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Socioeconomic disparities in HPV vaccine uptake: multivariable analysis of vaccination data from Tianjin (2018–2023)

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Objectives: As the first socio-demographic profiling of HPV vaccines in Chinese cities, this study assesses equity implications through compositional analysis of covered populations, with multilevel examination of vaccine-type selection determinants.

Method: Utilizing HPV vaccination data obtained from the Jinnan Center for Disease Control and Prevention (CDC) spanning from 2018 to 2023, we conducted a retrospective analysis. Hierarchical logistic regression was employed to model the joint effects of age, ethnicity, occupation, and urban−rural residence on vaccination behaviors. Vaccine type preference was categorized as bivalent, quadrivalent, or nonavalent.

Result: Three key disparities were revealed in the analysis. Age-stratified access revealed the highest proportion of recipients among women aged 33−38 years (29.6%) and 39−44 years (21.9%), contrasting with less than 1% participation in the 9−14 year-old cohort. Educationally, 87.3% held at least a bachelor's degree, compared to 12.7% with below-college education (χ^2 = 6048.89, $p < 0.001$). Clear urban−rural divide, with 99.7% of recipients in urban areas and just 0.3% in rural areas (χ^2 = 76.79, $p < 0.001$). Vaccine-type selection showed socioeconomic patterns, with nonavalent vaccines preferred by urban professionals (OR = 1.577, 95% CI: 1.16−2.142) and those with incomes above 5000 yuan (OR = 1.958, 95% CI: 0.26−3.527).

Conclusion: Demonstrating Hart's Inverse Care Law, Tianjin's program disproportionately immunizes socioeconomically secure urbanites. We propose: (1) school-based mandates for pre-sexual debut cohorts; (2) rural vaccination-social insurance integration; (3) domestic 9-valent vaccine development with needs-based subsidies. These evidence-based reforms are critical for achieving equitable 90% coverage by 2030.

KEYWORDS

HPV vaccines, vaccine equity, socio-economic status, multivariable logistic regression, urban−rural disparities

1 Introduction

Cervical cancer, primarily caused by persistent infection with high-risk types of HPV, remains a significant global health issue. In 2020, the disease resulted in over 600,000 new cases and 341,831 deaths worldwide (1), disproportionately affecting socioeconomically disadvantaged populations, particularly in low- and middle-income countries. These disparities arise from barriers such as limited healthcare access, low health literacy, and

financial constraints (2–4). Despite substantial advances in cervical cancer prevention through HPV vaccination, socio-economic and geographical inequalities continue to hinder vaccine accessibility and uptake, particularly in developing countries like China.

In China, the incidence of cervical cancer has increased by 3.5% from 2018 to 2020, with 109,700 new cases, accounting for 5.2% of all female cancer cases (5). HPV types 16 and 18 are responsible for approximately 70% of cervical cancer cases (6), with other high-risk types such as 31, 33, 45, 52, and 58 contributing significantly (7, 8). HPV vaccination programs have proven to be effective in reducing the prevalence of HPV infections and the incidence of cervical cancer (9, 10). The introduction of bivalent, quadrivalent (4-Valent), and nonavalent (9-Valent) vaccines has been particularly successful in preventing HPV-related cancers globally (11, 12).

However, despite these advances, China faces stark disparities in HPV vaccination coverage, with only 2.24% of the female population vaccinated by 2020 (13). This low vaccination rate highlights significant gaps in public health efforts, particularly in terms of accessibility and education (14). Socio-economic factors such as age, education, and occupation contribute to inequities in vaccine uptake, leading to a paradox where socioeconomically secure urban populations are more likely to be vaccinated, while higher-risk groups, including younger and rural populations, remain under-vaccinated.

Tianjin, a rapidly developing municipality in northern China, provides an ideal case study for exploring these challenges. Jinnan District, one of Tianjin's key districts, is particularly notable for its demographic diversity and socio-economic stratification. According to the 2020 census, Jinnan District's population stands at 928,066, with women comprising 47.14% and the working-age group (15–59 years) making up 70.61% (15). A substantial portion of the female population is within the age range eligible for HPV vaccination (9–45 years), making Jinnan a relevant site for studying HPV vaccination patterns.

This study seeks to assess the socio-economic attributes and geographical distribution of the HPV vaccination population in Jinnan District. The objective is to analyze the composition of the currently vaccinated cohort and identify the key factors influencing vaccine type preferences, ultimately providing valuable insights for the future enhancement of vaccination promotion strategies and reducing cervical cancer incidence in the region.

2 Materials and methods

2.1 Ethics approval, study population

This study was approved by the Nankai University Biomedical Ethics Committee (Approval No. NKU-IRB-2023141). Informed consent was not required for the retrospective analysis, as all data were anonymized and fully de-identified to ensure privacy, with access restricted to authorized personnel. The dataset, which includes both vaccination records and socio-demographic information (age,

occupation, marital status, and geographic location), was provided by the Tianjin Jinnan District CDC as part of the city's routine public health surveillance system. The data covered the period from January 2018 to June 2023 and pertained to women residing in the Jinnan District of Tianjin who participated in the vaccination program. A formal request was submitted to the CDC for the data, which was commissioned specifically for this study.

2.2 Data collection and study procedure

To ensure the validity and reliability of the study, the data collection process adhered to a systematic procedure:

A Data Collection: The Tianjin Jinnan District CDC collected and maintained vaccination records and socio-demographic information through its routine public health surveillance system, which includes both electronic health records and paper-based records.
B Data Anonymization: The CDC anonymized the data to ensure participant privacy and confidentiality.
C Data Transfer: The anonymized dataset was transferred to the research team for analysis.
D Data Cleaning and Preparation: The research team conducted data cleaning and preparation to ensure the dataset was ready for analysis.

2.3 Statistical analysis

IBM SPSS Statistics 25.0 was used for data analysis. Categorical variables were summarized as frequencies and percentages, and continuous variables as means and standard deviations. Associations between socio-demographic factors and vaccine type preference were assessed using chi-square tests. Collinearity was assessed using variance inflation factors (VIFs), and final variables for the model were selected accordingly. Logistic regression identified predictors of vaccine type preference, with statistical significance set at $p < 0.05$.

Age was initially grouped into seven five-year brackets for descriptive statistics but was reclassified into four broader categories (9–19, 20–29, 30–39, 40–50 years) in the regression analysis due to small sample sizes in the youngest and oldest groups. Results are presented in tables and charts with narrative explanations.

3 Results

3.1 Socio-demographic characteristics

The study cohort comprised 33,002 female HPV vaccine recipients, with a mean age of 33.0 years (SD = 7.6). Detailed socio-demographic characteristics are presented in Table 1. The majority of recipients were urban residents (99.7%), with 85.1% married and 99.5% of Han ethnicity. Educational attainment was high, with 87.3% holding at least a bachelor's degree. Occupation-based categorization showed that homemakers (25.8%) were the largest group, followed by labor-intensive workers (13.7%) and students (13.3%). Income levels varied, with 46.7% earning between 5,000 and 7,000 RMB per month.

TABLE 1 Socio-demographic characteristics, distribution of vaccine type.

Variable	N (100%)	Cervarix	Cecolin	Gardasil 9	Gardasil 4	χ^2	p
Age group (years)						20174.793	<0.001
9–14	238 (0.7%)	23 (9.4%)	145 (59.4%)	76 (31.1%)	–		
15–20	1,659 (5.0%)	49 (2.1%)	190 (8.1%)	2,084 (89.5%)	3 (0.1%)		
21–26	6,030 (18.3%)	14 (0.2%)	657 (12.2%)	4,664 (87.0%)	22 (0.4%)		
27–32	6,442 (19.5%)	205 (3.1%)	2,729 (42.3%)	1,773 (27.5%)	1,735 (26.9%)		
33–38	9,776 (29.6%)	440 (4.5%)	5,458 (55.8%)	377 (3.8%)	3,501 (35.8%)		
39–44	7,215 (21.9%)	517 (7.1%)	4,397 (60.9%)	186 (2.5%)	2,115 (29.3%)		
45–50	1,642 (5.0%)	223 (13.5%)	1,071 (65.2%)	10 (0.6%)	338 (20.5%)		
Education degree▭						6048.89	<0.001
Compulsory education	1,457 (4.4%)	52 (3.5%)	291 (19.9%)	1114 (76.4%)	–		
Below bachelor's degree	436 (1.3%)	85 (19.4%)	92 (21.1%)	130 (29.8%)	129 (29.5%)		
Higher education	1,567 (4.7%)	19 (1.2%)	125 (7.9%)	1374 (87.6%)	49 (3.1%)		
Bachelor	28,797 (87.3%)	1,214 (4.2%)	14,114 (49.0%)	6,304 (21.8%)	7,165 (24.8%)		
Post-bachelor degree	745 (2.3%)	101 (13.5%)	25 (3.3%)	248 (33.2%)	371 (49.7%)		
Marital status						7586.46	<0.001
Married	28,075 (85.1%)	1,348 (4.8%)	13,912 (49.6%)	5,283 (18.8%)	7,532 (26.8%)		
Single	4,927 (14.9%)	123 (2.4%)	735 (14.9%)	3,887 (78.8%)	182 (3.6%)		
Ethnic group						103.544	<0.001
Non-Han	151 (0.5%)	27 (17.8%)	22 (14.5%)	64 (42.3%)	38 (25.1%)		
Han	32,851 (99.5%)	1,444 (4.3%)	14,625 (44.5%)	9,106 (27.7%)	7,676 (23.3%)		
Residence						76.794	<0.001
Rural	104 (0.3%)	18 (17.3%)	12 (11.5%)	48 (46.1%)	26 (25.0%)		
Urban	32,898 (99.7%)	1,453 (4.4%)	14,635 (44.5%)	9,122 (27.7%)	7,688 (23.3%)		
Occupation						8027.227	<0.001
Freelancers (FLC)	2,137 (6.5%)	60 (2.8%)	1,192 (55.8%)	600 (28.1%)	285 (13.3%)		
Homemakers (HM)	8,527 (25.8%)	458 (53.7%)	4,011 (47.0%)	1,807 (21.2%)	2,251 (26.4%)		
Intensive labor personnel (ILP)	4,529 (13.7%)	182 (4.0%)	2,643 (58.4%)	565 (12.5%)	1,139 (25.1%)		
Personnel ensuring basic social services (PEBSS)	3,658 (11.1%)	149 (40.7%)	1,980 (54.1%)	577 (15.8%)	952 (26.0%)		
Service personnel (SP)	4,230 (12.8%)	168 (39.7%)	2,226 (52.6%)	774 (18.3%)	1,062 (25.1%)		
State-owned enterprise personnel (SOEP)	1,809 (5.5%)	113 (62.4%)	620 (34.3%)	333 (3.6%)	743 (9.6%)		
Students (STD)	4,374 (13.3%)	90 (6.1%)	691 (4.8%)	3,498 (38.2%)	95 (1.3%)		
Technical personnel (TP)	3,738 (11.3%)	251 (6.7%)	1,284 (34.3%)	1,016 (27.1%)	1,187 (31.7%)		
Monthly income (RMB)						7534.961	<0.001
1500–2500	4,552 (13.8%)	93 (4.7%)	823 (18.0%)	3496 (76.8%)	140 (3.0%)		
2500–5000	10,859 (32.9%)	320 (2.9%)	6,322 (58.2%)	1,996 (18.3%)	2,221 (20.4%)		
5000–7000	15,422 (46.7%)	974 (6.3%)	6,885 (44.6%)	3,067 (19.8%)	4,496 (29.1%)		
7000–10000	1,950 (5.9%)	81 (4.1%)	531 (27.2%)	595 (30.5%)	743 (38.1%)		
Sum	33,002	1,471 (4.5%)	14,647 (44.4%)	9,170 (27.8%)	7,714 (23.4%)		

▭ Education degree represents the highest level of formal education attained by the participants.

Figure 1 presents the vaccine adoption trends among various age groups. Notably, the adoption rate for the 9–14 age group is strikingly low, standing at merely 0.7%. Interestingly, within the 45–50 age bracket, 5% of individuals have initiated vaccination, beyond the recommended age range. Among the youngest cohort, the *E. coli*-based bivalent vaccine emerges as the most preferred option, constituting 59.4% of vaccinations, with the 9-valent vaccine following closely at 31.1%.
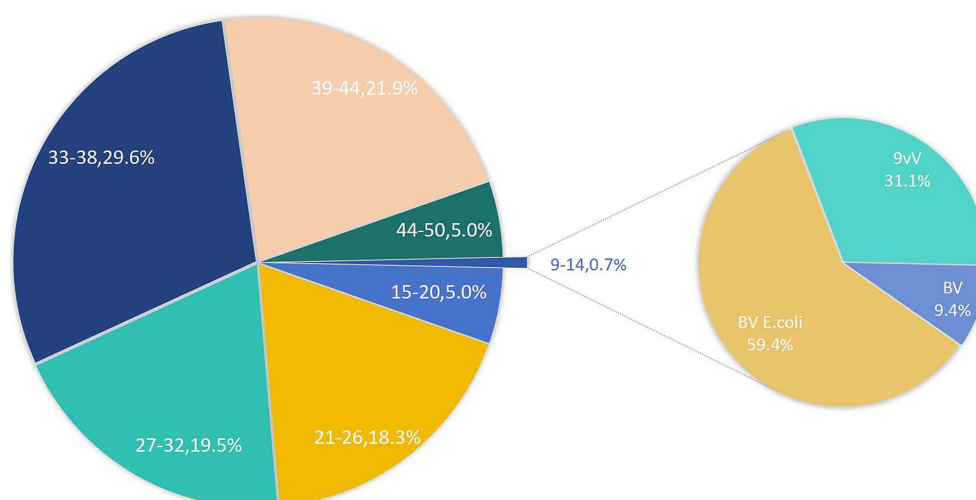
FIGURE 1
Age range of HPV vaccination and type distribution for ages 9–14.

3.2 HPV vaccine type distribution

The HPV vaccine's annual response rate has significantly and cumulatively increased over time (Table 2). Initially dominated by the quadrivalent Gardasil 4 (2018–2020), which accounted for 50–80% of doses, a major shift occurred in 2021 when the domestic Cecolin bivalent vaccine captured 63.7% of doses by 2022, driven by policy incentives and cost-effectiveness. Despite growing availability, the 9-valent vaccine remained a minority choice, representing just 21–33% of doses.

Completion rates showed critical attrition: 89.4% received the second dose, but only 75.95% completed the full three-dose regimen, with minimal uptake for the fourth dose (0.02%). Among the five extra-protocol vaccinations, four were delayed catch-up doses, and one involved switching vaccine types.

An analysis of vaccine uptake by occupation revealed key trends (Figure 2). In 2018, technical professionals led adoption (54.7%), but by 2020, homemakers became the largest group, comprising 25% of vaccinations, continuing into subsequent years. Vaccination rates among technical professionals and state-owned enterprise employees significantly declined, reaching 9.6 and 4.9% by 2023. Figure 3 highlights vaccine preferences across occupations. Homemakers showed broad vaccine type preferences, technical professionals displayed a similar pattern. In contrast, students preferred the 9-valent vaccine, with 38.2% selecting it, marking them as a key consumer group for this vaccine.

3.3 Key predictors of vaccine type preference

3.3.1 The chi-square test

The analysis began with chi-square tests to examine the relationships between independent variables and vaccine type preference. Significant results ($p < 0.001$) were found for all variables, justifying their inclusion in the regression analysis. Key variables such as Age Group ($\chi^2 = 20174.793$), Education Level ($\chi^2 = 6048.89$), and Marital Status ($\chi^2 = 7586.46$) showed strong significance (Table 1). These results confirm their relevance as predictors of vaccine preference.

3.3.2 Collinearity and model fit assessment

Before regression analysis, collinearity diagnostics were conducted (Table 3). Moderate collinearity between education and marital status led to their exclusion. The remaining variables showed satisfactory tolerance (all >0.8) and VIF < 1.5, confirming minimal multicollinearity and suitability for the model. Model adequacy was confirmed by Pearson's chi-square and Nagelkerke's pseudo R-squared, both indicating strong significance. The likelihood ratio test highlighted the key roles of Occupational Category and Monthly Income/Expenditure in predicting vaccine preference, while variables like Ethnicity and Place of Residence, though less significant, were retained for a more comprehensive analysis (Table 4).

3.3.3 The regression model

Logistic regression identified age as the strongest predictor of vaccine selection. Younger individuals (20–29 years) showed extraordinary preference for the 9-valent vaccine (OR = 405.99, 95% CI: 296.5–555.9, $p < 0.001$), whereas older recipients (30–39 years) favored domestic bivalent or quadrivalent options (OR = 1.62–2.50, $p < 0.001$).

Ethnicity and urbanization compounded these trends: Han Chinese (OR = 8.87, $p < 0.001$) and urban residents (OR = 7.29, $p < 0.001$) disproportionately chose domestic vaccines, reflecting both accessibility and cultural trust in locally produced biologics. Occupation-mediated disparities persisted, with public sector employees leaning toward 9-valent vaccines (OR = 1.58, $p < 0.05$) and freelancers/essential workers preferring domestic options (OR = 2.24–2.94, $p < 0.001$) (Table 5).

4 Discussion

This comprehensive analysis of HPV vaccination patterns in China reveals critical socio-demographic and economic determinants

TABLE 2 The annual distribution of HPV vaccine doses and completion rates.

Categories	Total dose	Cervarix	Cecolin	Gardasil9	Gardasil4
Year					
2018	280 (0.3%)	56 (20.0%)	–	–	224 (80.0%)
2019	596 (0.7%)	174 (29.1%)	103 (17.2%)	319 (53.5%)	–
2020	6,277 (7.2%)	1,239 (19.7%)	84 (1.3%)	1,810 (28.8%)	3,144 (50.0%)
2021	14,907 (17.0%)	1,251 (8.3%)	5,069 (34.0%)	4,658 (31.2%)	3,929 (26.3%)
2022	46,722 (53.4%)	975 (2.0%)	29,769 (63.7%)	10,168 (21.7%)	5,810 (12.4%)
2023	18,778 (21.5%)	499 (2.6%)	6,442 (34.3%)	6,153 (32.7%)	5,684 (30.2%)
Programme completion					
Second dose	29,489 (89.36%)	1,419 (4.8%)	14,036 (47.5%)	7,523 (25.5%)	6,511 (22.0%)
Third dose	25,064 (75.95%)	1,303 (5.1%)	12,681 (50.5%)	6,197 (24.7%)	4,883 (19.4%)
Fourth dose	5 (0.02%)	1 (20.0%)	–	2 (40.0%)	2 (40.0%)
Total dose	87,560	4,194 (4.7%)	41,364 (47.2%)	19,110 (21.8%)	22,892 (26.1%)

FIGURE 2
Yearly vaccination coverage by occupational categories.
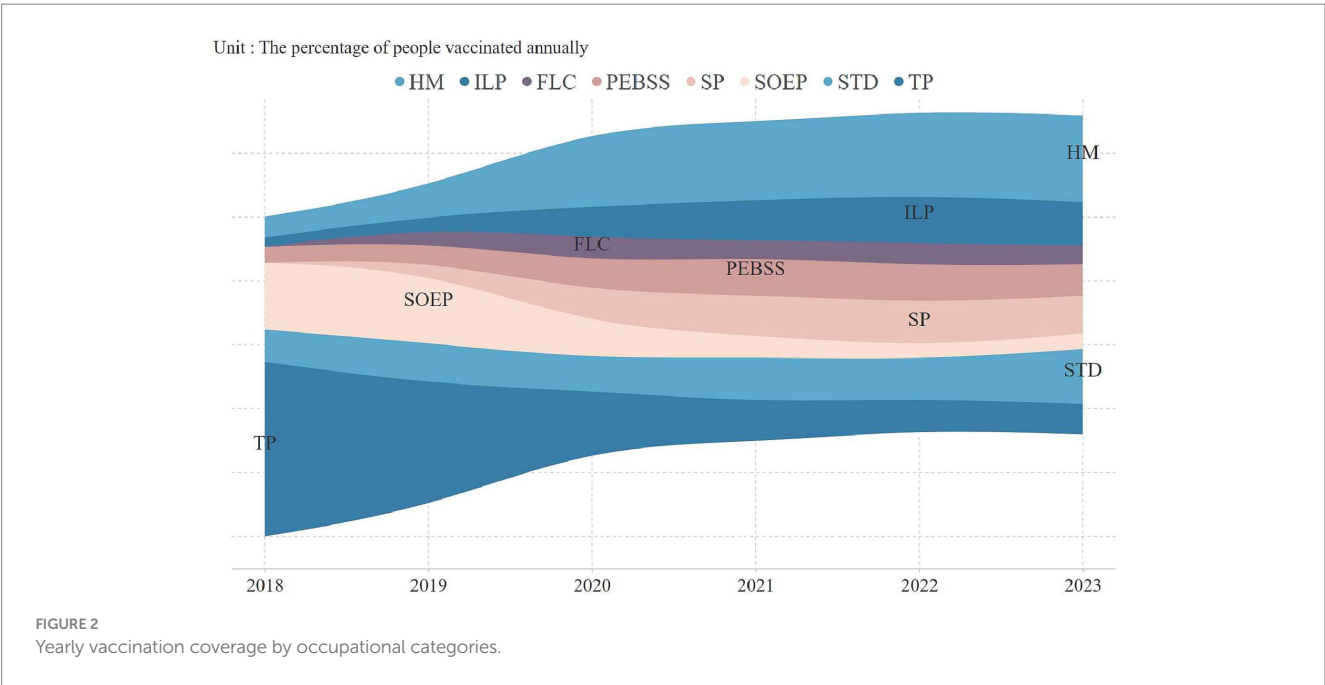
shaping vaccine uptake and type preferences, offering novel insights into public health challenges in a rapidly evolving healthcare landscape. While previous studies have predominantly focused on regional prevalence and vaccination willingness, our findings highlight the complex interplay of age, urban–rural disparities, ethnicity, and socio-economic status in driving inequitable vaccine distribution—a phenomenon increasingly recognized in global contexts but underexplored in China's unique socio-cultural environment.

Age composition in the vaccinated population emerged as a significant issue, with a severe imbalance observed across different age groups. Women aged 33 and older demonstrated the highest vaccination proportion, reflects greater health awareness, economic stability, and improved healthcare access in this age group. In contrast, vaccination participation were notably low among the 9–14 age group—the optimal target for HPV vaccination (16, 17).

More than half of these adolescents preferred the domestic bivalent vaccine, driven by financial constraints rather than the most protective options (18, 19). This preference highlights the financial barriers faced by families, especially in rural and economically disadvantaged areas, where transportation costs and out-of-pocket expenses limit timely access to vaccination (20). Limited healthcare infrastructure and a lack of health education about the long-term benefits of HPV vaccination further delay decision-making, particularly among parents who prioritize immediate financial concerns over preventive health (21). Furthermore, the participation rate among women aged 15–26, who are eligible for catch-up vaccinations, was only 23.3%. This confirms a significant delay in vaccine adoption, consistent with previous studies, particularly among younger populations (22, 23), Economic pressures and a lower sense of urgency regarding preventive healthcare appear to be the primary contributors to this delay.
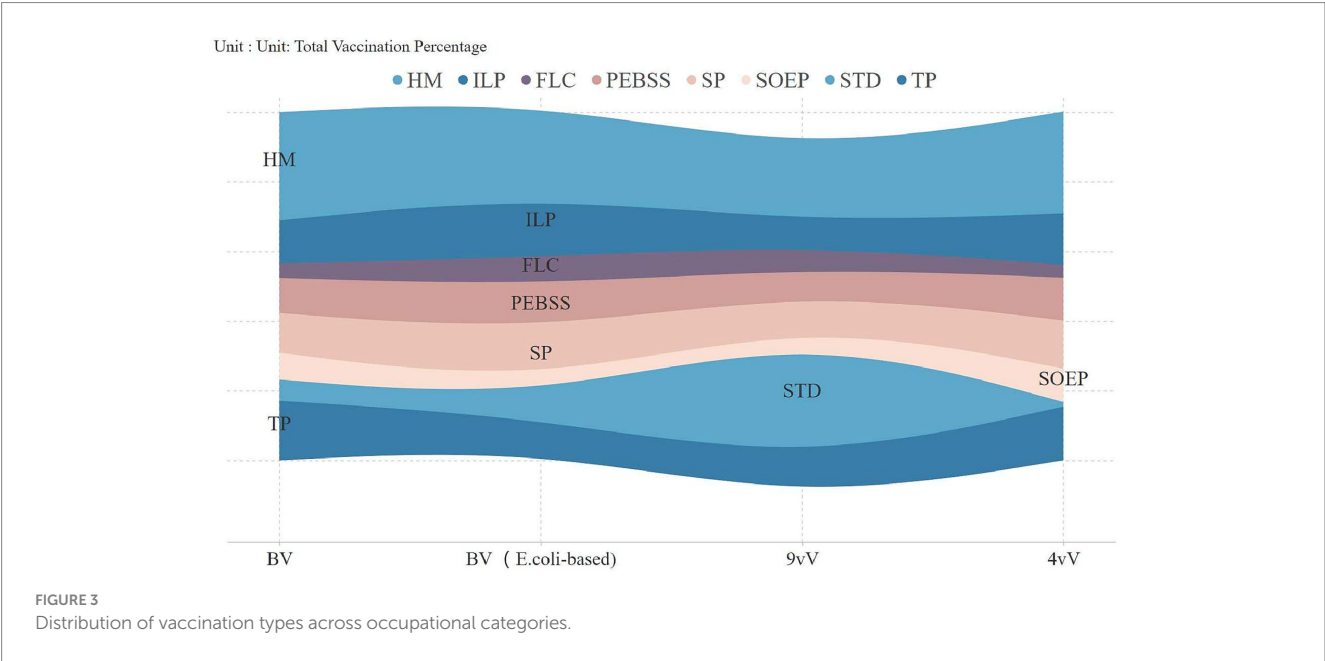
FIGURE 3
Distribution of vaccination types across occupational categories.

TABLE 3 Collinearity statistics.

Variable	B	S.E.	Beta	t	p	95% CI	Tolerance	VIF
Constant	2.871	0.021		135.384	<0.001	[2.829, 2.913]		
Ethnic group	−0.048	0.071	−0.004	−0.68	0.497	[−0.188, 0.091]	0.966	1.035
Residence	0.04	0.086	0.003	0.468	0.64	[−0.128, 0.208]	0.967	1.034
Occupation	0.034	0.002	0.088	15.462	<0.001	[0.03, 0.039]	0.897	1.115
Monthly income	0.15	0.006	0.141	23.773	<0.001	[0.137, 0.162]	0.826	1.21
Age	−0.176	0.006	−0.165	−27.612	<0.001	[−0.188, −0.163]	0.82	1.22

Independent variable: Type Of Vaccine.
B shows the change in the dependent variable for a one-unit change in the independent variable. Beta compares the strength of predictors in standard deviations.

TABLE 4 Likelihood ratio test and model fit metrics.

Effect	−2 log likelihood	χ^2	df	p
Intercept	2052.467a	0	0	
Occupation	2695.901	643.434	21	<0.001
Monthly income	2899.862	847.395	12	<0.001
Age	16797.15	14744.683	9	<0.001
Residence	2085.34	32.873	3	<0.001
Ethnic group	2106.74	54.273	3	<0.001
Goodness-of-fit indicators	Pearson's Chi-Squared	1292.8		<0.001
Nagelkerke R-squared				0.558

A p-value < 0.001 indicates a significant model fit. Degrees of freedom.

Epidemiological studies in Jilin, China have shown the widespread nature and genetic diversity of HPV, including high-incidence strains such as HPV16, HPV52, and HPV58. These studies highlight a bimodal age-specific prevalence, with peaks in the 30–34 and 55–59 age groups (24). Early vaccination, particularly before sexual debut (i.e., the 9–14 age group), remains the most effective preventive strategy to reduce the incidence of HPV-related diseases in these high-risk age groups. Studies also manifest that the antibody response in the 9–14 age group is twice as high as in individuals aged 16–26 (25). Therefore, early vaccination is crucial for maximizing protection in younger individuals, while the catch-up vaccination for 15–26 year-olds should be targeted with strategies that address the barriers preventing timely uptake, such as financial constraints and healthcare access.

Additionally, urban–rural and ethnic differences play a significant role in vaccine distribution (26–28). The study potentially substantiates

TABLE 5 Logistic regression for vaccine type selection.

Parameter	Estimate (B)	S.E.	df	p	OR (95% CI)
BV (E. coli-based)					
Intercept	−1.787	0.757	1	<0.05	–
Age group = 9–19	0.293	0.248	1	0.237	1.341 (0.825–2.179)
Age group = 20–29	1.217	0.141	1	<0.001	3.375 (2.562–4.447)
Age group = 30–39	0.482	0.059	1	<0.001	1.62 (1.443–1.818)
Age group = 40–50	Ref.	–	0	–	–
Ethnic Group = Han	2.182	0.307	1	<0.001	8.866 (4.858–16.18)
Ethnic Group = Non-Han	Ref.	–	0	–	–
Residence = Urban	1.986	0.395	1	<0.001	7.286 (3.359–15.806)
Residence = Rural	Ref.	–	0	–	–
Occupation = Freelancing	1.077	0.152	1	<0.001	2.935 (2.18–3.951)
Occupation = Homemaker	0.259	0.09	1	<0.05	1.295 (1.085–1.546)
Occupation = Intensive Labor Personnel	0.484	0.113	1	<0.001	1.623 (1.3–2.026)
Occupation = Personnel Ensuring Basic Social Service	0.805	0.111	1	<0.001	2.238 (1.801–2.781)
Occupation = Service Personnel	0.459	0.112	1	<0.001	1.582 (1.27–1.971)
Occupation = State-Owned Enterprise Personnel	0.107	0.124	1	0.39	1.113 (0.872–1.419)
Occupation = Student	−1.08	0.437	1	<0.05	0.34 (0.144–0.8)
Occupation = Technical Personnel	Ref.	–	0	–	–
Monthly Income = 1500–2500	1.189	0.716	1	<0.001	1.208 (0.297–4.913)
Monthly Income = 2500–5000	−0.203	0.595	1	0.733	0.816 (0.254–2.62)
Monthly Income = 5000–7000	−1.085	0.593	1	0.067	0.338 (0.106–1.08)
Monthly Income = 7000–10000	−1.226	0.603	1	<0.05	0.294 (0.09–0.957)
Monthly Income = 10000–15000	Ref.	–	0	–	–
9-Valent Vaccine					
Intercept	−4.647	0.784	1	<0.001	–
Age group = 9–19	4.578	0.254	1	<0.001	97.329 (59.218–159.969)
Age group = 20–29	6.006	0.16	1	<0.001	405.992 (296.533–555.857)
Age group = 30–39	1.383	0.106	1	<0.001	3.988 (3.24–4.909)
Age group = 40–50	Ref.	–	0	–	–
Ethnic Group = Han	1.907	0.299	1	<0.001	6.733 (3.747–12.097)
Ethnic Group = Non-Han	Ref.	–	0	–	–
Residence = Urban	1.146	0.367	1	<0.05	3.146 (1.532–6.46)
Residence = Rural	Ref.	–	0	–	–
Occupation = Freelancing	0.218	0.173	1	0.206	1.244 (0.887–1.744)
Occupation = Homemaker	−0.043	0.115	1	0.711	0.958 (0.764–1.201)
Occupation = Intensive Labor Personnel	−0.163	0.143	1	0.253	0.85 (0.643–1.123)
Occupation = Personnel Ensuring Basic Social Service	0.097	0.137	1	0.48	1.102 (0.842–1.442)
Occupation = Service Personnel	0.018	0.137	1	0.894	1.019 (0.778–1.333)
Occupation = State-Owned Enterprise Personnel	0.455	0.156	1	<0.05	1.577 (1.16–2.142)
Occupation = Student	−0.414	0.462	1	0.37	0.661 (0.267–1.635)
Occupation = Technical Personnel	Ref.	–	0	–	–
Monthly Income = 1500–2500	0.621	0.791	1	0.433	1.86 (0.395–8.772)
Monthly Income = 2500–5000	0.386	0.668	1	0.564	1.471 (0.397–5.447)
Monthly Income = 5000–7000	1.043	0.665	1	<0.001	1.958 (0.26–3.527)

(Continued)

TABLE 5 (Continued)

Parameter	Estimate (B)	S.E.	df	p	OR (95% CI)
Monthly Income = 7000–10000	1.617	0.677	1	<0.001	2.853 (0.491–6.985)
Monthly Income = 10000–15000	Ref.	–	0	–	–
4-Valent Vaccine					
Intercept	1.964	0.711	1	<0.05	–
Age group = 9–19	−22.994	0	1		1.03E-10
Age group = 20–29	0.792	0.148	1	<0.001	2.207 (1.651–2.95)
Age group = 30–39	0.915	0.061	1	<0.001	2.497 (2.215–2.816)
Age group = 40–50	Ref.	–	0	–	–
Ethnic Group = Han	1.02	0.275	1	<0.001	2.774 (1.618–4.754)
Ethnic Group = Non-Han	Ref.	–	0	–	–
Residence = Urban	0.413	0.337	1	0.22	1.512 (0.781–2.927)
Residence = Rural	Ref.	–	0	–	–
Occupation = Freelancing	−0.307	0.162	1	0.058	0.736 (0.536–1.011)
Occupation = Homemaker	−0.181	0.093	1	0.05	0.834 (0.696–1.0)
Occupation = Intensive Labor Personnel	0.079	0.116	1	0.497	1.082 (0.861–1.36)
Occupation = Personnel Ensuring Basic Social Service	0.201	0.114	1	0.078	1.222 (0.978–1.528)
Occupation = Service Personnel	0.097	0.115	1	0.399	1.102 (0.879–1.38)
Occupation = State-Owned Enterprise Personnel	0.337	0.124	1	<0.05	1.401 (1.099–1.785)
Occupation = Student	−1.43	0.459	1	<0.05	0.239 (0.097–0.589)
Occupation = Technical Personnel	Ref.	–	0	–	–
Monthly Income = 1500–2500	−1.781	0.722	1	<0.05	0.168 (0.041–0.694)
Monthly Income = 2500–5000	−2.06	0.592	1	<0.05	0.127 (0.04–0.407)
Monthly Income = 5000–7000	−2.436	0.589	1	<0.001	0.087 (0.028–0.278)
Monthly Income = 7000–10000	−1.644	0.599	1	<0.05	0.193 (0.06–0.625)
Monthly Income = 10000–15000	Ref.	–	0	–	–

OR (Odds Ratio) measures the association between exposure and outcome. The 95% CI shows the range within which the true Odds Ratio is likely to fall with 95% confidence.

that urban populations, advantaged by superior healthcare infrastructure and enhanced access to information, demonstrated elevated vaccination rates—an observation corroborated by research conducted in highly developed economies such as the United States, characterized by its substantial GDP (29, 30). In contrast, rural populations and ethnic minorities face considerable challenges, including limited access to healthcare resources, economic constraints, and lower levels of health literacy. These barriers have contributed to lower vaccination rates and a preference for the domestic bivalent vaccine (31). Moreover, cultural factors, such as language barriers and a reliance on traditional medicine, might further exacerbate these disparities (32). Ethnic minority communities, particularly those in remote areas, often face additional challenges, including skepticism toward medical interventions and a lack of familiarity with vaccination programs, all of which impede vaccine uptake.

The economic stratification of vaccine type preferences unveils China's evolving health consumption paradigm. While middle-income groups exhibit rational cost–benefit calculations favoring domestic bivalent vaccines, the unexpected 28.5% 9-valent preference among lowest-income cohorts challenges conventional behavioral models. This anomaly reflects the emergence of "health investment families"—particularly student populations supported by intergenerational resource pooling (33, 34)—where aspirational health behaviors transcend current socioeconomic status. Simultaneously, social media's dual role as information conduit and status-signaling platform accelerates demand differentiation, creating vaccine market segmentation that mirrors broader consumer trends in digital China (35, 36).

Three-dose regimen attrition (24.05% non-completion) exposes critical weaknesses in immunization service design. The temporal decay in adherence correlates not merely with logistical barriers but reflects fundamental cognitive biases in risk perception—a phenomenon where immediate costs outweigh abstract future benefits (37). This behavioral economics perspective necessitates reengineering vaccination systems through commitment devices and loss-framed incentives rather than conventional awareness campaigns.

To address these challenges, a multi-dimensional intervention system is necessary. First, a tiered subsidy scheme for low-income families should be designed (38, 39), linking the out-of-pocket cost for the 9-valent vaccine to income levels, while simultaneously implementing a bundled payment system for the three-dose regimen to improve completion rates. Second, an AI-based vaccination management system should be developed, utilizing social media to send personalized reminders, particularly establishing digital health

records for the 9–26 age group (40). Furthermore, HPV vaccination should be integrated into the performance assessment system for primary healthcare, with rural doctors trained as community-level vaccine advocates (41). It is important to note that while this study's retrospective design reveals macro-epidemiological patterns, it fails to capture the influence of micro-level mechanisms such as cultural taboos and doctor-patient interactions. Future research should use mixed-methods approaches to deconstruct the role of intersecting social identities, such as ethnicity and occupation, in shaping vaccination behaviors.

5 Conclusion

China's HPV vaccination landscape in Tianjin reflects broader socio-economic inequalities across the country. By addressing age-related disparities, bridging the urban–rural divide, and implementing occupation-specific strategies, policymakers can transform cervical cancer prevention from a privilege into a universal safeguard. These efforts would not only promote health equity but also position China as a global leader in overcoming vaccine hesitancy—a critical challenge in an era marked by evolving pathogens and fragmented trust.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by Medical Ethics Review Committee of Nankai University. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because in consideration of the retrospective design of the study, the requirement for informed consent was ethically waived, and the data gathered was exclusively utilized for research endeavors.

Author contributions

JX: Conceptualization, Data curation, Methodology, Software, Visualization, Writing – original draft, Writing – review & editing. XS: Funding acquisition, Investigation, Supervision, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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