



Digital Health Literacy and Parental Willingness for School-Based Human Papillomavirus Vaccination: The Importance of Online Information Searching Skill

Putri Bungsu Machmud¹✉, Jessica Veronica¹, Erni Astutik^{2,3}

¹Department of Epidemiology, Faculty of Public Health, Universitas Indonesia, Depok, Jawa Barat, Indonesia

²Department of Epidemiology, Biostatistics, Population Studies, and Health Promotion, Faculty of Public Health, Universitas Airlangga, Surabaya, East Java, Indonesia

³Faculty of Medicine and Health, The University of Sydney, Australia

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Abstract

Human Papillomavirus (HPV) vaccination is a highly effective primary prevention measure, with over 90% efficacy in preventing cervical cancer. This cross-sectional study examines the relationship between parental health literacy and willingness to accept school-based HPV vaccination in Depok City, Indonesia. Data were collected via an online self-administered questionnaire completed by 208 parents. Despite a high overall willingness rate (88.9%), significant gaps remain between general vaccine awareness and detailed operational knowledge regarding dosage and timing. Using a cross-sectional design and multivariable logistic regression, the research identifies that insufficient information exposure is the primary barrier to vaccine acceptance (AOR: 0.06; 95%CI: 0.02 – 0.22). Notably, digital health literacy, specifically proficient online information-searching skills, emerged as a critical enabler of vaccination intent. Conversely, lower skills in self-generated digital content were associated with higher willingness, suggesting a correlation between passive digital engagement and program acceptance. These findings indicate that the success of the School Children's Immunization Month (BIAS) depends on transitioning from one-way administrative announcements to interactive, literacy-based communication strategies. Strengthening parental digital competencies and fostering structured school-based dialogues are essential to bridging the knowledge-action gap. Future research should employ longitudinal designs to evaluate the long-term impact of digital literacy interventions on actual vaccine uptake across diverse Indonesian contexts.

INTRODUCTION

Vaccination stands as a cornerstone of primary prevention for numerous Vaccine-Preventable Diseases (VPDs), notably against human papillomavirus (HPV) infection, with evidence indicating more than 90 % efficacy in preventing cervical cancer (Ellingson et al., 2023; Markowitz et al., 2020). This high efficacy is robustly demonstrated by vaccines like the quadrivalent

HPV vaccine, which provides durable, long-term protection (Maldonado et al., 2022; Setiawan et al., 2024). Research confirms its sustained effectiveness and immunogenicity, forming a strong scientific basis for immunization programs, including school-based vaccination, to achieve high population coverage and reduce the future burden of HPV-related cancers (Bai et al., 2024; Davies et al., 2021; Hou et al., 2025; Teixeira et

✉ Correspondence Address:
E-mail: putri.bungsu10@ui.ac.id



al., 2021; Zhao et al., 2025).

Global HPV vaccination coverage remains suboptimal, with many countries, including Indonesia, struggling to meet WHO targets despite implementing national programs. In Greece, early initiation rates are below 10%, and series completion among girls is only 52.5% (Doulou et al., 2026), while Japan continues to recover from a historic collapse in coverage (Miyagi, 2024). New Zealand demonstrates the efficacy of school-based delivery (Cosgrove et al., 2025), yet even its successful model reveals coverage gaps between regions. Indonesia exemplifies these systemic challenges, where with only 13 of 34 provinces reaching its 90% target for schoolgirls and national coverage stalled below 75% (Risabni Fardaniah, 2025). Across these diverse contexts, common barriers persist inadequate funding, socio-cultural hesitancy, logistical hurdles, and pervasive misinformation (Universitas Muhammadiyah Yogyakarta, 2025). These intersecting factors consistently undermine vaccination campaigns, highlighting that without tailored, well-resourced, and literacy-focused interventions, the global goal of eliminating cervical cancer will remain out of reach.

A primary barrier to achieving high HPV vaccination coverage is parental refusal, a phenomenon often rooted in insufficient knowledge and persistent misconceptions regarding both HPV risks and vaccine benefits (Abdullahi et al., 2020). Research demonstrates that while parents may appreciate the convenience of school-based programs, their limited understanding of the vaccine's full protective scope, including efficacy for males and prevention beyond cervical cancer, can erode confidence and impede vaccination decisions (Davies et al., 2021; Dubé et al., 2019). This challenge is compounded by a critical knowledge-action gap, as evidenced in Beijing, where 56.4% parental awareness contrasted sharply with only a 13.7% vaccination rate among eligible daughters, underscoring that passive information dissemination is inadequate without deeper comprehension and support to navigate practical barriers (Zhao et al., 2025).

Central to addressing this gap is health literacy, a critical determinant that directly shapes how individuals process health information and form vaccination intentions. Higher health literacy, particularly the interactive-critical dimension involving information evaluation and informed decision-making, is strongly associated with greater vaccination willingness (Li et al., 2025). In contrast, basic awareness alone is insufficient and can leave individuals, especially those with lower

literacy, vulnerable to misconceptions and hesitancy due to gaps in understanding vaccine safety and efficacy (Kricorian et al., 2022; Ladomenou et al., 2026). Therefore, effective public health strategies must move beyond simply providing facts. They must prioritize clear, accessible, and strategically designed communication that actively builds critical health competencies (Li et al., 2025). By doing so, such initiatives can empower parents, transform knowledge into confident decision-making, and ultimately bridge the persistent divide between awareness and actual vaccine uptake.

However, to develop effective communication interventions in the digital era, the prevailing approach to health literacy itself requires critical re-evaluation. Many studies assessing health literacy continue to rely on manual and conventional methodologies, which often fail to fully capture an individual's capacity to navigate today's health information environment, predominantly shaped by digital platforms (Gao et al., 2024; Kricorian et al., 2022; Ladomenou et al., 2026; Li et al., 2025). The ability to search for, evaluate the credibility of online sources, and apply health information found on the internet, collectively known as digital health literacy, constitutes a crucial yet largely under-integrated dimension in existing measurement tools and interventions. This gap is particularly consequential given that the flow of misinformation, a primary barrier to vaccination, predominantly originates and proliferates through digital channels.

This methodological and contextual gap is especially pronounced in specific urban settings where digital access outpaces digital competence. Depok City, a rapidly urbanizing satellite of Jakarta, was deliberately selected as the study site for several strategic reasons. First, despite its urban characteristics and proximity to the national capital, HPV vaccination coverage in Depok remains suboptimal. Data from the local health office indicates that first-dose coverage reached only 89.9% and second-dose coverage 81.9% in 2024 (Aji Hendro, 2025; Warta Depok, 2025), markedly below the West Java provincial target of 95% (Aziz Kurmala, 2024). This coverage deficit cannot be attributed solely to vaccine supply or logistical constraints, as the National School Children's Immunization Month (BIAS) operates uniformly across the province. Second, emerging evidence suggests that Depok exhibits a distinct form of digital health literacy and the capacity to effectively utilize online health information (Fathurrahman et al., 2024). Studies in similar urban Indonesian contexts indicate that while basic

navigation skills may be adequate, critical evaluation and application of health information remain challenging. Third, health-related decisions in Depok's communities are deeply embedded within strong relational and communal frameworks, where trust in teachers, family members, and community leaders often competes with or overrides information obtained through impersonal digital channels (Athifa et al., 2025a). These intersecting conditions, a measurable coverage shortfall against provincial benchmarks, coupled with a complex interplay between digital exposure and traditional decision-making, establish Depok as an ideal setting to examine how digital health literacy shapes parental acceptance of school-based vaccination.

Consequently, this study aimed to examine the association between parental health literacy, encompassing both general and digital health literacy, and their willingness to have their school-aged children receive the HPV vaccine, while also exploring the influence of other related factors.

METHOD

Study Design and Setting

A cross-sectional study was conducted to examine factors associated with HPV vaccination willingness. The study was implemented in elementary school across Depok City, Indonesia, with data collection occurring between May and June 2024.

Sampling and Recruitment

The sampling frame consisted of all accredited elementary schools obtained from the Ministry of Education's Dapodik database (206 public and 103 private). School located beyond a 45-minute travel radius from the research base or public transit hubs located were excluded, resulting 181 public and 175 private eligible schools. From this pool, seven public and seven private school were selected using cluster sampling.

The minimum required sample size was calculated using the formula for cross-sectional studies with cluster sampling: $n = [Z^2 \times p(1-p) \times DE] / d^2$, where $Z=1.96$ for 95% confidence level, $p=0.85$ (estimated willingness from a pilot study in a similar population), $d=0.05$ (margin of error), and $DE=1.5$ (design effect for cluster sampling). This yielded a target of 276 participants. Accounting for an anticipated 20% non-response rate, we invited 580 parents.

The study population consisted of parents of fifth-grade girls attending elementary school in Depok City, West Java, in 2024. A total of 580 parents were initially invited to participate

and were sent the questionnaire link. The analytical sample included eligible participants from the recruited schools who completed the survey. Participants were excluded if they submitted inconsistent responses and did not reply to verification requests, or if they left the willingness to vaccinate question blank and did not respond to follow-up communications.

Data were collected using a self-administered digital questionnaire (Google Forms) distributed to parents/guardians through their respective homeroom teachers. Respondents were given one week to complete the survey. The first page of the questionnaire contained a full explanation of the study's purpose, participants' rights, and the informed consent statement. Electronic consent was obtained by requiring participants to click an "agree" button before proceeding to the main questions. Parents/guardians who experienced technical difficulties or confusion while completing the questionnaire were assisted by the homeroom teacher or the researcher via remote communication (such as telephone or instant messaging).

Variables

Parental acceptance of the school-administered HPV vaccine served as the primary outcome measure. Acceptance was operationalized using a single-item question: "Are you willing to accept the HPV vaccine provided at school for your daughter?" Respondents selected from a five-point Likert scale ranging from very willing to very unwilling. For subsequent analysis, this variable was collapsed into a binary outcome: willingness (very willing or willing) versus unwillingness (unsure, unwilling, or very willing). This dichotomization was chosen for two primary reasons. First, from a public health program perspective, the actionable distinction is between acceptance (willing) and non-acceptance (including hesitancy and refusal). Second, the small number of respondents in the "unsure" ($n=12$), "unwilling" ($n=8$), and "very unwilling" ($n=3$) categories precluded stable ordinal analysis with four levels. To ensure robustness, we conducted a sensitivity analysis using ordinal logistic regression on the original 5-point scale (see Supplemental Table S1), which confirmed the consistency of our main findings.

The analysis incorporated an extensive set explanatory variables encompassing multiple theoretical domains. Sociodemographic factors included age categorization (<30 , $30-90$, ≥ 40 years), sex (male/female), education level (primary, secondary, higher education), current

occupational status (employed/unemployed), personal history of cervical cancer, and the administrative type of the child's educational institution (public/private).

Parental knowledge regarding HPV infection, cervical cancer, and HPV immunization was assessed using a self-administered questionnaire. Each item in the instrument was scored dichotomously, with correct responses assigned a value of 2 and incorrect responses assigned 0. The total knowledge score was calculated using the formula: $(\text{total score} / 16) \times 100\%$. Based on the final percentage, knowledge was categorized into two levels: poor for scores $<60\%$ and good for scores $\geq 60\%$.

Parental exposure to vaccine-related information, including vaccine types, benefits, and side effects, obtained from service providers (teachers or health workers) was assessed using a self-administered questionnaire. Based on responses to a series of key items, information exposure was categorized into three levels: 1) No exposure (score 0), if parents reported not receiving any information; 2) Inadequate exposure (score 1), if parents acknowledged receiving information from a teacher or health worker but considered it insufficient; and 3) Adequate exposure (score 2), if parents received information from these sources and deemed it sufficient. These numerical scores were subsequently used in quantitative analyses.

We also considered variables related to health competency measures included a composite score for general health literacy and multidimensional index assessing digital health literacy proficiencies. The health literacy assessment in this study utilizes a dual-instrument approach, employing the Digital Health Literacy Instrument (DHLI) (Van Der Vaart & Drossaert, 2017) and the HLS-19 Q-12 (McCaskill et al., 2024) to evaluate multi-dimensional health-related competencies. The DHLI methodology utilizes 21 self-report items across seven distinct digital skill domains, measured on a 4-point Likert scale ranging from "very easy" to "very difficult" or "never" to "very often". Data processing involves reversed scoring of specific items to ensure that a higher aggregate value consistently reflects superior digital literacy. Consequently, respondents are stratified into a binary classification where High Literacy is defined by mean scores exceeding 2.5, indicating a proficient capacity to navigate and evaluate digital health information, while Low Literacy is assigned to mean scores between 1.0 and 2.5, signifying significant operational or evaluative barriers.

Concurrently, general health literacy is quantified through the HLS-19 Q-12, where the final score represents the percentage of items rated as "easy" or "very easy," contingent upon a minimum 80 % completion rate. This instrument categorizes respondents into a tripartite hierarchy starting with High (Excellent), which is defined by "very easy" responses totaling at least 50 % of the items while "difficult" or "very difficult" responses remain below 8.33 %. The Fair (Sufficient) category is attained when a minimum of 10 out of 12 items (over 83.33 %) are characterized as manageable ("easy" or "very easy"). Finally, the Low category serves as a comprehensive classification encompassing "Problematic" and "Inadequate" literacy levels, with the latter specifically identified when more than half of the items are reported as "difficult" or "very difficult" and "very easy" responses constitute less than 8.33 % of the total.

Statistical Methods

Data analysis was performed using SPSS (version 20). Descriptive statistics, including frequencies and percentage, were calculated for all categorical variables. To identify factors associated with parental willingness to accept school-based HPV vaccination for their children, we conducted multivariable logistic regression. All independent variables with a plausible association to the outcome based on prior literature were first entered into univariable logistic regression models, yielding crude odds ratios (Model 1, Table 4). Subsequently, a full multivariable model including all variables was constructed to generate adjusted odds ratios (Model 2, Table 4). All odds ratios are reported with their corresponding 95% confidence intervals (CI).

Due to concerns regarding the small number of unwilling participants ($n=23$) relative to the number of predictors (events-per-variables <5), we conducted two additional analyses. First, we performed ordinal logistic regression using the original 5-point Likert scale outcome to assess whether dichotomization affected conclusions (Supplemental Table S1). Second, we constructed a reduced multivariable model including only variables with $p < 0.20$ in bivariate analysis (information exposure, knowledge, religion, and digital literacy subscales: information searching, determining relevance, self-generated content) to evaluate the stability of estimates (Supplemental Table S2). Results remained consistent across models.

Ethics Approval

Ethical approval for this study was obtained from the Research Ethics Committee of the Faculty of Public Health, University of Indonesia (Approval No. Ket-270/UN2.F10.D11/PPM.00.02/2024). All procedures adhered to the principles of the World Medical Association Declaration of Helsinki. Prior to participation, a trained data collector provided an informed consent form, explained the study's objectives, outlined participant rights and compensation, and ensured voluntary participation without coercion before commencing the interview.

RESULTS AND DISCUSSION

Sample Characteristics and Key Findings

From 580 distributed questionnaire, 275 initial responses were received (crude response rate: 47.4 %). From these, participants were excluded if they left the willingness-to-vaccinate question blank and did not respond to follow-up communications, or if they submitted inconsistent responses and failed to reply to our verification requests. Specifically, 58 participants were excluded because they left the primary outcome question or other critical items incomplete, leaving 217 eligible respondents for further quality checks. After a consistency review, an additional 9 participants were excluded due to inconsistent responses without subsequent verification. This process yielded a final analytical sample of 208 participants, representing a valid response rate of 95.9 % among eligible respondents (Figure 1). The cohort was predominantly female (92.3 %), with a median age of 39 years (IQR: 34–43). Most participants were Muslim (90.9 %), had attained a secondary level of education (58.7 %), and were employed (70.7 %). Overall willingness to accept vaccination was notably high at 88.9 %, with a small proportion (11.1 %) expressing hesitancy or refusal (Table 1).

Despite high reported information exposure about HPV vaccination (84.1 %), overall knowledge was poor (53.8 %; median score: 4, IQR: 2–6). While general awareness was high, such as knowing the vaccine is available in school (84.6%) and prevents cervical cancer (73.6%), which critical operational knowledge was lacking. Few knew the required number of doses (15.9% to 17.8%), the target age group (27.0%), and the recommended timing for vaccination (47.1%). This indicates a substantial gap between general awareness and detailed understanding (Table 2).

Table 1. Sociodemographic characteristic and Willingness to vaccinated

Variable	n (%)
Age (years old)	39 (34 - 43) *
<30	22 (10.6)
30 – 39	83 (39.9)
≥40	103 (49.5)
Sex	
Men	16 (7.7)
Women	192 (92.3)
Education level	
Primary	54 (26.0)
Secondary	122 (58.7)
Higher	32 (15.4)
Occupational status	
Unemployed	61 (29.3)
Employed	147 (70.7)
Religion	
Christian	16 (7.7)
Moslem	189 (90.9)
Others (Hindu, Budha)	3 (1.5)
History of cervical cancer	
Yes	5 (2.4)
No	203 (97.6)
Type of child's school	
Public	141 (67.8)
Private	67 (32.2)
Willingness to vaccinated	
Yes	185 (88.9)
No or not sure	23 (11.1)

*Median (IQR)

Participants' general health literacy was predominantly at a medium level (72.1%), with a mean score of 32.48 (± 5.05) (Table 3). The Digital Health Literacy Index revealed moderately high competency across all domains (mean scores: 8.05 to 8.88). The highest score was for navigation skills (8.88 ± 1.50), while the ability to generate self-content was the lowest (8.05 ± 1.51). This indicates a functional capacity to find and use digital health information, but relatively lower confidence in critical evaluation and content creation.

Table 2. Information exposure and knowledge about HPV vaccination

Variable	n (%)
Information exposure	
Sufficient	175 (84.1)
Insufficient/No information	33 (15.9)
Knowledge	
Good	96 (46.2)
Poor	112 (53.8)
Knowledge score	4 (2 – 6) *
Correct answer	
Q1: The HPV vaccine is one of the vaccines provided in schools	176 (84.6)
Q2: HPV is transmitted through sexual contact	117 (56.3)
Q3: Cervical cancer is caused by the Human Papillomavirus	131 (63.0)
Q4: The number of HPV vaccine doses administered in school	37 (17.8)
Q5: The vaccine is intended to protect children from infections caused by HPV	42 (20.2)
Q6: The HPV vaccine can protect a child from cervical cancer	153 (73.6)
Q7: The age group of individuals who require the HPV vaccine	77 (37.0)
Q8: The recommended time for vaccination (before an individual becomes sexually active)	(98 (47.1)
Q9: The number of HPV vaccine doses required to protect an individual from cervical cancer	33 (15.9)

*Median (IQR)

Table 3. Health Literacy Score and Digital Health Literacy Index

Variable	n (%)
Health Literacy Score**	32.48 ± 5.05
High	36 (17.3)
Medium	150 (72.1)
Low	22 (10.6)
Digital Health Literacy Index**	
Operational skill	8.41 ± 1.72
Information searching	8.62 ± 1.43
Evaluating reliability	8.18 ± 1.51
Determining relevance	8.47 ± 1.41
Navigation adding	8.88 ± 1.50
Self-generated content	8.05 ± 1.51

**Mean ± Std. Deviation

Predictors of Vaccination Willingness

After adjustment (Table 4 and Table 5), insufficient information exposure was the only factor significantly associated with lower odds of vaccination willingness (AOR: 0.06; 95% CI 0.02 – 0.22; $p < 0.001$). Good knowledge showed a potential trend with higher willingness (AOR: 3.01; $p = 0.052$), while non-Muslim religion showed a non-significant trend toward lower willingness (AOR: 0.23; $p = 0.053$). No other sociode-

mographic variables were significant predictors (Table 4).

Other than that, Table 5 revealed that specific digital health literacy, but not general health literacy, were associated with vaccination willingness. Low information searching skill was a strong barrier (AOR: 0.10; 95% CI: 0.02 – 0.46; $p = 0.001$), while low self-generated content skill was associated with higher odds of willingness (AOR: 5.41; 95% CI: 1.31 – 22.37; $p = 0.020$).

Table 4. Sociodemographic characteristic and Willingness to vaccinated

Variable	Willingness to vaccine (%)	Model 1				Model 2				
		OR (95% CI)	β	SE	p-value	AOR (95% CI)	β	SE	p-value	
Age (years old)										
<30	21 (11.4)	1	-	-	-	1	-	-		
30 – 39	73 (39.5)	0.06 (0.01 – 1.35)	-2.81	1.68	0.077	0.07 (0.01 – 1.36)	-2.66	1.51	0.079	
≥40	91 (49.2)	0.05 (0.01 – 1.13)	-2.99	1.59	0.059	0.06 (0.01 – 1.21)	-2.81	1.53	0.067	
Education level										
Primary	49 (26.5)	1	-	-	-	1	-	-		
Secondary	106 (57.3)	0.95 (0.21 – 4.31)	-0.05	0.77	0.944	0.87 (0.22 – 3.47)	-0.14	0.70	0.844	
Higher	30 (16.2)	3.07 (0.28 – 34.1)	1.12	1.19	0.362	2.68 (0.32 – 22.84)	0.98	1.09	0.366	
Occupational status										
Unemployed	128 (69.2)	1	-	-	-	1	-	-		
Employed	57 (30.8)	2.53 (0.59 – 10.81)	0.93	0.74	0.211	2.88 (0.76 – 11.00)	1.06	0.68	0.121	
Religion										
Moslem	170 (91.9)	1	-	-	-	1	-	-		
Others	15 (8.1)	0.22 (0.04 – 1.19)	-1.51	0.85	0.078	0.23 (0.05 – 1.02)	-1.47	0.77	0.053	
History of cervical cancer										
Yes	4 (2.2)	1	-	-	-	1	-	-		
No	181 (97.8)	0.68 (0.02 – 23.08)	-0.38	1.75	0.829	0.71 (0.02 – 22.80)	-0.34	1.79	0.847	
Type of child's school										
Public	127 (68.6)	1	-	-	-	1	-	-		
Private	58 (31.4)	0.90 (0.27 – 3.05)	-0.10	0.61	0.869	0.90 (0.27 – 3.05)	-0.10	0.62	0.869	
Information exposure										
Sufficient	162 (87.6)	1	-	-	-	1	-	-		
Insufficient/None	23 (12.4)	0.05 (0.01 – 0.21)	-2.99	0.70	<0.001	0.06 (0.02 – 0.22)	-2.81	0.61	<0.001	
Knowledge										
Poor	89 (48.1)	1	-	-	-	1	-	-		
Good	96 (51.9)	2.75 (0.88 – 8.65)	1.01	0.59	0.083	3.01 (0.99 – 9.10)	1.10	0.57	0.052	

Model 1: Full model; Model 2: Adjusted for all variables (including health literacy score and digital health literacy). Bold values indicate statistical significance at $p < 0.05$. β =regression coefficient; SE=standard error; OR=odds ratio; AOR=adjusted odds ratio; CI=confidence interval

Low skill in determining relevance showed a marginal positive association (AOR: 4.46; $p=0.059$). Operational skills, evaluating reliability navigation skills, and general health literacy level were not significant predictors.

Sensitivity analyses using ordinal logistic regression (Supplemental Table S1) and a reduced multivariable model (Supplemental Table S2) yielded results consistent with the main findings: insufficient information exposure and low infor-

mation searching skill remained the strongest predictors, while the association for self-generated content remained unstable with wide confidence intervals.

Several variables, including good knowledge ($p=0.052$), non-Muslim religion ($p=0.053$), and low skill in determining relevance ($p=0.059$), showed p -values approaching but not reaching the conventional threshold of 0.05. These findings should be interpreted as suggestive trends

Table 5. Health Literacy and Willingness to vaccinated

Variable	Willingness to vaccine (%)	Model 1				Model 2			
		OR (95% CI)	β	SE	p-value	OR (95% CI)	β	SE	p-value
Health Literacy Score									
High	32 (17.3)	1	-	-	-	1	-	-	-
Medium	134 (72.4)	0.78 (0.18 – 3.36)	-0.25	0.73	0.742	0.79 (0.19 -3.29)	-0.24	0.73	0.746
Low	19 (10.3)	0.36 (0.03 – 4.02)	-1.02	1.20	0.407	0.36 (0.03 – 3.87)	-1.02	1.24	0.398
Digital Health Literacy									
Operational skill									
High	116 (62.7)	1	-	-	-	1	-	-	-
Low	69 (37.3)	1.57 (0.29 – 8.43)	0.45	0.85	0.598	1.28 (0.27 – 6.12)	0.25	0.80	0.759
Information searching									
High	143 (77.3)	1	-	-	-	1	-	-	-
Low	42 (22.7)	0.14 (0.02 – 0.83)	-1.97	0.90	0.030	0.10 (0.02 – 0.46)	-2.30	0.77	0.003
Evaluating reliability									
High	101 (54.6)	1	-	-	-	1	-	-	-
Low	84 (45.4)	0.51 (0.13 – 1.95)	-0.67	0.67	0.323	0.50 (0.14 – 1.84)	-0.69	0.66	0.299
Determining relevance									
High	130 (70.3)	1	-	-	-	1	-	-	-
Low	55 (29.7)	6.80 (1.15 – 40.13)	1.92	0.89	0.034	4.46 (0.94 – 21.09)	1.49	0.79	0.059
Navigation adding									
High	128 (69.2)	1	-	-	-	1	-	-	-
Low	57 (30.8)	0.82 (0.24 – 2.84)	-0.20	0.64	0.758	0.83 (0.24- 2.85)	-0.19	0.63	0.765
Self-generated content									
High	99 (53.5)	1	-	-	-	1	-	-	-
Low	86 (46.5)	5.93 (1.20 – 29.24)	1.78	0.81	0.029	5.41 (1.31 – 22.37)	1.69	0.72	0.020

Model 1: Full model; Model 2: Adjusted for all variables (including sociodemographic variables). Bold values indicate statistical significance at $p < 0.05$. β =regression coefficient; SE=standard error; OR=odds ratio; AOR=adjusted odds ratio; CI=confidence interval

rather than conclusive evidence. The observed p-values may reflect limited statistical power due to the modest sample size ($n=208$) and the small number of unwilling participants ($n=23$). Therefore, while these variables warrant attention in future hypothesis-driven research, we refrain from claiming definitive associations. Readers are cautioned against overinterpreting these borderline results.

Implications for Program Strategy and Health Communication

This study determined that the most significant independent barrier to vaccine acceptance was a lack of sufficient exposure to information, emphasizing the foundational importance of basic awareness. After controlling for levels of infor-

mation exposure, the capacity to actively search for health information online surfaced as a key enabling skill. Conversely, a more passive approach to digital engagement, identified by lower rates of content creation, correlated with a greater willingness to accept vaccines. These results shift the analytical emphasis from fixed demographic attributes, such as age or education, to dynamic factors including an individual's knowledge, methods of information access, and specific digital navigation competencies. This pattern corresponds with contemporary models of health behaviour that highlight the central importance of information pathways and digital self-efficacy within the modern healthcare ecosystem.

Based on contemporary health behaviour frameworks, the implementation of school-based

vaccination programs in Indonesia, particularly the School Children's Immunization Month (BIAS), faces a fundamental challenge in the aspect of communication and education. Although the program operates through established school-based information distribution mechanisms, such as circular letters and announcements, this strategy has proven ineffective in transforming awareness into comprehensive understanding (Beavis et al., 2024). Parents may have been "exposed" to information, but the content provided often fails to address critical operational questions, such as the exact dosing schedule, detailed explanations of vaccine differences by grade level, or follow-up procedures for absent students (Athifa et al., 2025; Nasywa et al., 2025). This gap between exposure and comprehension directly contributes to low dose completion rates and high rates of vaccination delay, as reflected in coverage data that remains below targets in various regions (Athifa et al., 2025; Beavis et al., 2022). The finding by Athifa et al., which highlights insufficient information as a primary reason for parental refusal, further strengthens this analysis (Athifa et al., 2025). Consequently, the BIAS program requires a reorientation from a one-way, purely informational communication approach towards an interactive and contextual educational strategy. This shift aligns with the Health Belief Model principle, which emphasizes the need for individuals to clearly perceive the benefits and ease of a preventive action (Nasywa et al., 2025). By strengthening in-depth and dialogical educational dimensions within the program, not only can vaccination coverage be increased, but public trust in school-based immunization initiatives can also be built more sustainably.

This counter-intuitive finding, that lower digital content production skills were associated with higher willingness, carries a strategic implication for the BIAS program's communication approach. Rather than assuming that increasing parents' overall digital engagement will automatically improve vaccine acceptance, this finding suggests that passive digital consumption may actually serve as a protective factor against exposure to polarizing vaccine misinformation. Consequently, program designers should resist the urge to push parents toward active content creation or participation in unmoderated online health forums. Instead, communication strategies should prioritize the delivery of clear, consistent, and authoritative messages through trusted, low-risk digital channels, such as official school WhatsApp groups and teacher-administered announcements, spaces where parents are recipients rather

than producers of content. This approach ensures that parents who are digitally passive receive accurate information without being inadvertently drawn into algorithm-driven echo-chambers that host vaccine-critical narratives. Furthermore, these official channels should be complemented by structured offline dialogues with health workers and teachers, who remain highly trusted figures in the Indonesian context (Athifa et al., 2025). By aligning digital communication with existing patterns of passive information consumption and reinforcing it with interpersonal trust, the BIAS program can more effectively convert awareness into informed, confident vaccination decisions, particularly among parents who are less active in the digital sphere.

The Role of Digital Health Literacy and Information Ecology

Furthermore, these findings imply that the impact of information depends not only on its availability but also on parents' capacity to interpret and contextualize what they receive. In digital environments where content is heterogeneous and often uncured, fragmented or overly technical messages may increase ambiguity rather than facilitate understanding. Our findings suggest that parental decisions regarding the HPV vaccine are not made solely through rational evaluation of information but are also significantly influenced by support and advice from trusted individuals. Evidence indicates that supportive family members significantly increase parents' vaccination intentions, and that trust in health-care providers' recommendations plays a central role in shaping vaccine acceptance when parents encounter hesitancy or misinformation (Chung et al., 2017). Therefore, efforts to improve HPV vaccine uptake should shift from merely expanding informational reach towards strengthening message clarity, relevance, and practical utility for parental decision-making. The type of information encountered on social media regarding HPV vaccination can influence the decisions parents make about vaccinating their children (Wijayanti et al., 2023).

Within the context of Indonesia's school-based immunization program (BIAS), these implications are critical. The program's current communication strategy, which relies on one-way circulars and school announcements, fails to facilitate this essential process of interpretation and contextualization. The information provided is often general and administrative, leaving contextual parental questions unanswered. The absence of a structured dialogue to address these speci-

fic queries leaves parents with partial information, which in the digital environment can easily be filled by alternative narratives from unverified sources. Consequently, the BIAS program must integrate structured dialogue mechanisms, such as questions and answer sessions with health workers at schools or teacher-moderated parent forums, which can serve as trusted channels for contextualizing official information (Khalil et al., 2025). This approach aligns with evidence that trust in healthcare providers is a key determinant, and that integrating official messages with interpersonal support can significantly boost vaccination intent. Additionally, the program's digital communication materials should be specifically designed for platforms like WhatsApp or parent social media groups. These materials must feature clear, visual messaging that directly addresses common misconceptions, thereby reducing ambiguity and reinforcing the program's core message within the digital ecosystem where parents are actively engaged (Llavona-Ortiz et al., 2022).

The finding that requires particular caution is the association between lower self-generated digital content skills and higher vaccination willingness (AOR=5.41; 95 %CI: 1.31–22.37; $p=0.020$). This counter-intuitive result invites a deeper socio-cultural and theoretical explanation. One plausible mechanism is the "digital passivity" hypothesis, which draws from contemporary theories of digital information ecology. According to this perspective, parents who are less active in producing or sharing health-related content online may inadvertently occupy a less exposed position within the digital information ecosystem. Heavy digital content creators, by contrast, are often algorithmically funneled into engagement-driven loops, where sensationalized narratives, vaccine-critical content, and misinformation echo-chambers thrive (Athifa et al., 2025; Winarto et al., 2022). Parents with low content-production skills may bypass these polarized digital spaces, remaining more receptive to institutional, top-down health communication such as government circulars, school announcements, and messages from healthcare workers. This digital passivity may paradoxically reinforce compliance with the official health agenda, as they have fewer opportunities to encounter counter-narratives that challenge the authority of the BIAS program. Furthermore, in the Indonesian cultural context, health decision-making is deeply embedded within relational and communal frameworks, where trust in familiar interpersonal sources often outweighs information obtained through impersonal digital channels (Athifa et al., 2025; Winarto et al., 2022). Thus,

parents who are less engaged in digital content creation may rely more heavily on these trusted traditional networks, which are more likely to endorse government-led immunization initiatives.

However, this interpretation must be balanced against significant methodological constraints. The extremely wide confidence interval and the small number of unwilling participants ($n=23$) suggest considerable statistical imprecision. Residual confounding by trust in official sources remains a distinct alternative explanation; parents who rarely create digital content may simply have elevated baseline trust in teachers and health workers, which drives their willingness rather than their digital skill level per se. Consequently, while the digital passivity hypothesis provides a theoretically grounded explanation, it remains speculative until tested in qualitative or longitudinal studies. Future research should directly measure parental trust in vaccine information sources, quantify exposure to online echo-chambers, and employ qualitative methods to explore the decision-making pathways of digitally passive parents, thereby disentangling these overlapping mechanisms.

Toward Integrated and Trust-Centered Communication Strategies

Our findings highlight the importance of parents' ability not only to access vaccine-related information but also to comprehend, evaluate, and apply it effectively when making immunization decisions for their children. Evidence suggests that higher levels of digital health literacy and vaccine literacy are significantly associated with greater vaccine acceptance, and that the credibility of information sources play a vital role in facilitating decision-making (Ashfield et al., 2024; Geller et al., 2025). Previous studies indicate when school-based immunization programs are coordinated with general practice, it can create convenient opportunities for parents and their children to engage with healthcare providers (Zheng et al., 2021). Evidence from multiple settings shows that such integration not only enhances access but also strengthens parent-provider communication, facilitating informed discussions about vaccine benefits and safety (Zheng et al., 2021).

However, this pattern may appear to contrast with conventional assumptions in digital health behaviour theories that greater online engagement should consistently facilitate evidence-based health decisions. Evidence from prior studies suggests that the relationship between social media use and vaccination behaviour is highly

context-dependent, shaped by social norms and interpersonal influences rather than information exposure alone (Zhang et al., 2024). In the Indonesian context, health-related decision-making is often embedded within strong relational and communal frameworks, where trust is preferentially placed in familiar interpersonal sources such as family members or community figures rather than impersonal digital channels (Winarto et al., 2022). Consequently, vaccination decisions, including those concerning children, which may be shaped more by close social networks than by formal digital information, allowing interpersonal beliefs to either reinforce or hinder vaccine acceptance.

Although smartphone ownership and internet connectivity have increased rapidly in Indonesia, high digital access does not automatically lead to regular use of formal digital health services such as telemedicine. Instead, many individuals encounter health-related information through non-clinical online spaces such as social media feeds and informal networks, where credibility and completeness vary widely. Previous research shows that Indonesians frequently use social media as a health information source, yet users face challenges in assessing information trustworthiness and translating it into evidence-based decisions (Kbaier et al., 2024).

Limitation of the Study

This study acknowledges several methodological limitations. First, the cross-sectional design employed does not allow for establishing causal relationships between independent and dependent variables, as both were measured concurrently. Second, there is potential for information bias regarding children's immunization status, as data referred to vaccinations administered up to one year prior. Although the researchers selected vaccine types considered distinctive to minimize reporting errors, the risk of bias remains. Additionally, the possibility of selection bias must be considered. Some schools were excluded from the randomization process due to remote location and logistical constraints, potentially overlooking relevant characteristics or dynamics of those institutions.

Regarding sample adequacy, the study targeted a minimum sample size of 276 after accounting for the design effect, yet the obtained response was only 208 out of 580 distributed invitations. This insufficient response rate was primarily due to refusals, delayed responses, and bureaucratic hurdles from several schools, including one that withdrew during data collection. Al-

though the researchers attempted to replace the withdrawing school through re-randomization and conducted repeated follow-ups, time constraints and the complexity of administrative procedures hindered adequate recruitment of replacements. For future studies utilizing cluster random sampling within limited timeframes, it is recommended to set a recruitment target of 2–3 times the initial calculated sample size to account for potential non-response and preserve the study's statistical power.

Critically, the most consequential limitation pertains to the statistical stability of the multivariable regression model. The study achieved 208 respondents, which is 75.4 % of the target sample size of 276. A post-hoc power analysis indicated that with 23 events (unwilling participants) and $\alpha=0.05$, the study had 80 % power to detect an odds ratio of approximately 3.5 or larger. Smaller effect sizes (e.g., OR 2.0–2.5) may have been undetectable, and the wide confidence intervals for some estimates (e.g., self-generated content) reflect this imprecision. More importantly, with 23 events and 14 predictors entered into the full multivariable model, the events-per-variable (EPV) ratio was approximately 1.6, which is far below the recommended minimum of 5–10 events per predictor. This severe underpowering has direct and profound implications for the stability of the model. An EPV below the recommended threshold substantially increases the risk of overfitting, whereby the model captures random noise rather than true underlying associations in the population. Overfitting manifests in several ways: (a) regression coefficients (β) and odds ratios may be inflated in magnitude, (b) standard errors may be artificially deflated, leading to narrower confidence intervals and an inflated Type I error rate, and (c) the model's predictive performance is unlikely to replicate in external validation samples.

The implications of this statistical fragility are particularly relevant for the interpretation of our findings. While our reduced model analysis (including only variables with $p<0.20$ in bivariate analysis) yielded consistent results for the primary predictors, information exposure and information searching skills, lending them greater credibility, the estimates for variables with borderline significance and extremely wide confidence intervals require much more cautious interpretation. For example, the adjusted odds ratio for low self-generated content skill (AOR: 5.41; 95%CI: 1.31–22.37), despite reaching nominal statistical significance, spans a fivefold range. This extreme imprecision, combined with the low EPV, strongly suggests that this estimate is unstable and likely

inflated due to overfitting. Consequently, this finding should be treated as hypothesis-generating and exploratory rather than confirmatory evidence of a protective effect. Readers are urged to interpret the full model's adjusted estimates, particularly for variables with wide confidence intervals, with considerable skepticism. The stability of the overall model is compromised, and the counter-intuitive associations may reflect statistical artifacts rather than true population phenomena.

Futhermore, the DHLI instrument was developed in a Western context, and certain subscales, particularly self-generated content, may not fully capture digital health behaviors in the Indonesian cultural setting where public sharing of health opinions is less common. This may introduce measurement bias and affect the interpretation of domain-specific findings.

Given these statistical limitations, we emphasize that replication studies with larger samples, specifically designed to oversample vaccine-hesitant parents to enrich the event rate, are urgently needed before any definitive conclusions can be drawn regarding the role of self-generated digital content in vaccination decisions. Further research should also employ longitudinal design to track actual vaccine uptake and incorporate qualitative methods to explore the decision-making pathways of digitally passive parents. Despite these limitations, we believe the findings of this study offer valuable insights that can inform the development of future vaccination intervention strategies, particularly in underscoring the foundational role of information exposure and information-searching skills.

CONCLUSION

In conclusion, this study demonstrates that while parental willingness for school-based HPV vaccination in Depok City is high at 88.9 %, a critical 'knowledge-action gap' persists, particularly regarding the specific clinical details of the vaccine. The findings reveal that digital health literacy, specifically the competency to effectively search for and verify online information, is a more powerful determinant of vaccination intent than simple information exposure. One unexpected finding-lower self-generated content skills associated with higher willingness-requires particular caution; given wide confidence intervals and limited statistical power, this result should be considered hypothesis-generating rather than conclusive. Similarly, the observed trends for knowledge and religion did not reach statistical significance and warrant replication in larger studies.

This suggests that current public health strategies must evolve beyond the passive dissemination of administrative facts toward fostering critical health competencies that empower parents to navigate complex digital information environments. Consequently, the long-term success of the School Children's Immunization Month (BIAS) program, and the broader goal of cervical cancer elimination, depends on implementing interactive, literacy-based interventions that bridge the divide between general awareness and confident, informed participation. To advance this field, future researchers should move beyond cross-sectional designs to longitudinal studies that track actual vaccine uptake, while also exploring qualitative nuances of online misinformation across more diverse geographic and socioeconomic landscapes in Indonesia.

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DECLARATION OF GENERATIVE AI

This manuscript received limited assistance from an AI-based language tool (Quillbot and ChatGPT) for language refinement and grammar checking. The authors critically reviewed and finalized all content and accept full responsibility for the published work. No AI tools were used in data analysis or the interpretation of findings.

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.

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