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LETTER

Human papillomavirus vaccination willingness under resource inequities: momentary intervention effects of an educational video

Yuxi Liu[1,*], Rujing Shi[2*], Mengmeng Jia[3], Luodan Suo[4,5,6], Wenxuan Li[7], Luzhao Feng[1], Juan Li[4,5,6]

[1]School of Population Medicine and Public Health, Chinese Academy of Medical Sciences & Peking Union Medical College, Key Laboratory of Pathogen Infection Prevention and Control (Peking Union Medical College), Ministry of Education, State Key Laboratory of Respiratory Health and Multimorbidity; Public Health Emergency Management Innovation Center, Beijing 100730, China; [2]Department of Programmed Immunization, Haidian District Center for Diseases Control and Prevention, Beijing, China; [3]National Institute of Pathogen Biology, Chinese Academy of Medical Sciences & Peking Union Medical College, Beijing 102629, China; [4]Beijing Key Laboratory of Surveillance, Early Warning and Pathogen Research on Emerging Infectious Diseases, Beijing Center for Disease Prevention and Control, Beijing 100013, China; [5]Beijing Research Center for Respiratory Infectious Diseases, Beijing 100013, China; [6]School of Public Health, Capital Medical University, Beijing 100069, China; [7]Department of Epidemiology and Biostatistics, Key Laboratory of Molecular Cancer Epidemiology, Key Laboratory of Prevention and Control of Human Major Diseases, Ministry of Education, National Clinical Research Center for Cancer, Tianjin Medical University Cancer Institute and Hospital, Tianjin Medical University, Tianjin 300060, China

In 2022, cervical cancer accounted for approximately 662,301 new cases worldwide, representing 6.9% of all cancers diagnosed in women. Furthermore, it was the fourth leading cause of cancer-related deaths among women[1]. In China, human papillomavirus (HPV) vaccination is not included in the National Immunization Program, thus creating marked urban–rural disparities: only 5.7% of rural children are vaccinated[2]. Local publicly funded initiatives have increased vaccination uptake in some cities (e.g., Shenzhen pilot; Jinan first-dose coverage > 90% among eligible girls)[3,4]. Between 2017 and 2022, first-dose HPV vaccination among females 9–45 years of age rose from 0.01% to 10.15%, but remained far below the World Health Organization (WHO)'s 2030 target of 90% among 15-year-old girls[5,6]. Beijing's 2023–2030 action plan prioritizes 9–14-year cohort and provides free voluntary vaccination for first-year female students, alongside targets to strengthen screening and treatment[7]. To decrease hesitancy, the WHO's behavioural and social drivers (BeSD) framework guides identification of behavioral and social drivers, and supports brief, timely interventions[8]. Video- and Short Message Service (SMS)-based prompts have been demonstrated to improve vaccine knowledge, attitudes, and uptake, thus supporting momentary educational approaches in resource-limited settings[9,10]. For a single-event vaccination behavior such as HPV vaccination, incorporating acceptance determinants at the design stage might increase efficiency and cost-effectiveness.

This study used a quasi-experimental pre-post within-subjects design embedded in a multi-university survey, integrating an intention assessment with a brief educational video to analyze its effects on university students' willingness to receive the HPV vaccine (**Figure S1**). The study was implemented across 23 universities in Beijing (from January 10 to February 10 of 2025) and yielded 6,244 valid questionnaires. Identical items on HPV knowledge, attitudes, and willingness were administered immediately before and after a 5-min educational video. We described respondent characteristics, vaccination status, and willingness, and examined heterogeneity and determinants aligned with BeSD domains. Pre-post changes in binary outcomes were assessed with the McNemar test, and changes in multicategory outcomes were assessed with the Stuart–Maxwell test. Associations between explanatory factors and

*These authors contributed equally to this work.
Correspondence to: Luzhao Feng and Juan Li
E-mail: fengluzhao@cams.cn and lijuan@bjcdc.org
ORCID ID: https://orcid.org/0000-0002-5206-5995 and https://orcid.org/0000-0001-6096-3886
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Table 1 Demographic characteristics of the university students by vaccination status and vaccine hesitancy level

Variable *n* (%)	Overall 6,244	Vaccinated 1,080 (17.30)	Not vaccinated 5,164 (82.62)		
			Ready for vaccination 2,089 (40.46)	Willing but want to wait 1,967 (38.10)	Unwilling or hesitant to vaccinate 1,108 (21.44)
Sex					
Male	2,658	106 (3.99)	661 (25.90)	987 (38.68)	904 (35.42)
Female	3,586	974 (27.16)	1,428 (54.67)	980 (37.52)	204 (7.81)
Age, years (SD)	18.95 (1.82)	19.52 (2.24)	18.69 (1.62)	18.83 (1.65)	19.14 (1.90)
Father's education level					
Middle school or below	2,008	223 (11.11)	774 (43.39)	649 (36.38)	361 (20.24)
High school/technical school	1,470	247 (16.80)	523 (42.76)	458 (37.45)	242 (19.79)
Bachelor's degree/associate's degree	2,370	505 (21.31)	684 (36.68)	765 (41.02)	416 (22.31)
Master's degree or above	396	105 (26.45)	108 (36.99)	95 (32.53)	89 (30.48)
Mother's education level					
Middle school or below	2,428	251 (10.34)	943 (43.32)	799 (36.70)	435 (19.98)
High school/technical school	1,541	291 (18.88)	494 (39.52)	489 (39.12)	267 (21.36)
Bachelor's degree/associate's degree	2,043	490 (23.98)	590 (37.99)	613 (39.47)	350 (22.54)
Master's degree or above	232	48 (20.69)	62 (33.70)	66 (35.87)	56 (30.43)
Place of origin					
Beijing	616	177 (28.73)	116 (26.42)	182 (41.46)	141 (32.12)
Cities outside Beijing	3,771	705 (18.70)	1,263 (41.19)	1,166 (38.03)	637 (20.78)
Rural areas	1,857	198 (10.66)	710 (42.80)	619 (37.31)	330 (19.89)
Monthly living expenses (CNY)					
≤ 1,000	494	47 (9.51)	160 (35.79)	159 (35.37)	128 (28.64)
1,001–2,000	3,529	436 (12.35)	1,235 (39.93)	1,202 (38.86)	656 (21.21)
2,001–3,000	1,753	443 (25.27)	555 (42.37)	501 (38.24)	254 (19.39)
≥ 3000	468	154 (32.91)	139 (44.27)	105 (33.44)	70 (22.29)
Sexual history					
Sexually active	426	119 (27.93)	136 (44.30)	107 (34.85)	64 (20.85)
Not sexually active	5,463	903 (16.50)	1,851 (40.50)	1,756 (38.42)	963 (21.07)
Prefer not to disclose	355	58 (16.34)	102 (34.34)	104 (35.02)	91 (30.64)
HPV infection history					
Infected	139	48 (34.53)	30 (32.97)	44 (48.35)	17 (18.68)
Not infected	5,751	996 (17.32)	1,937 (40.74)	1,808 (38.02)	1,010 (21.24)
Unknown	354	36 (10.17)	122 (38.36)	115 (36.16)	81 (25.47)
Recommendation from healthcare professionals for HPV vaccination					
Yes	1,665	628 (37.72)	629 (60.66)	310 (29.89)	98 (9.45)
No	3,632	355 (9.77)	1,139 (34.76)	1,407 (42.94)	731 (22.31)
Unknown	947	97 (10.24)	321 (37.76)	250 (29.41)	279 (32.82)

Table 1 Continued

Variable *n* (%)	Overall 6,244	Vaccinated 1,080 (17.30)	Not vaccinated 5,164 (82.62)		
			Ready for vaccination 2,089 (40.46)	Willing but want to wait 1,967 (38.10)	Unwilling or hesitant to vaccinate 1,108 (21.44)
Perception of vaccine accessibility					
Agree	2,500	837 (33.48)	860 (51.71)	584 (35.12)	219 (13.17)
Disagree	3,744	243 (6.49)	1,229 (35.11)	1,382 (39.49)	889 (25.40)

*Percentage willingness to vaccinate is based on the unvaccinated population. SD, standard deviation; CNY, chinese yuan renminbi.

vaccination willingness were analyzed with logistic regression. A two-sided *P*-value < 0.05 was considered statistically significant. No external control group was included; the outcomes captured immediate within-person change after the single-exposure video. The study was approved by the Medical Ethics Committee of the Beijing Center for Disease Prevention and Control, Beijing, China (Approval No. BJCDC2025011). All participants provided written informed consent.

Respondent characteristics

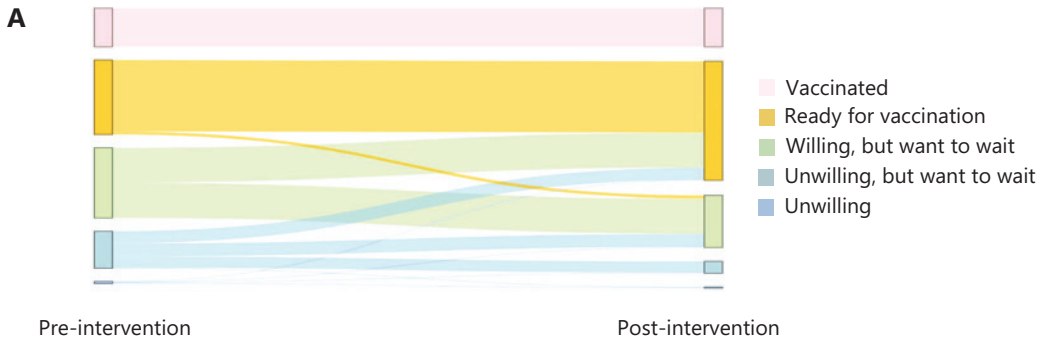
A total of 6,244 valid questionnaires were collected (**Table 1**), the average participant age was 18.95 ± 1.82 years. Rural residents accounted for 29.74% of participants, among whom 198 (10.66%) had received the HPV vaccine; this percentage was lower than that among students from Beijing (28.73%) and other urban areas (18.70%). Among female respondents, 974 (27.16%) had been vaccinated (average age 19.52 years). Students whose parents had higher educational qualifications had relatively higher vaccination rates. Respondents with higher monthly living expenses exhibited higher vaccination rates; among those with monthly living expenses ≥ 3,000 CNY, 154 (32.91%) had received the HPV vaccine. Among vaccinated participants, 79.72% had received the nonavalent vaccine (**Table S1**); 84.35% reported reminders for subsequent doses. The mean service satisfaction score was 4.44 (SD = 0.62) on a 0–5 scale.

Heterogeneity in vaccination willingness

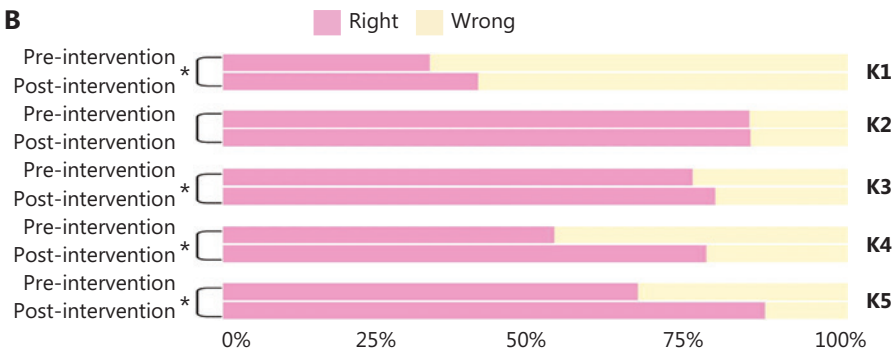
Among participants not yet vaccinated, vaccination willingness was significantly associated with sex, age, place of origin, monthly living expenses, and sexual history (**Figure S2**). Compared with respondents willing to vaccinate immediately, those who were hesitant or unwilling had distinct characteristics: female sex was associated with markedly lower odds of hesitancy (OR = 0.10, 95% CI: 0.08–0.12, $P < 0.01$), older age was positively associated with hesitancy or refusal (OR = 1.14, 95% CI: 1.08–1.12, $P < 0.01$). Rural-origin respondents were associated with lower likelihood of hesitancy or refusal than urban origin (OR = 0.51, 95% CI: 0.35–0.74, $P < 0.01$). Regarding sexual history, participants without a sexual history (OR = 2.75, 95% CI: 1.91–3.99, $P < 0.01$) or those who were unwilling to disclose their sexual histories (OR = 2.55, 95% CI: 1.60–4.07, $P < 0.01$) had elevated likelihood of hesitation or refusal. Among respondents indicating that they were "willing to vaccinate but prefer to wait," similar associations with female sex (OR = 0.44, 95% CI: 0.39–0.50, $P < 0.01$) and not being sexually active (OR = 1.78, 95% CI: 1.33–2.39, $P < 0.01$) were observed and remained significant. Rural (OR = 0.58, 95% CI: 0.44–0.78, $P < 0.01$) or other-city origin respondents (OR = 0.56, 95% CI: 0.43–0.72, $P < 0.01$), compared with Beijing origin, were associated with greater inclination to vaccinate immediately.

Determinants of vaccination willingness

We compared unvaccinated individuals—grouped by their willingness to vaccinate—with vaccinated individuals to analyze differences in BeSD-aligned domains. (**Table S2**). A decline in trust was associated with a significantly decreased likelihood of willingness to vaccinate (OR = 1.26, 95% CI: 1.05–1.15, $P = 0.01$). Among individuals who were hesitant or unwilling to be vaccinated, individuals with vaccine safety concerns were more likely to exhibit a negative attitude than those who did not (OR = 2.30, 95% CI: 1.62–3.29, $P < 0.01$). Social processes were also associated with attitudes: respondents who did not receive vaccination recommendations from healthcare professionals were



n (%)	Pre-intervention (*n* = 5,164)	Post-intervention (*n* = 5,164)
Vaccinated	1,080 (17.38)	1,080 (17.38)
Ready for vaccination	2,092 (33.50)	3,337 (53.44)
Willing, but want to wait	1,964 (31.45)	1,457 (23.33)
Unwilling, but want to wait	1,048 (16.78)	338 (5.41)
Unwilling	60 (0.96)	31 (0.51)

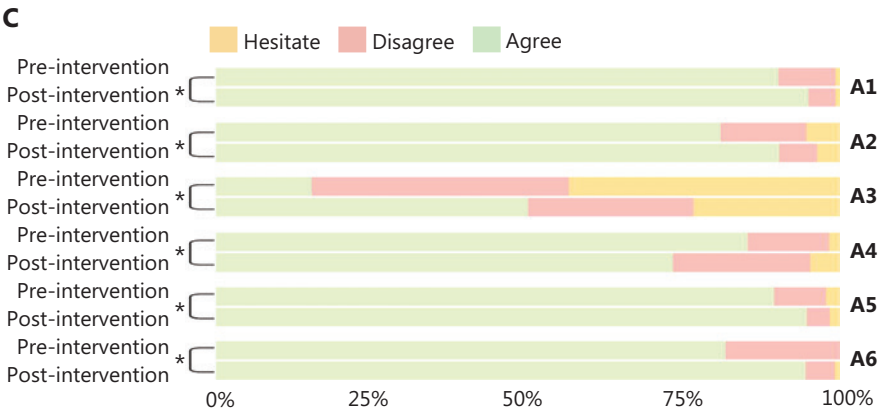


K1: HPV infection does not cause AIDS.
K2: The main mode of transmission of HPV is sexual transmission.
K3: The optimal time to receive the HPV vaccine is before the first sexual activity.
K4: Both men and women need to receive the HPV vaccine.
K5: Women who have been vaccinated for HPV still need to undergo cervical screening.

Right (*n*)	Pre-intervention	Post-intervention	*P*
K1: HPV infection does not cause AIDS.	2,041	2,525	<0.01
K2: The main mode of transmission of HPV is sexual transmission.	5,257	5,296	0.89
K3: The optimal time to receive the HPV vaccine is before the first sexual activity.	4,676	4,888	<0.01
K4: Both men and women need to receive the HPV vaccine.	3,335	4,810	<0.01
K5: Women who have been vaccinated for HPV still need to undergo cervical screening.	4,221	5,410	<0.01

Figure 1 Continued

more likely to adopt negative attitudes than the counterparts who had received such advice (OR = 1.94, 95% CI: 1.65–2.30, $P < 0.01$). Peer influence reinforced these trends: lower peer vaccination rates was associated with lower likelihood of vaccination (OR = 2.18, 95% CI: 1.86–2.58, $P < 0.01$). Family support played a crucial role: weaker family support was associated with significantly lower likelihood of vaccination, particularly among those who were hesitant or unwilling to be vaccinated (OR = 6.38, 95% CI: 5.20–7.89, $P < 0.01$). Practical issues also played key roles: low accessibility was associated



A1: I am confident in the efficacy of the HPV vaccine.
A2: I would get vaccinated if healthcare services provide the HPV vaccine free of charge.
A3: I believe I might be at risk of contracting HPV.
A4: I think contracting HPV is serious.
A5: I would get the HPV vaccine if recommended by the government.
A6: I believe the HPV vaccine is safe.

Agree (*n*)	Pre-intervention	Post-intervention	*P*
A1: I am confident in the efficacy of the HPV vaccine.	5,627	5,909	<0.01
A2: I would get vaccinated if healthcare services provide the HPV vaccine free of charge.	5,007	5,604	<0.01
A3: I believe I might be at risk of contracting HPV.	984	3,147	<0.01
A4: I think contracting HPV is serious.	5,303	4,559	<0.01
A5: I would get the HPV vaccine if recommended by the government.	5,075	5,850	<0.01
A6: I believe the HPV vaccine is safe.	5,537	5,847	<0.01

Figure 1 Changes in knowledge, attitudes, and willingness toward HPV vaccination. Changes in HPV vaccination willingness before and after the intervention (A). Changes in HPV-related knowledge levels before and after the intervention (B). Changes in attitudes toward HPV and the HPV vaccine before and after the intervention (C). This figure illustrates the changes in HPV vaccination willingness, knowledge, and attitudes after a 5-min educational video intervention. Initially, participants who were not vaccinated (n = 5,164) were categorized into the following 4 groups according to their willingness to receive the HPV vaccine: ready for vaccination; willing but want to wait; unwilling but want to wait; and unwilling. Additionally, knowledge and attitudes were evaluated with 5 and 6 questions, respectively. After the intervention, participants showed notable improvements in both HPV-associated knowledge and attitudes. *Results with statistical significance. AIDS, acquired immunodeficiency syndrome; HPV, human papillomavirus.

with significantly more pronounced hesitancy and refusal (OR = 5.22, 95% CI: 3.91–7.00, $P < 0.01$), and high out-of-pocket vaccination costs were negatively associated with willingness to vaccinate (OR = 1.99, 95% CI: 1.62–2.45, $P < 0.01$).

Post-intervention changes

The willingness to be vaccinated increased among unvaccinated respondents after they had watched an educational video on HPV-related knowledge (**Figure 1A**). The proportion of respondents willing to vaccinate immediately increased from 33.50% to 53.44%, whereas that of participants who were entirely unwilling to vaccinate decreased from 0.96% to 0.51%. The intervention promoted the dissemination of HPV-related knowledge (**Figure 1B**): comprehensive HPV knowledge increased from 32.69% to 40.44% ($P < 0.01$); knowledge of HPV vaccination timing increased from 74.88% to 78.28% ($P < 0.01$); recognition of sex-inclusive vaccination increased from 53.41% to 77.03% ($P < 0.01$); and awareness that screening remains necessary after vaccination increased from 67.60% to 86.64% ($P < 0.01$). The intervention also improved attitudes toward HPV and HPV vaccination (**Figure 1C**):

among non-vaccinated individuals, HPV risk perception increased from 15.76% to 50.40% ($P < 0.01$), and vaccine acceptance increased from 81.28% to 93.69% ($P < 0.01$).

Objective constraints and enablers of change

Objective factors significantly influenced changes in vaccination willingness after the intervention (**Table S3**). Participants who remained unwilling to vaccinate exhibited significantly lower knowledge acquisition than those whose willingness improved (OR = 0.86, 95% CI: 0.80–0.92, $P < 0.01$). Participants whose parents supported HPV vaccination showed a marked increase in vaccination willingness (OR = 0.32, 95% CI: 0.14–0.65, $P < 0.01$). Vaccine affordability emerged as a key factor: compared with individuals who transitioned from unwillingness to willingness, those who perceived HPV vaccination costs as scarcely affordable (OR = 1.68, 95% CI: 1.13–2.54, $P = 0.01$) or unaffordable (OR = 1.79, 95% CI: 1.19–2.73, $P < 0.01$) were more likely to remain hesitant or unwilling.

Integrating intention assessment with a brief educational-video momentary intervention produced immediate and measurable improvements in HPV-related knowledge, attitudes, and willingness in a large university sample. However, the study was based on convenience sampling among universities in Beijing, thus potentially limiting the generalizability of the findings. In addition, clustering by university was not adjusted, and the subgroup analyses were exploratory in nature. These issues should be further addressed in future studies with larger and more representative populations. The profile of willingness was shaped by social processes, including healthcare-professional recommendations, peer vaccination uptake, family support, as well as by practical constraints, including accessibility and affordability. Our results indicated that an educational video alone is insufficient for subgroups facing limited access or high out-of-pocket burden. Implementation should therefore pair momentary education with one-click appointment links, campus or near-campus sessions, evening/weekend clinics, automated reminders for series completion, and providing targeted subsidies when affordability is a barrier. Brief provider-recommendation scripts and family-engagement messages can strengthen social cues. Such integration is feasible in university settings and resource-limited contexts, and may accelerate equitable HPV vaccination and cervical cancer prevention.

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Conflict of interest statement

No potential conflicts of interest are disclosed.

Author contributions

Conceived and designed the analysis: Yuxi Liu, Luzhao Feng, Juan Li.
Collected the data: Rujing Shi, Mengmeng Jia.
Performed the analysis: Wenxuan Li, Luodan Suo.
Wrote the paper: Yuxi Liu.

Data availability statement

The data generated in this study are available upon request from the corresponding author.

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