

Impact of digital communication message on HPV vaccine decision-making among Japanese mothers: A randomized controlled trial

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ABSTRACT

Background: In Japan, human papillomavirus (HPV) vaccine uptake has been hindered by public distrust and misinformation. Understanding which message components can effectively influence mothers' vaccine decision-making is critical for restoring confidence and improving coverage.

Objective: To assess the impact of different message components on mothers' willingness to vaccinate their daughters against HPV.

Methods: This study employed an online $2 \times 2 \times 2 \times 2$ between-person factorial randomized controlled trial with a nationally representative sample of 1439 Japanese mothers of daughters aged 11–18. Participants were randomly assigned to view one of 16 digital text-based messages varying by four components: messenger (individual or organization), content (effectiveness or safety), style (storytelling or scientific data), and misinformation (misinformation or factual information). Outcomes were willingness to vaccinate, confidence in vaccine safety and effectiveness, message trust, and concern about HPV-related diseases. Logistic regression and model fit statistics were used to assess the impact of components.

Results: Among 1324 mothers analyzed, messages with factual information significantly increased willingness to vaccinate daughters compared to misinformation (25.9 % vs. 11.3 %; OR = 2.75; 95 % CI = 2.02–3.74), while trust was higher for organizational messages (91.6 %; OR = 1.58; 95 % CI = 1.10–2.27). Storytelling messages increased concerns about HPV-related diseases more than scientific data (40.4 % vs. 31.9 %, OR = 1.45; 95 % CI = 1.15–1.82). Although factual information and trusted sources positively influenced attitudes, a single digital message was insufficient to significantly increase vaccination uptake. Furthermore, misinformation reduced confidence in vaccine safety and effectiveness.

Conclusions: Digital messages containing factual information and delivered by organizations positively influence mothers' intentions to vaccinate their daughters against HPV in Japan. These findings support strategies that emphasize trusted sources and factual content while countering misinformation to improve vaccine confidence and uptake. The study was registered at [Clinicaltrials.gov](https://clinicaltrials.gov) (NCT06347627).

1. Introduction

In Japan, cervical cancer incidence has been increasing since the late 1990s and has been the second leading cause of death for women aged 15 to 44 for over a decade [1,2]. In April 2013, the Ministry of Health, Labour and Welfare (MHLW) added HPV vaccines to Japan's national

immunization program (NIP). However, soon after the introduction, videos and news of girls with unconfirmed adverse events following immunization spread widely on social media. These reports created panic among the public. Although there was no evidence that HPV vaccines caused the reported symptoms, in June 2013, the Vaccine Adverse Reactions Review Committee (VARRC) of the MHLW decided to

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suspend the proactive recommendations for HPV vaccines.

Initially, the suspension was temporary until accurate information about side effects following HPV vaccine uptake could be provided to the public [3], and the vaccination program remained in the NIP. However, no notifications or vaccine coupons were sent to eligible girls [4], and consequently, HPV vaccine coverage dropped significantly from 70 % to less than 1 % by the end of 2013 [5].

After 8.5 years, the MHLW finally decided to restart the proactive recommendation of the HPV vaccine in 2021 and in 2022, local municipalities restarted sending HPV vaccine information to eligible girls and their parents [6]. This decision provides a critical opportunity to regain the public's trust in the vaccine and improve its coverage. However, improving trust in the HPV vaccine will be complex. Previous studies have shown that misinformation persists as a long-term memory even if an individual is briefly exposed to it [7]. Based on a survey conducted in 2019, 85.9 % of Japanese mothers still remembered news reports regarding so-called adverse events after HPV vaccination that circulated widely in 2013 [8]. The proportion of mothers who were unwilling to give consent for their daughters to receive the HPV vaccine, even if proactive recommendations were to resume, rose from 18.5 % in 2014 to 45.5 % in 2019. The evidence presents the need for a solid communication strategy to correct inaccurate information and develop interventions that can support girls' and their parents' decision-making around HPV vaccination.

Specifically, online communication should be carefully planned and implemented. Internet and social media usage is high in Japan, with penetration rates of 84.9 % and 86.5 %, respectively [9]. Thus, online platforms are critical sources of information. However, the internet and social media have also become major platforms for misinformation, which tends to spread farther and faster than factual information [10].

Previous studies show that caregivers, especially mothers, are the primary decision-makers for their daughters' HPV vaccination in Japan [11–13]. Research indicates that HPV vaccine acceptance is largely shaped by mothers' perceptions of the vaccine's risks and benefits, and that their views carry more weight than those of their daughters in vaccination decisions. To restore public trust in the vaccine and improve its uptake, it is therefore essential to design online communication strategies that address the key factors influencing Japanese mothers' HPV vaccine decisions. However, there is limited data about how mothers currently perceive HPV vaccination after being exposed to inconsistent vaccine communication and what determines their vaccine decisions. While some studies have explored how the content of messages affects Japanese mothers' intentions to vaccinate their daughters against HPV [14,15], few have assessed how different components of these messages impact mothers' perceptions and decision-making, especially under the new Japanese policy. The evidence is crucial for understanding the long-term effects of misinformation on vaccine intentions among the general population and for developing effective communication strategies that can restore confidence in HPV vaccination.

The study aims to explore how mothers interact with online information about HPV vaccines and how the interactions influence their vaccine decision-making. The objectives are: 1) to understand how mothers perceive HPV vaccine information they get online, 2) to assess how their intentions to vaccinate daughters are affected by the information, and 3) to identify communication factors that impact mothers' confidence and willingness to consent to HPV vaccination for their daughters.

2. Methods

2.1. Study design and participants

This study implemented a sixteen-arm randomized controlled trial (RCT) in an online survey environment. First, participants, who were Japanese mothers with daughters aged 11–18 who had received either

zero or only one shot of the HPV vaccine, answered a pre-trial survey. Then, mothers were randomly assigned and evenly allocated to view one of sixteen digital communication messages using a $2 \times 2 \times 2 \times 2$ between-person factorial trial on 'components of message.' Lastly, the study collected data as a post-trial survey to evaluate how message components influenced mothers' willingness to consent to HPV vaccination for daughters, confidence in the vaccine safety and effectiveness, trust in the message they viewed, and concern about HPV-related diseases.

A total of 1600 participants were recruited from a nationwide panel with relevant demographic information maintained by Opinion Research Business (ORB) International, a polling firm and the sole UK member of the WIN/Gallup International Association (WIN/GIA). To ensure representativeness, quota-based sampling was used based on the latest Japanese census data, targeting key demographic variables such as region of residence and mother's age. Upon conducting a survey, ORB sent links to potential participants who were signed up to their panel to read a participant information sheet. To be eligible for participation, one had to be a mother with daughters aged 11–18 who had received either zero or only one shot of the HPV vaccine. This inclusion allowed us to capture not only those hesitant about HPV vaccines before receiving any shots but also those who had received one shot but were uncertain about whether to proceed with subsequent doses. Those interested in participating in the study read through the participant information sheet and provided consent by signing the participant consent form.

This study obtained ethical approval from the School of Tropical Medicine and Global Health, Nagasaki University (NU_TM2022_241_1), the London School of Hygiene and Tropical Medicine (28248), and the University of Hong Kong (UW 23–139).

2.2. Randomization and masking

ORB utilized an automated computer system for randomization, assigning mothers to view one digital communication message each. The study was conducted under triple-blinding, meaning participants, investigators, and outcomes assessors were unaware of the participant's group assignment. ORB oversaw the cleaning and anonymization of data, removing all personal identifiers and replacing them with unique numerical identifiers specific to the study. The original data, including personal identifiers, were securely stored on a password-protected computer accessible only to authorized study personnel. Investigators and outcomes assessors were granted access solely to the de-identified dataset.

2.3. Procedures

As shown in [Fig. 1], the study began by assessing potential participants to determine their eligibility for the survey and trial. Those who met the inclusion criteria proceeded to a pre-trial survey, providing information on sociodemographic, vaccination history, future intentions to receive HPV vaccines, and general experiences with vaccination and vaccine-preventable diseases. Additionally, the survey explored key factors influencing HPV vaccine acceptance, such as trusted sources of information and previous communications about HPV disease and vaccines.

Participants were then randomly assigned to view one of sixteen digital communication messages about HPV vaccines as a part of a $2 \times 2 \times 2 \times 2$ between-person factorial trial on 'components of message' [Table 1] [Table S1]. These messages were developed based on real social media posts from November 2021 and April 2022, during the period when the Japanese government was preparing to reinstate an active recommendation of HPV vaccines for eligible girls after eight and a half years of suspension. A message was delivered following an introductory explanation: "People and organizations use digital communication (e.g., X (ex-Twitter), Facebook, newsletters, etc.) to share information about the HPV vaccine. We'd like to understand how

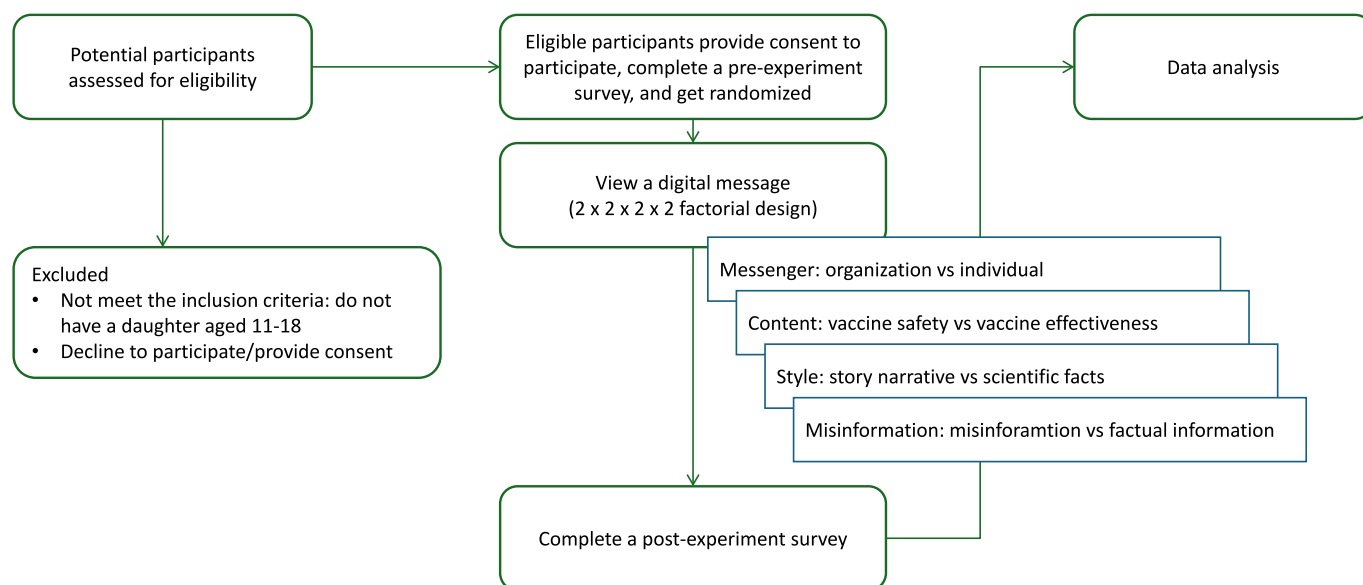


Fig. 1. Study flowchart. A total of 1600 Japanese mothers with daughters aged 11–18 who had received either zero or only one shot of the HPV were recruited from a nationwide panel with relevant demographic information maintained by ORB International. A quota-based sampling methodology was used to ensure that the sample of adults represents the target population in the country's different regions and ages.

these messages about the vaccine might affect parents." The sixteen messages assessed four factors: messenger, style, content, and misinformation. Each message was the same except for the independent variable in consideration.

First, the messenger component was about whether the message was from an individual or an organization. As individual messengers, the study set fictional caregivers who actively communicate about HPV vaccines. As organizational messengers, the study used the existing accounts of the MHLW or the Japan Cancer Society or a fictional account of an anti-vaccine group. Second, the style component was about whether the message conveys information through storytelling or scientific data. Messages included personal stories for the storytelling style and statistics for the scientific data style. Third, the content component was about whether the message conveyed information about the effectiveness of the HPV vaccine in preventing diseases or the safety of the HPV vaccine. The contents were built on both factual information and misconceptions about HPV vaccine safety and effectiveness that were often mentioned in the actual social media posts. Last, the misinformation component was about whether the message conveyed misinformation or factual information.

After viewing a message, participants completed post-trial survey questions. The questions assessed how the message influenced their trust, confidence, and motivation to vaccinate. The survey also included questions about participants' use of and trust in other communication strategies. The study debriefed all respondents exposed to misinformation after the survey. Both the survey and trial were conducted in the local language and translated into English for analysis.

2.4. Outcomes

The primary outcome of this study was a degree of change in mothers' willingness to consent to HPV vaccination for their daughters. Response options were on a 5-point Likert scale, ranging from "much less willing to get the HPV vaccine for my daughter" to "much more willing." Responses of "somewhat more" or "much more" were categorized as high willingness, while all other responses were classified as low willingness. This scale has been used and validated in prior HPV vaccine studies among Japanese caregivers [16]. Participants who answered "much more" or "somewhat more" were classified as high willingness, and "much less," "somewhat less," or "neither more or less" were

classified as low willingness.

As the second primary outcome, we evaluated changes in mothers' confidence in the safety and effectiveness of HPV vaccination after viewing an experimental message on a 5-point Likert scale. The options were "much less confident that the HPV vaccination is safe/effective," "somewhat less," "neither more or less," "somewhat more," and "much more." Those indicating "much more" or "somewhat more" were classified as high confidence and "much less," "somewhat less," or "neither more nor less" as low confidence.

Additionally, we assessed participants' perceptions of the displayed message regarding trust and concerns about diseases prevented by HPV vaccines. Trust was categorized as either trust ("completely," "quite a lot," "a moderate amount," and "a little") or no trust ("not at all"). Concerns about HPV-related diseases were categorized as either low concerns ("much less," "somewhat less," and "neither more nor less") or high concerns ("somewhat more" and "much more").

2.5. Statistical analysis

To ensure the 95 % confidence interval estimate of the proportion of people who received HPV vaccination is within 5 % of the true proportion (margin of sampling error 0.05), a sample of size 385 was needed to generate the most conservative sample sizes. We increased this to 1600 to enable subpopulation analysis by daughter's age and their eligibility for routine or catch-up vaccination programs.

We used descriptive statistics to analyze participants' sociodemographic characteristics. In addition, we conducted the chi-square tests to ensure each message was randomized to groups that did not differ in sociodemographic characteristics. For the 'components of message' trial, we conducted bivariate analyses to examine the association between the four messaging factors (messenger, content, style, and misinformation) and the five outcome variables (trust, concerns about diseases prevented by HPV vaccines, confidence in safety, confidence in effectiveness, and willingness to get HPV vaccines for daughters). Furthermore, we performed logistic regression analyses to assess how the four messaging components impact mothers' perceptions toward HPV vaccines separately for each outcome variable. We also calculated the Akaike Information Criterion scores to evaluate how each messaging component interacts with one another and which combination is the best fit. All statistical analyses were performed using STATA v17 [17], with the

Table 1

Contents and characteristics of 16 experimental messages. 1) Me, messaging (I, individual or O, organization); 2) C, content (E, effectiveness or S, safety); 3) S, style (S, storytelling or D, scientific data); 4) Mi, misinformation (M, misinformation or F, factual information).

#	Message	Characteristics				Number of participants assigned
		Me	C	S	Mi	
1	Many people have missed the opportunity to be vaccinated against HPV because they were unaware that it was a routine vaccination or misunderstood it as a “dangerous vaccine.” Many doctors feel very frustrated about this. I want people to know accurate information.	I	S	S	F	80
2	A tweet made by a woman in her twenties: I got the cervical cancer vaccine at my own expense a long time ago. I didn't have any adverse reactions. I decided to get the vaccine because someone I knew, who was still young, died of cervical cancer. If I am to find something wrong during a medical check-up, even if it doesn't turn out to be cancerous, I can get worried. I want to do anything I can to prevent it.	O	S	S	F	77
3	Some women get cervical cancer because their opportunity to receive HPV vaccination was lost. It is not only regrettable for the women but for physicians, including myself, as well. The regret is incomparable to my own childhood experience of losing my mother. I hope more people get to know how the HPV vaccine can protect many people regardless of gender.	I	E	S	F	83
4	A tweet made by a physician: I sometimes remember how my mother, battling cervical cancer, used to beg for help regardless of how much it would cost. I also remember the sound of the hearse siren I heard at the end of her farewell ceremony after she passed away after all the efforts. Now that I am a doctor and we have the HPV vaccine, it's a billion times more regrettable than it was then to see a patient die from a preventable disease. Let's prevent cervical cancer.	O	E	S	F	80
5	A classmate of my daughter who was HPV vaccinated also has a walking disability and is in a wheelchair.	I	S	S	M	84
6	A statement made by Ms. Mikoto Yamamori, a plaintiff in the Tokyo lawsuit. The words are from the November 12, 2021, protest press conference against the resumption of active recommendation: I received the HPV vaccine in the first year of junior high school, and I suffered from many adverse reactions after the vaccination. Even after nine years, I still struggle with symptoms such as headaches and body aches every day.	O	S	S	M	89
7	MoH makes up the story that people in other countries are	I	E	S	M	74

Table 1 (continued)

#	Message	Characteristics				Number of participants assigned
		Me	C	S	Mi	
	receiving HPV vaccines. They do not explain the vaccine's side effects and make it look effective even though it is not.					
8	HPV vaccines are ineffective, but the side effects are significant. However, this fact is difficult to understand for those who don't look closely at information and its sources. They manipulate information by calling anything inconvenient a conspiracy theory. The vaccine promotion policy will not stop.	O	E	S	M	82
9	Attached is a discussion summary based on the fact sheet regarding HPV vaccination. In terms of efficacy, safety, and cost-effectiveness, it was confirmed that there is no problem considering including the vaccine in routine vaccination. Future issues are the introduction of two-dose vaccination, vaccination for males, consideration of the routine vaccination target age, and earlier promotion to those eligible.	I	S	D	F	87
10	- HPV vaccine is a vital vaccination to protect women from cervical cancer. - Safety has been confirmed. - Vaccination up to the age of 16 is recommended. For those born between 1997 and 2005, the vaccine should be given as early as possible.	O	S	D	F	85
11	Cervical cancer: Here is a summary of the HPV vaccine, which has returned to active vaccination recommendations. There have been increases in cervical cancer among gestational age, and their mortality rates are rising. Vaccination and cancer screening are effective and should be kept in mind.	I	E	D	F	84
12	Active recommendation of #HPV vaccine will be resumed from today, April 1. Girls from 6th grade to 1st grade of high school are eligible. Also, those born between April 2, 1997, and April 1, 2006, and who have not yet received the HPV vaccine will be able to receive the vaccine at public expense for the next three years. Please see below for details.	O	E	D	F	86
13	Various reports of side effects have been confirmed for the HPV vaccine, including cramps, vomiting, generalized pain, fainting, and blackout.	I	S	D	M	81
14	Attached is a leaflet, “The True Story of HPV Vaccine,” prepared by HPV Vaccine Litigation Support Net. The active recommendation of the #HPV vaccine has been resumed in April 2022, but victims across the	O	S	D	M	86

(continued on next page)

Table 1 (continued)

#	Message	Characteristics				Number of participants assigned
		Me	C	S	Mi	
15	country still suffer from severe adverse reactions. We urge everyone eligible for vaccination to read this information. In a recent tweet, a physician said that although he actively recommended the HPV vaccination when it was introduced years ago, cervical cancer incidents have not decreased at all, even in the vaccinated generation. In other words, the vaccine is not effective. I don't see any benefit, including the possibility of severe adverse reactions from the vaccine.	I	E	D	M	79
16	The number of girls vaccinated with HPV vaccines is expected to increase based on the Ministry of Health, Labor, and Welfare and local government's decision to resume proactive recommendations. However, medical checkups are still necessary after vaccination, and adverse reactions are more frequent than in other vaccines. No treatment has been established, and many people are still suffering from the effects of the adverse events. Do not simply get vaccinated because it is free and recommended! Judge carefully.	O	E	D	M	87

statistical significance set at $p < 0.05$. The study was registered at [Clinicaltrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT06347627) (NCT06347627).

3. Results

3.1. Participant characteristics

A total of 1600 mothers of daughters aged 11–18 participated in the RCT, which included pre- and post-trial surveys, conducted between December 22, 2023, and January 22, 2024. After excluding 209 participants who refused to answer their daughter's HPV vaccination uptake status and 67 participants who did not know their daughter's HPV vaccination status, we included 1324 mothers for analysis. [Table 2] presents participants' sociodemographic characteristics. The majority of participants were aged 40–49, had a college or university degree, had a household income over four million Japanese yen (JPY) (equivalent to approximately 27,700 USD; the Gross Domestic Product per capita in Japan was approximately 37,100 USD in 2023) had no background in medicine or health-related science, and had daughters eligible for routine HPV vaccination. Compared to national averages, the sample skewed slightly toward higher education and household income. Regarding participants' residence, 46.8 % of mothers lived in prefectures with a population density of over 1000 people per km² [Table S2]. After randomization, each of the 16 messages was displayed to 84 to 95 participants. According to chi-square tests, each messaging component was randomized to groups that did not differ in sociodemographic characteristics with all $p > 0.05$.

Table 2
Sociodemographic characteristics of participants.

Demographics and socioeconomic status	n	(%)
Caregiver's age, years		
Under 29	19	(1.4)
30–39	200	(15.1)
40–49	827	(62.5)
50–59	271	(20.5)
60 or over	6	(0.5)
Refused	1	(0.1)
Highest education level		
Junior high school or less	57	(4.3)
High school or GED	385	(29.1)
College or university	838	(63.4)
Some graduate or more	41	(3.1)
Refused	3	(0.2)
Income		
Under 4 M	340	(25.7)
Over 4 M	895	(67.6)
I do not know	89	(6.7)
Population density of residence		
Low	702	(53.1)
High	620	(46.9)
Background in medicine or health-related science		
No	1028	(78.2)
Yes	286	(21.8)
Refused	10	(0.8)
Daughter's eligibility for the HPV vaccination program		
Routine	979	(73.9)
Catch-up	345	(26.1)

Note. Population density of residence was dichotomized into “high” and “low” categories. “High” density includes participants residing in the seven most densely populated prefectures: Tokyo, Osaka, Kanagawa, Saitama, Aichi, Chiba, and Fukuoka. All other prefectures were categorized as “low” density.

3.2. Trial analysis

Willingness to consent to HPV vaccination for daughters was high among mothers who were exposed to messages that included factual information (25.9 %; [Fig. 2]). In contrast, the lowest willingness was seen among those who viewed messages with misinformation (11.3 %). Analysis using logistic regression also derived the same result, as messages that contained factual information significantly affected mothers' positive willingness to receive the vaccine compared to messages that contained misinformation (25.9 % vs. 11.3 %; OR = 2.75; 95 % CI = 2.02–3.74; [Table 3]). Additionally, messages delivered by organizations also led more mothers to be willing to consent to HPV vaccination for their daughters than those by individual healthcare providers (20.7 % vs. 16.3 %, OR = 1.34; 95 % CI = 1.01–1.80). The content and style of messages did not affect mothers' willingness to consent to HPV vaccination except when the misinformation component was included in the model [Table S3]. Based on the AIC scores, a model that included misinformation and messenger components achieved the best cross-validated prediction. An exploratory analysis revealed no statistically significant association between age group and willingness to vaccinate [Table S4]. The proportion of mothers reporting high willingness was relatively similar across age groups, and odds ratios relative to the reference group (under 29 years) were not statistically significant. As shown in Table S5, willingness to vaccinate was also not significantly associated with age group across different message content conditions, with effect sizes small and confidence intervals wide. In Table S6, there was more variation by age in response to message style. Mothers under age 29 showed a numerically higher rate of willingness after viewing storytelling-style messages (33.3 %) compared to scientific-style messages (8.3 %), though small sample sizes precluded statistical significance. Mothers in their 30s and 40s showed similar willingness levels across both styles, and overall, no statistically significant age-by-style interaction was observed. Factual information was the only component that supported mothers' confidence in HPV vaccine safety and effectiveness (21.8 %

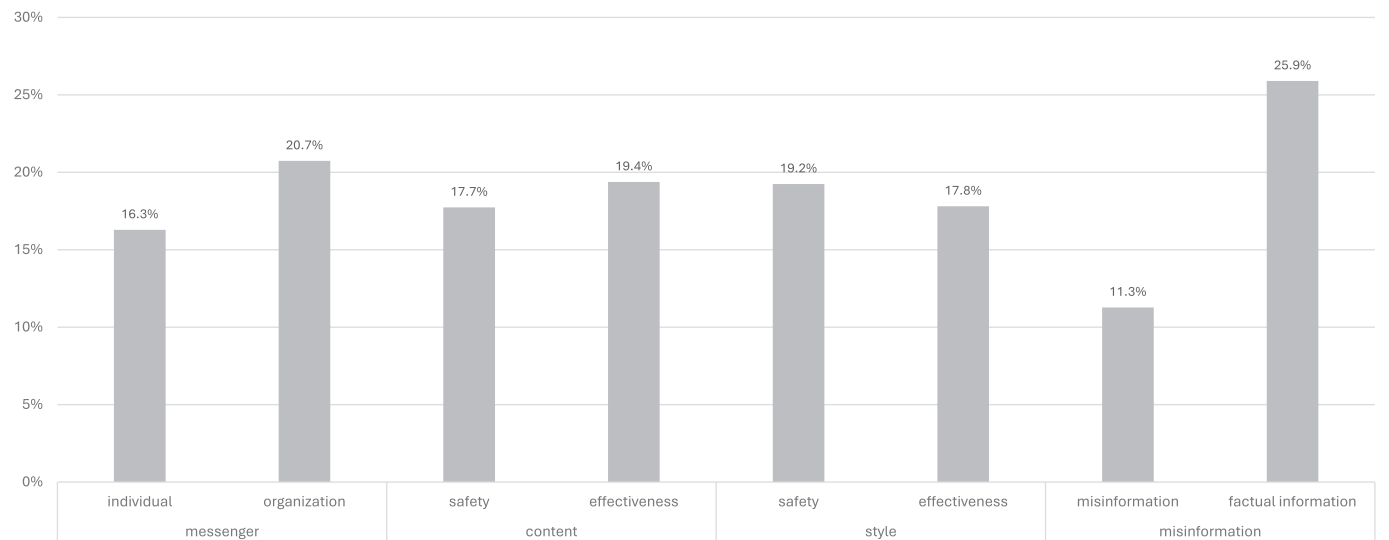


Fig. 2. Effects of messaging factors on caregivers’ willingness to receive HPV vaccines for daughters. Percentage of participants who answered “somewhat more willing to get the HPV vaccine for my daughter” or “much more willing” on a 5-point Likert scale after viewing the assigned trial message.

Table 3
Effects of messaging factors on caregivers’ willingness to receive HPV vaccines for daughters. We dichotomized responses regarding willingness by combining “much less willing to get the HPV vaccine for your child,” “somewhat less,” and “neither more or less” (low willingness) versus “somewhat more,” and “much more” (high willingness). OR = odds ratio, CI = confidence interval, Ref = reference group. **p* < 0.05, ***p* < 0.01, ****p* < 0.001.

Messaging component	Caregivers with high willingness to receive HPV vaccines for daughters after viewing a message ¹ /total in condition	(%)	OR (95 % CI)
<i>Messenger</i>			
Individual	99/608	(16.3)	Ref
Organization	130/627	(20.7)	1.34 (1.01–1.80)*
<i>Content</i>			
Safety	111/626	(17.7)	Ref
Effectiveness	118/609	(19.4)	1.12 (0.84–1.49)
<i>Style</i>			
Scientific data	122/634	(19.2)	Ref
Story telling	107/601	(17.8)	0.91 (0.68–1.21)
<i>Misinformation</i>			
Misinformation	70/621	(11.3)	Ref
Factual information	159/614	(25.9)	2.75 (2.02–3.74)***

and 27.5 %, respectively [Table S7]). HPV vaccination confidence was the lowest among those who viewed messages that included misinformation (8.9 % for confidence in the safety and 9.5 % for confidence in the effectiveness). For both confidence in safety and effectiveness, the best model based on AIC was the one with misinformation and messenger included [Table S8].

A relatively high percentage of mothers trusted the message they viewed regardless of the messaging components, varying from 87.3 % to 91.6 % [Table S9]. This was also true for misinformation, of which 88.5 % of mothers who viewed messages containing misinformation believed its content. However, only messages delivered by organizations were trusted statistically significantly (91.6 %; OR = 1.58; 95 % CI = 1.10–2.27). The result of AIC also presents that the simple model with only a messenger component included is the best fit [Table S10]. Logistic regression analyses agree with the result, and the only models with a significance level of *p* ≤ 0.05 were those including a messenger

component.

The percentage of mothers who became concerned about HPV-related diseases was the highest among those who viewed messages with misinformation (53.5 %) [Table S11]. On the contrary, mothers who were exposed to messages with factual information were the least likely to become concerned (18.4 %). Messages expressed in a story-telling style led more mothers to become concerned about HPV-related diseases than those with scientific data (40.4 % vs. 31.9 %, OR = 1.45; 95 % CI = 1.15–1.82). Additionally, messages about HPV vaccine safety were a factor for mothers to become worried about HPV diseases (38.9 %). The results of AIC agree with the assessment, and we regard the model with misinformation, style, and content components as the best fit [Table S12].

4. Discussion

Using a 2 × 2 × 2 × 2 between-person factorial trial on ‘components of message,’ this study found that factual information and messages from organizations had a positive influence on Japanese mothers’ intentions to vaccinate their daughters against HPV. This finding is consistent with previous research from the U.S., which demonstrated that tweets from organizations were more effective than those from individuals in motivating parents to vaccinate their children against HPV [18]. Additionally, the style and content of messages were effective in raising mothers’ concerns about HPV-related diseases when combined. In contrast, misinformation had a negative impact on mothers’ perceptions of the HPV vaccine. These findings offer new insights into how different components of messages and their combinations affect mothers’ views on HPV vaccination, which is essential for understanding the real-world impact of messages and developing effective communication strategies to support mothers in their vaccine decision-making.

Consistent with earlier research [19,20], this study found that misinformation significantly undermines mothers’ confidence in the safety and effectiveness of the HPV vaccine, as well as their intentions to vaccinate their daughters. Given the growing concerns about the spread of vaccine misinformation via the Internet and social media [21,22], there is an urgent need for online measures to swiftly counteract false or inaccurate information. Conversational Artificial Intelligence (AI) represents one promising tool to address this challenge [23]. AI-driven chatbots have successfully identified and corrected inaccurate information about the COVID-19 vaccine [24]. Deploying chatbots that provide factual information about HPV vaccines, tailored to fit the

Japanese context, could be a crucial strategy to mitigate the impact of vaccine misinformation and support mothers in making informed vaccination decisions. Moreover, chatbots can be utilized for prebunking – empowering individuals to be resistant to potential misinformation [25,26]. Previous findings have shown that prebunking strategies can effectively reduce an individual's susceptibility to misinformation, lessening its impact [27]. When tailored to Japanese users, such digital interventions could enhance health literacy, reduce susceptibility to misinformation, and support vaccine confidence at scale.

While message style and content did not influence mothers as strongly as misinformation or the messenger, they did affect mothers' concerns about HPV-related diseases. Specifically, messages using a storytelling style and those focusing on HPV vaccine safety were particularly effective in raising concerns. This finding aligns with previous research showing that narratives from patients or parents persuade Japanese mothers to have their daughters receive HPV vaccines [14]. The content of messages also increased mothers' intention of HPV vaccination when the messages targeted the fundamental human motive of kin care, including safety information about the vaccine [15]. Although raising awareness about HPV-related diseases is important, thoroughly informing mothers about the safety of the HPV vaccine is crucial. Historically, public trust in science and government has been low in Japan [28]. However, during the COVID-19 pandemic, the Japanese government managed to achieve high vaccine coverage, exceeding 80 % [29]. This success was largely due to the government's proactive role in developing and implementing clear communication strategies [30,31]. By effectively utilizing websites and social media to provide accurate information on vaccine efficacy and side effects, as well as addressing misinformation, the government significantly contributed to the success of the COVID-19 vaccination campaign. By leveraging these insights, HPV vaccination efforts can be enhanced and ultimately improve public health outcomes.

Exploratory analyses were also conducted to assess whether responses to different message styles and content varied by maternal age group. While no statistically significant interactions were observed, we noted some suggestive trends. For example, younger mothers – particularly those under the age of 29 – appeared more responsive to storytelling-style messages than to scientific-style messages, and somewhat more receptive to messages emphasizing vaccine safety. Mothers in older age groups, such as those in their 30s and 40s, showed relatively consistent responses regardless of message style or content. These findings, while inconclusive due to limited sample sizes and wide confidence intervals, point to potential age-related variation in communication preferences.

This study had several limitations. First, the environment in which participants viewed online messages differed from their usual real-world experiences. In this study, participants were shown a single message about HPV vaccination, whereas, in reality, mothers are exposed to multiple messages that include both factual information and misinformation. While presenting just one message allowed us to assess which components of messages affect mothers' perceptions and intentions regarding HPV vaccination, it would be valuable for future research to expose participants to multiple messages to better understand how these influence mothers' vaccine decision-making. Secondly, although a quota-based sampling methodology was used to ensure demographic representativeness, some deviations from national averages were observed. The sample included a high proportion of mothers aged 40–49 years (62.5 %), which aligns with national data indicating that approximately 65 % of children aged 11–18 in Japan have mothers in this age group [32]. However, the proportion of university graduates (63.4 %) and those with household incomes above 4 million JPY (67.6 %) was higher than national averages for women with adolescent children. This reflects a modest selection bias, possibly due to online recruitment and characteristics of survey panels, which may limit the generalizability of the findings to the broader population. Future studies with larger, stratified samples are warranted to explore whether

tailoring message formats to specific demographic segments could enhance message effectiveness. Lastly, self-reported intentions to vaccinate may not always translate into actual vaccine uptake, although intention remains a strong predictor of behavior.

Despite these limitations, this study revealed that messages containing factual information from trusted organizations influence mothers' positive willingness to have their daughters receive HPV vaccination. Conversely, misinformation negatively impacts mothers' confidence in and intention to vaccinate. Developing new communication tools that effectively correct inaccurate information, while emphasizing clear and transparent factual information from trusted organizations, may be vital to restoring mothers' confidence in the HPV vaccine, leading to an improved HPV vaccine uptake and protecting adolescents' health.

CRediT authorship contribution statement

Kana Kobayashi: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Ken Masuda:** Writing – review & editing, Supervision, Project administration. **Joseph T. Wu:** Writing – review & editing, Methodology, Conceptualization. **Leesa Lin:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Leesa Lin is member of the Vaccine Confidence Project, a global research consortium that has received research grants from GlaxoSmithKline (GSK) and Merck. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.vaccine.2025.127327>.

Data availability

Data will be made available on request.

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