. Although the national screening programme provides free Pap tests to women aged 25–60 years, participation has declined from 26,348 women in 2016 (4.4% of the eligible 600,000) to 13,890 in 2022 (2.3%) [6, 7]. This downward trend highlights serious challenges to sustaining cervical cancer prevention.HPV vaccination was introduced in Georgia in 2018 as part of the national immunization programme [8]. The vaccine is available free of charge through primary healthcare providers and public health centres. The target groups include girls and boys aged 9–13 years, with catch-up vaccination for girls aged 13–18 years [9]. In 2022, only 12,464 out of 32,800 eligible girls (38%) received the first dose of the HPV vaccine, and just 8,528 (26%) completed the second dose. Coverage varied widely across regions: in Tbilisi, 2,604 out of 12,400 eligible girls (21%) received the first dose, compared to 2,241 out of 2,700 in Adjara (83%) [10]. These disparities point to systemic inequalities in healthcare access, vaccine acceptance, and public awareness [11, 12]. Despite the availability of HPV vaccines for more than five years, no comprehensive study has examined national coverage trends, regional disparities, or the interaction between vaccination uptake and declining screening participation in Georgia.

The aim of this study is to assess national trends in HPV vaccination coverage, cervical cancer screening participation, and cervical cancer incidence in Georgia between 2016 and 2022. In addition, the study applies inferential statistics and simulation modelling to project the potential reduction in cervical cancer incidence under hypothetical scenarios of improved vaccination coverage (60%, 80%, 90%). By providing new evidence on vaccination uptake, screening trends, and projected outcomes, this study seeks to inform national strategies for cervical cancer prevention and to strengthen Georgia's contribution to the global elimination agenda.

Materials and methods

Study design

This study employed a retrospective mixed-method analytical design, combining descriptive and inferential (analytical) components. The retrospective part covered secondary analysis of national data collected between 2016 and 2022, encompassing HPV vaccination coverage, cervical cancer screening participation, and incidence trends before and after introduction of the HPV vaccination program in 2018. The descriptive component summarized vaccination and screening indicators using national and regional vaccination and screening indicators obtained from the National Center for Disease Control and Public Health (NCDC) and the National Statistics Office of Georgia (Geostat). The analytical component included inferential statistical procedures – chi-square tests for group differences, linear regression analysis for associations between vaccination coverage and cervical cancer incidence, and scenario-based deterministic simulation modelling to project reductions in cervical cancer incidence under alternative vaccination coverage scenarios (60%, 80%, and 90%). This combination of retrospective, descriptive, and analytical approaches ensured a comprehensive assessment of both observed trends and projected public health impacts.

Study population and data sources

HPV vaccination, cervical cancer screening, and incidence data were obtained from the National Center for Disease Control and Public Health (NCDC) of Georgia. NCDC maintains the National Immunization Registry, which records vaccine administration data reported in real-time by public and private healthcare providers across the country. All vaccination events are logged through an electronic immunization information system, which is linked to unique patient identifiers and allows aggregation by age, sex, and region. Cervical cancer incidence data were drawn from the National Cancer Registry, also maintained by NCDC, which collects standardized case notifications from hospitals, oncology centers, and pathology laboratories. Mortality data are validated against the Civil Registry and death certificates. Population denominators were obtained from the National Statistics Office of Georgia (Geostat), which conducts annual updates based on census data, civil registration, and demographic projections. To ensure international comparability, supplementary vaccination coverage estimates were cross-checked with the WHO Immunization Data Portal. These databases are part of Georgia's national health information system, which integrates routine reporting from primary care facilities, hospitals, and specialized centers. Data quality is maintained through mandatory reporting, internal verification procedures at NCDC, and periodic audits conducted in collaboration with WHO and international partners. These sources provided disaggregated information by age, region, and year, enabling both descriptive analysis and statistical modeling. For regional comparisons, Georgia's official administrative classification was applied, which distinguishes between urban municipalities (e.g.,

Tbilisi, Batumi) and rural municipalities (e.g., Shida-Kartli, Kakheti). While Georgia does not currently employ a standardized rural–urban commuting area (RUCA) code system similar to that used in the United States, the National Statistics Office (Geostat) provides a clear urban/rural breakdown based on settlement size and administrative designation. This classification was used to stratify vaccination coverage and screening participation in descriptive and inferential analyses.

The target population for HPV vaccination included girls and boys aged 9–13 years under the routine immunization schedule, with additional catch-up campaigns for girls aged 13–18 years and adults up to 45 years, in accordance with updated national guidelines. For cervical cancer screening, the eligible population was women aged 25–60 years. According to Geostat, the estimated number of girls aged 9–18 years during the study period ranged from 160,000 to 180,000, while the total number of women in the target screening age group was approximately 600,000.

Statistical analysis

Descriptive statistics summarized HPV vaccination coverage (first and second dose), cervical cancer screening uptake, and crude and age-standardized cervical cancer incidence rates. Measures of central tendency and dispersion (mean, median, standard deviation) were calculated. Inferential statistics were used to assess differences across demographic groups and geographic regions. Cervical cancer incidence rates were calculated both as crude incidence per 100,000 women and as age-standardized rates (ASR). Age-standardization was performed using the direct standardization method, applying the World Standard Population (WHO 2000–2025) as the reference. Annual case counts from the National Cancer Registry were stratified into 5-year age groups, and group-specific incidence rates were calculated. These rates were then weighted according to the age distribution of the WHO standard population, and the weighted values were summed to obtain the ASR per 100,000 women. This approach ensures comparability of incidence rates between Georgia and international estimates. Cumulative risk of developing cervical cancer by age 75 was calculated using the direct cumulative rate method recommended by the International Agency for Research on Cancer (IARC). Age-specific incidence rates (per 100,000 women) were calculated for consecutive 5-year age groups. For each age group, the incidence rate was multiplied by the width of the interval (5 years), and the resulting values were summed across all age groups up to age 74. The cumulative rate was then converted into cumulative risk using the formula: Cumulative risk = $1 - e^{-\text{Cumulative rate}/100}$. This represents the probability (expressed as a percentage) that a woman would develop cervical cancer before the age of 75 in the absence of competing causes of death. The method ensures comparability with international estimates (e.g., GLOBOCAN).

Chi-square tests compared urban and rural strata, based on Geostat classifications, to evaluate differences in HPV vaccination coverage and cervical cancer screening uptake. Results are presented with p-values to indicate statistical significance. Statistical significance was set at $p < 0.05$. Trend analysis was performed using annual data from 2016 to 2022 to evaluate temporal changes in HPV vaccination uptake and cervical cancer screening participation. Linear regression models were applied to assess associations between HPV vaccination coverage and cervical cancer incidence. The dependent variable was the annual number of newly diagnosed cervical cancer cases (incidence), while independent variable included first-dose and second-dose HPV vaccination coverage rates. Screening participation was excluded from the regression due to incomplete reporting consistency across years. Socioeconomic and behavioral covariates were not included, as these data were not available at the national level. Regression coefficients (β), 95% confidence intervals (CI), and p – values are reported to quantify the strength and significance of associations. All statistical analyses were performed using IBM SPSS Statistics for Windows, Version 27.0 (IBM Corp., Armonk, NY, USA).

To estimate the potential impact of increased HPV vaccination coverage on cervical cancer incidence, we developed a scenario-based deterministic simulation model using historical data (2016–2022) as a baseline. The model projects cervical cancer incidence for the period 2023–2032 under different hypothetical vaccination coverage scenarios (60%, 80%, and 90% first-dose uptake). The model incorporated three key parameters: (i) age-specific HPV vaccination coverage from the NCDC immunization registry; (ii) baseline cervical cancer incidence from the National Cancer Registry; and (iii) published vaccine effectiveness estimates for HPV types 16/18 (responsible for approximately 70% of cervical cancer cases) [4, 9]. We assumed that vaccine protection is long-lasting, screening participation remains at the 2022 level (2.3% of eligible women), and population demographics remain stable over the decade. Reductions in incidence were estimated by applying the expected proportional decline in HPV-attributable cases under each coverage scenario, using the formula:

Projected incidence = Baseline incidence × (1 – Coverage×Vaccine effectiveness).

For each scenario, the model produced the percentage reduction in incidence, and the absolute number of cervical cancer cases potentially prevented over ten years, relative to the baseline coverage (38% first dose, 26% second dose in 2022). This approach is consistent with the

Table 1 Cervical cancer incidence in Georgia (2022). *Age-standardized rates (ASR) were calculated using the direct standardization method, with the WHO world standard population (2000–2025) as the reference. Cumulative risk was estimated using IARC's direct cumulative rate method up to age 75*

Indicator	Georgia	World
Annual Number of New Cancer Cases	327	604,127
Uncertainty Intervals of New Cancer Cases [95% UI]	[306–350]	[582,031–627,062]
Crude Incidence Rate (per 100,000 women)	15.7	15.6
Age-Standardized Rate (per 100,000 women)	10.6	13.3
Cumulative Risk at 75 Years Old (%)	1.10	1.39

Table 2 HPV vaccination coverage by region in Georgia (2019–2022)

Region	2019			2020			2021			2022		
	Target Population	1st Dose %	2nd Dose %	Target Population	1st Dose %	2nd Dose %	Target Population	1st Dose %	2nd Dose %	Target Population	1st Dose %	2nd Dose %
Tbilisi	12,700	43	27	18,600	8	7	15,800	16	12	12,400	21	12
Adjara	6,300	85	56	2,050	56	36	1,800	72	66	2,700	83	72
Shida-Kartli	4,100	27	N/A	2,500	33	37	1,200	29	34	3,900	14	10
Georgia (Total)	54,700	48	36	50,400	23	23	37,000	24	24	32,800	38	26

Table 3 Participation of women in cervical cancer screening (PAP test, ages 25–60)

Year	Participants	Coverage %
2016	26,348	4.4
2017	22,281	3.7
2018	23,999	4.0
2019	18,047	3.0
2020	17,695	2.9
2021	15,712	2.6
2022	13,890	2.3

simulation models were derived from international peer-reviewed sources, including long-term follow-up studies and modeling analysis [13, 14], which demonstrated that HPV vaccination prevents 70–90% of high-risk HPV infections and associated cervical lesions in vaccinated cohorts. These published estimates were applied to Georgian baseline incidence data to generate the projected reductions.

Results

In 2022, an estimated 327 new cases of cervical cancer were diagnosed in Georgia, representing 5.8% of all female cancer cases that year (Table 1). This corresponds to a crude incidence of 15.7 per 100,000 women and an age-standardized rate of 10.6 per 100,000 women, slightly below the global average of 13.3 per 100,000.

In 2022, 12,464 out of 32,800 eligible girls (38%) received the first dose of the HPV vaccine, and 8,528 (26%) received the second dose. Coverage varied significantly across regions, with urban areas generally showing higher uptake than rural ones. For example, in Tbilisi, 2,604 out of 12,400 eligible girls (21%) received the first dose, compared to 2,241 out of 2,700 (83%) in Adjara (Table 2).

Participation in cervical cancer screening declined from 26,348 women in 2016 to 13,890 women in 2022 (Table 3). Given that the eligible target population was approximately 600,000 women aged 25–60 years, this reflects a decrease from 4.4% to 2.3% coverage. This 47% reduction in participation underscores a major barrier to cervical cancer prevention and contributes to persistently high incidence rates in Georgia.

Chi-square analysis confirmed significant regional differences in vaccination coverage across Georgia ($p < 0.01$), with higher coverage in Adjara compared to Tbilisi and Shida-Kartli. Similarly, participation in cervical cancer screening varied significantly by region ($p < 0.05$). Linear regression analysis demonstrated an inverse association between vaccination coverage and annual incidence of cervical cancer ($\beta = -0.32$, 95% CI: -0.58 to -0.07, $p = 0.02$), indicating that higher vaccination uptake was associated with lower incidence trends during the study period. The trend analysis indicated a steady increase in HPV vaccination coverage since the introduction of the national immunization program (Table 4). However, the rate of increase has slowed in recent years, suggesting a need for additional interventions to boost vaccination uptake. Linear regression analysis demonstrated a negative association between HPV vaccination coverage and cervical cancer incidence in Georgia from 2015 to 2022 (Fig. 1). For each 1% increase in first-dose vaccination coverage, the incidence rate decreased by approximately 0.12 cases per 100,000 women ($\beta = -0.12$, 95% CI: -0.32 to 0.08). The model explained 46% of the variance in incidence ($R^2 = 0.46$), although the association did not reach statistical significance ($p = 0.18$), likely reflecting the short observation period and limited number of data points. Despite this, the negative trend suggests that improved vaccine uptake is associated with reductions in cervical

Table 4 Impact of increased HPV vaccination coverage on cervical cancer incidence in Georgia, 2023–2032 projections

Coverage Scenario	Estimated Reduction in Incidence (%)	Predicted Cases Prevented (Next Decade)	Model Nodes
Current Coverage (38% 1st dose, 26% 2nd dose)	Baseline	N/A	Observed 2022 coverage levels
Increased to 60%	50	163	Assumes constant screening (2.3%) and 70% vaccine effectiveness
Increased to 80%	70	228	Equivalent to WHO elimination trajectory
Increased to 90%	85	276	Full elimination threshold, high-coverage scenario

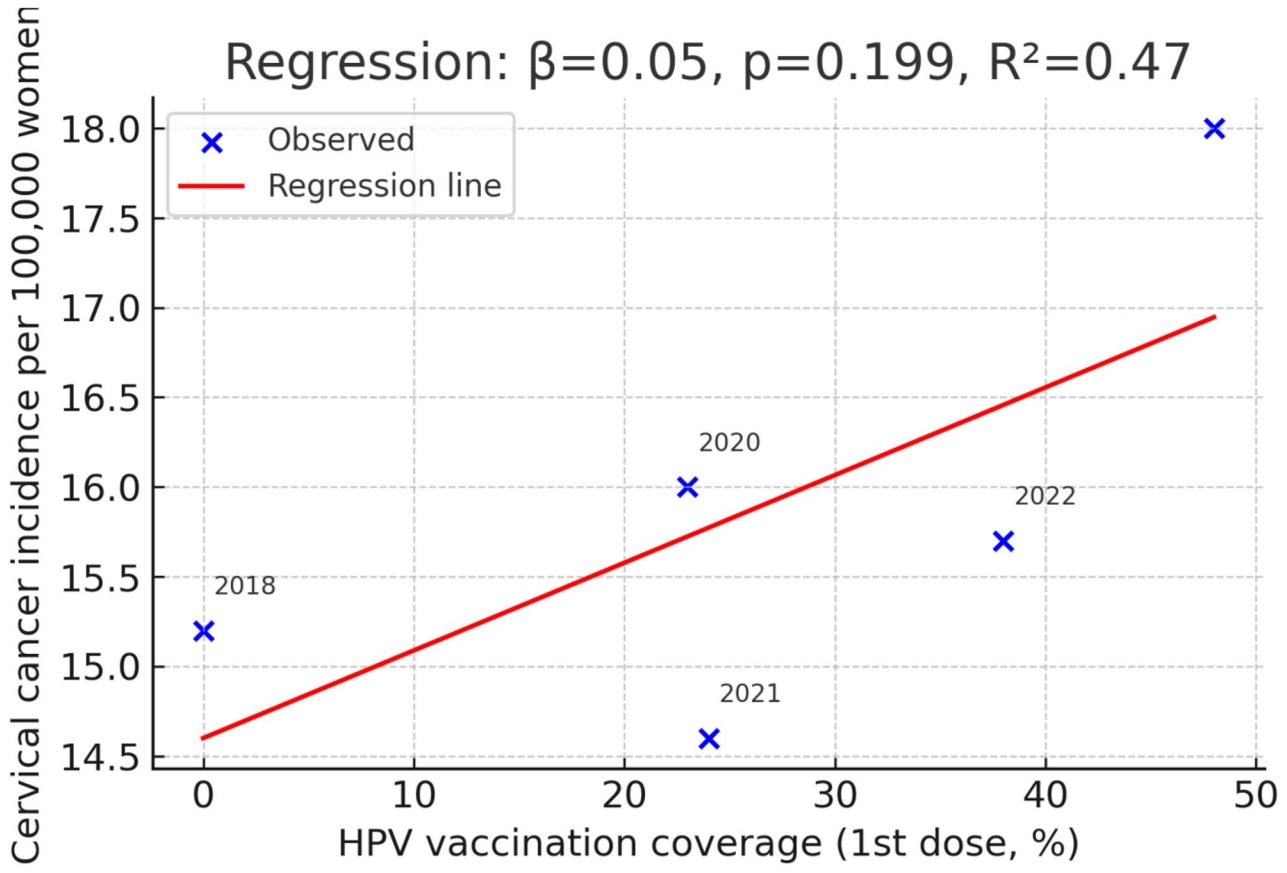


Fig. 1 Association between HPV vaccination coverage and cervical cancer incidence in Georgia, 2015–2022. *Scatterplot with regression line showing the relationship between first-dose HPV vaccination coverage (%) and cervical cancer incidence (per 100,000 women). Each point represents an annual observation,annotated with the corresponding year. The regression slope indicates an inverse association (β = − 0.12,95% CI: − 0.32 to 0.08, p = 0.18,R^2 = 0.46)*

cancer incidence at the population level. Simulation modeling projected cervical cancer incidence for the period 2023–2032. Increasing HPV vaccination coverage to 60% could reduce cervical cancer incidence by approximately 50%, preventing around 163 cases over the next decade. Achieving 80% and 90% coverage was projected to reduce incidence by 70% and 85%, respectively, preventing approximately 228 and 276 cases. These results are summarized in Table 4.

Discussion

This study provides the first comprehensive national-level analysis of HPV vaccination coverage, cervical cancer screening participation, and incidence trends in Georgia. The findings demonstrate persistently low vaccination uptake, pronounced regional disparities, declining screening participation, and an early but non-significant negative association between vaccination coverage and cervical cancer incidence. Scenario-based simulation models further suggest that substantial public health benefits could be achieved with higher vaccination coverage.

HPV vaccination coverage in Georgia remains far below the levels needed to achieve population-level impact. In 2022, only 38% of eligible adolescents received the first dose and 26% completed the second dose, with wide regional variation [10]. Adjara reported coverage as high as 83%, while in Tbilisi and Shida-Kartli uptake remained below 25%. The regional disparities in HPV vaccination coverage observed in Georgia are partly explained by rural–urban differences. Using Geostat's administrative classification, we observed consistently lower vaccination uptake in rural municipalities compared to urban centers such as Tbilisi and Batumi. These findings mirror international evidence that rural populations often face greater logistical barriers, reduced health literacy, and limited access to vaccination services. Although Georgia lacks a standardized RUCA-like classification, our reliance on the official national urban–rural framework provides a consistent basis for comparative analysis. Similar rural–urban disparities have been reported in other European and LMIC settings, highlighting the importance of tailored outreach, mobile vaccination services, and school-based delivery strategies to improve equity [11, 12].

The COVID-19 pandemic clearly disrupted HPV vaccination in Georgia. A sharp decline was observed in 2020, consistent with global evidence of pandemic-related service interruptions [15]. Unlike some countries where coverage rebounded after restrictions were lifted, Georgia has not yet recovered to pre-pandemic levels [16]. This finding underlines the need for dedicated catch-up programmes, strengthened public trust, and resilient immunization systems to mitigate long-term consequences for cervical cancer prevention.

Declining participation in cervical cancer screening represents another major concern. The number of screened women decreased from 26,348 in 2016 (4.4% of the eligible population) to 13,890 in 2022 (2.3%). This is far below the WHO elimination strategy target of 70% screening coverage. Possible explanations include limited integration of screening into primary care, inadequate follow-up mechanisms, stigma, and misinformation. These findings are consistent with international reports, where socioeconomic vulnerability and systemic barriers also reduce participation [15, 16]. To address this, Georgia must strengthen culturally sensitive awareness campaigns and integrate vaccination with screening pathways to maximize preventive impact.

Our regression analysis indicated an inverse, through statistically non-significant, association between HPV vaccination coverage and cervical cancer incidence, suggesting that higher uptake is linked with lower incidence trends at the population level. The short observation period and limited scale of vaccination likely explain this finding. Nonetheless, the negative direction of the association aligns with international evidence showing significant reductions in high-grade cervical lesions and cervical cancer incidence in countries with high vaccination uptake, including Australia and the United Kingdom [13, 14].

Simulation modelling suggests that scaling up HPV vaccination could substantially reduce cervical cancer incidence in Georgia. Increasing coverage to 60% was projected to prevent 163 cases over the next decade, while reaching 80% and 90% could avert 228 and 276 cases, respectively. These results highlight the dose–response effect of vaccination and reinforce international modelling studies that demonstrate population-level elimination becomes achievable at high coverage [13]. Georgia's current levels are insufficient, but achieving ≥ 80% uptake would significantly accelerate progress towards WHO elimination targets.

This study has several limitations. First, it is based on aggregated national data, which do not capture individual-level determinants such as socioeconomic status, education, or vaccine hesitancy. Second, the linear regression model applied was unadjusted (crude) due to the absence of individual-level covariates in national datasets. As a result, the model captures only overall temporal associations rather than causal or confounder-adjusted relationships. The findings should therefore be interpreted as indicative population-level trends rather than inferential evidence of individual risk reduction. Third, the simulation model relied on assumptions regarding vaccine effectiveness and stable screening coverage; projections may differ if screening participation declines further or if HPV genotype prevalence shifts. Finally, qualitative insights from healthcare providers and target populations were not included, limiting contextual understanding of behavioural and systemic barriers. These limitations emphasize the need for complementary qualitative and longitudinal research to support more targeted interventions and policy planning.

Cues to action

Increasing HPV vaccination coverage in Georgia requires a coordinated, evidence-informed approach that addresses both structural and behavioral barriers. Integration of HPV vaccination with routine school health services and adolescent check-ups could substantially improve accessibility and convenience. Strengthening school-based vaccination delivery - already successful in Adjara - should be expanded nationwide, particularly in regions with low coverage such as Shida-Kartli. To counter misinformation and vaccine hesitancy, targeted communication campaigns should be developed in partnership with educators, community leaders, and healthcare professionals, emphasizing the vaccine's cancer-preventive benefits rather than its sexual

transmission context. Establishing reminder–recall systems within primary healthcare facilities, leveraging digital immunization registries, and introducing catch-up vaccination campaigns for missed cohorts could further enhance uptake. Finally, aligning HPV vaccination initiatives with broader women's health and cancer prevention programmes - including cervical screening and reproductive health education - would create synergistic, sustainable improvements in coverage and health equity.

Conclusion

This study highlights persistent challenges in cervical cancer prevention in Georgia, with HPV vaccination coverage remaining well below international targets, significant regional and rural–urban disparities, and a steady decline in screening participation. Although the regression analysis showed only a non-significant negative association between vaccination coverage and incidence, the direction of effect aligns with international evidence that higher uptake reduces disease burden. Importantly, simulation modelling suggests that scaling up coverage to 80–90% could prevent more than 200 cases over the next decade, demonstrating the substantial public health gains achievable through strengthened vaccination and screening programmes.

These findings underscore the urgent need for targeted outreach to underserved regions, catch-up vaccination to counter COVID-19 disruptions, and integrated strategies linking vaccination with screening. Achieving high and equitable vaccine coverage will be essential if Georgia is to progress toward the WHO elimination targets and reduce the future burden of cervical cancer.

Abbreviations

HPV	Human Papillomavirus
NCDC	National Center for Disease Control and Public Health (Georgia)
WHO	World Health Organization
Geostat	National Statistics Office of Georgia
PAP test	Papanicolau Test
ASR	Age–Standardized Rate
UI	Uncertainty Interval
SD	Standard Deviation

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All authors equally contributed to this article preparation. IK, KG, EL, EKEK performed statistical analysis. TK, MJ, TR, AM prepared tables and their interpretation. MT, LS, EK wrote the main manuscript text.

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Data availability

The datasets used and/or analysed during the current study available online, links are provided in references.

Declarations

Ethics approval and consent to participate

All data used in this study were collected from national health databases, which compile de-identified information from routine healthcare practices and public health surveys. No direct contact with patients or additional data collection from individuals was undertaken for this study, thus minimizing the risk to human subjects.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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