



DIGITAL HEALTH SOLUTIONS TO HPV VACCINATION



EDITED BY: Suellen Hopfer, Heather M. Brandt and Amalie Dyda
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DIGITAL HEALTH SOLUTIONS TO HPV VACCINATION

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Editorial: Digital solutions to HPV vaccination

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Editorial on the Research Topic

Digital solutions to HPV vaccination

by Hopfer S, Dyda A and Brandt HM. (2022). Front. Digit. Health. 4:972234. doi: 10.3389/fdgth.2022.972234

Introduction

The rapid growth and diffusion of digital solutions, technologies and online media consumption is changing the landscape of implementing health behavior change campaigns and interventions as well as how individuals and families access and consume health information (1, 2). Novel, culturally targeted prevention strategies can be implemented digitally to reach virtual communities who access digital health messages daily especially young adults and youth (3–7). Technology may also improve health care more directly, with text-message reminders and other recall systems showing improvements in health outcomes. Digital solutions hold promise for raising awareness about health promotion, empowering individuals and delivering real-time health information that can be tailored to individual needs. Prioritizing digital health for vaccine information has been reflected in US federal public health goals for 2030 including health equity goals (8). We focus in this special issue on digital solutions to increasing HPV vaccination, a priority area for cancer prevention (9). The US federal National Cancer Institute (NCI) designated cancer centers have called for urgent back on track vaccine initiatives to attenuate the gap in HPV vaccination (10) that show 2.3 million doses of HPV vaccine missed (a decrease of greater than 20%) during the COVID-19 pandemic and is likely to persist for several years post-pandemic (11).

This special issue showcases predominantly social media studies as digital solutions that show promise for reaching parents and youth about HPV vaccination (Massey et al.; Zhang et al.; Sundstrom et al.; Buller et al.; Hopfer et al.). The special issue also presents feasibility studies on web-based or mobile applications (Woodall et al.; Olusanya et al. and Reno & Dempsey) that tailor vaccine information to parents, adolescents, and young adults through a variety of approaches. Most digital solutions presented are stand-alone, yet one

intervention presents digital efforts integrated as a component of a multi-level clinic intervention to reach rural populations and reduce missed HPV vaccine recommendation opportunities (Kepka et al.). Other studies (Woodall et al.; Olusanya et al.) suggest that mobile apps could be used to complement clinical pediatric well-child visits or could be disseminated by state health departments, school health officials, and pharmacy chains. The advantages of digital health not only become apparent by the structural channel affordances that lend themselves to greater engagement and tailoring with audiences but also accommodate busy schedules of parents and young adults.

Digital approaches inherently hold promise to make vaccine information more accessible for many populations who might otherwise not be reached and where messaging can be targeted to reach subgroups. Digital strategies may be delivered *via* peer networks (e.g., mothers of vaccinated adolescents as champions or influencers), such as those reported by Sundstrom et al. and Buller et al., to deliver vaccine messaging through trusted peers presents a promising approach for increasing HPV vaccination. Another benefit of digital interventions is the ability to deliver vaccine messaging in other languages e.g., Spanish to Latinx communities (Reno & Dempsey, CHICOS; Woodall et al. Vacteens/Vacunadolescente.org) or target vaccine messaging *via* parent personas (Massey et al.). Social media studies delivered vaccine messaging across multiple channels testing the impact of disseminating through different platforms (Hopfer et al.) in private and public groups, synchronous/asynchronous discussion groups, webinars, bi-weekly emails, weekly messaging, and lifestyle messaging (Massey et al., Olusanya et al.; Sundstrom et al.; Hopfer et al.).

Geographic targeting can also be achieved with digital messaging: one study focused on Northern rural California with low vaccination and high cancer rates (Zhang et al.), another study focused regionally on South Carolina (Sundstrom et al.) and yet another on rural Colorado (Reno & Dempsey). These U.S. regions are characterized by low HPV vaccination rates and high HPV-cancer incidence.

Engagement, as observed through analysis of comments and posts (Zhang et al.; Buller et al.), showcases the potential to take advantage of answering parent and youth questions real-time and debunking misinformation, but also answering questions asynchronously through newsletters, blogs, discussion forums, chat rooms, and portals (Sundstrom et al.; Hopfer et al.). A devoted moderator who can respond real-time to questions and correct misinformation was a recurring theme in combination with more automated digital interventions. The flow of unsolicited, real-time comments from parents give insight into vaccine concerns as well as exposure to circulating rumors and misinformation. Predominant vaccine concerns remain around HPV vaccine confidence and HPV complacency.

Communication and behavior change theories were adapted to understand the digital health environment: these ranged from social

cognitive theory (SCT), diffusion of innovation (DOI), extended parallel process model (EPPM), 3C model of vaccine hesitancy, and a champion network approach. One study integrated persona theory with health communication and human-centered design (Massey et al.) while another study applied dialog theory to segment HPV vaccine videos and adapt them to the social media environment (Hopfer et al.). An ideal area of opportunity lies in strengthening the integration of theoretical foundations into digital health solutions in HPV vaccination.

A number of these studies were in the development or piloting stage (Olusanya et al.), highlighting the emerging nature of digital solutions to increase vaccination. However, data on outcomes was also presented with results from randomized trials (Woodall et al., Buller et al.). This accrued evidence from the studies in this special issue on digital solutions highlights the various ways in which digital approaches are likely to increase HPV vaccination rates particularly in relation to increasing access and improving health promotion reach, through peer- and trusted channels and messengers. Use of narratives and informal peer dialogue (Massey et al.; Hopfer et al.; Sundstrom et al.) show promise to increase user engagement in the digital environment while also being able to answer and debunk circulating rumors real-time (Sundstrom et al.). Social media platforms offer one strategy to make information accessible (Zhang et al.). Additional strategies of using peer-champions (Sundstrom et al.), point-of-care delivered vaccine messages (Kepka et al.), and real-time tailoring (Hopfer et al.) also show promise as digital solutions to increase HPV vaccination.

Author contributions

SH, AD, HB contributed to writing the editorial for this special issue. All authors contributed to the article and approved the submitted version.

Conflict of interest

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

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HPV Vaccination Champions: Evaluating a Technology-Mediated Intervention for Parents

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Human papillomavirus (HPV) vaccination prevents 6 HPV-related cancers in men and women. Yet, rates of HPV vaccination among adolescents in the United States lag behind other developed nations, revealing a significant public health issue. This feasibility study tested a collaborative online learning environment to cultivate HPV vaccination champions. A 3-month training program recruited parents to serve as proponents and social media influencers to identify solutions to overcome barriers to HPV vaccination. A mixed methods study design included a pretest survey, three online asynchronous focus groups, a posttest survey, as well as a longitudinal follow-up survey at 6 months. Participants included 22 parents who self-identified as female (95.4%) and white (90.9%). Overall, there was a statistically significant difference in knowledge of HPV and HPV vaccination between pretest and posttest ($p = 0.0042$). This technology-mediated intervention increased parents' confidence and motivated them to speak more freely about HPV vaccination in-person and online with others in their social networks. Participants identified prevalent misinformation about HPV vaccination and learned how to effectively craft messages to address concerns related to safety and side effects, gender, understanding of risk, and sexual activity. Objective measures and qualitative open-ended assessment showed high intervention engagement and treatment satisfaction. All participants (100%) indicated that they enjoyed participating in the intervention. The effectiveness of this feasibility study suggests that social media is an appropriate platform to empower parents to counter vaccine hesitancy and misinformation through HPV vaccination information that is simple and shareable in-person and online.

Keywords: human papillomavirus, technology-mediated intervention, champions, parents, social media

INTRODUCTION

The human papillomavirus (HPV) is the most prevalent sexually transmitted infection (STI) in the United States, with 79 million Americans currently infected with the virus (1). The majority of sexually active men and women in the U.S. will be infected with HPV during their lifetime, and 14 million Americans become infected each year (1). While most HPV infections will not cause symptoms or result in health problems, persistent infections can cause genital warts and six types of cancer. HPV infection is linked to six different types of cancer and is estimated to cause more than 90% of cervical and anal cancers; 70% of vaginal, vulvar, and oropharyngeal cancers; and 60% of penile cancers. Every year, HPV is estimated to cause ~35,900 of the 45,300 new cases of HPV-associated cancer found in women and men (2). In South Carolina, more than 580 new cases of HPV-related cancers are diagnosed each year (3).

The HPV vaccine is critical to reduce HPV infection rates and HPV-related cancers. A vaccine to prevent HPV has been available in the U.S. since 2006. Gardasil®9 (Merck, Inc) has been offered in the U.S. since 2016 and is currently the only HPV vaccine available in the U.S. The Centers for Disease Control and Prevention (CDC) recommend that all children ages 11 and 12 receive two doses of HPV vaccine. Adolescents who receive the first dose of the HPV vaccine at age 15 or older or who are immunocompromised require three doses. The HPV vaccine is recommended for all men and women up to age 26 and is approved for some people up to the age of 45 (4). It provides protection from nine HPV types that cause genital warts and cervical, vaginal, vulvar, anal, oropharyngeal, and penile cancers. The HPV vaccine is safe and effective with only minor side effects, such as pain or swelling at injection site, fever, headache, nausea, and fainting (5). More than 100 million doses of HPV vaccine have been distributed in the U.S. and continuous monitoring further strengthens the evidence of the vaccine's safety and effectiveness (5).

Research shows that social media play a role in spreading the global anti-vaccination movement (6). Parents are exposed to negative messages about vaccination on social media (7). In South Carolina, a recent content analysis of social media found that online messages perpetuated barriers to HPV vaccination, including fears about vaccine safety and concerns about harmful side effects (8). A study of parents who sought vaccine information on the internet found that they were more likely to have lower perceptions of vaccine safety, vaccine effectiveness, and disease susceptibility compared with parents who did not seek vaccine information on the internet (9). Exposure to negative opinions about HPV vaccines on social media led to increased anti-vaccination posts, whereas neutral or positive information did not have the same impact on users' posts (10). In fact, mothers who are against childhood vaccinations are more likely to engage in communication about the issue, while those who support vaccinations remain silent (11). Researchers argue that social media platforms offer an important venue for sharing science-based information about the safety of vaccines and suggest that social media users may be able to debunk myths and inactivate misinformation (12).

HPV vaccination interventions have primarily focused on adolescents, parents, and clinicians. In addition to their robust use of social media, women tend to be the health decision makers in their families. Research shows that mothers serve as the primary decision makers for adolescents receiving HPV vaccination (13–15). Parents' social networks influence their vaccination decision-making by offering information and advice (16). Past HPV vaccine interventions targeted at parents have been effective in increasing knowledge and acceptance of the HPV vaccine, as well as intention to vaccinate children (17, 18). Shoup et al. created an effective social media intervention tool to address parental concerns about vaccination and improve childhood immunization rates (19). Another social media intervention successfully improved childhood vaccine acceptance among pregnant women (20).

Although Americans continue to report high levels of trust in health care providers and government health agencies, a recent study found that the social media accounts of patients and support groups were more influential than physician, academic society, and clinic accounts (21). Health education interventions have utilized social media champions to successfully promote health messages while other health interventions have demonstrated the success of preparing parents to be advocates in their own communities by providing them with information that can be used in discussions with other parents to improve vaccination uptake (22, 23). Research shows that cultivating champions is an effective implementation strategy to promote uptake of an evidence-based intervention (24–27).

Building on the evidence that social media can be a powerful platform for promoting vaccination, the current study was conducted as part of a statewide initiative to raise HPV vaccination rates in South Carolina. This research answers the call to action by researchers to assist parents who support vaccination to speak out easily and often by providing information that is simple and shareable online (11). According to Dr. Aaron E. Carroll, professor of pediatrics and associate dean at the Indiana University School of Medicine, "It seems important to engage the public more, and earn their trust through continued, more personal interaction, using different platforms and technologies. Dropping knowledge from on high—which is still the *modus operandi* for most scientists—doesn't work" (28). The purpose of cultivating HPV vaccination champions is to develop a collaborative online learning environment to increase HPV vaccination by training and supporting parents to serve as proponents and social media champions in order to overcome barriers to HPV vaccination.

MATERIALS AND METHODS

Design

A mixed methods study examined the feasibility of a technology-based intervention among parents in South Carolina. This study included the implementation and evaluation of a 3-month online training designed to cultivate HPV vaccination champions. The intervention was adapted from a successful theory-based, technology-mediated HPV vaccination awareness intervention for college students (29). Recruitment methods are

described below. Participants joined a private Facebook group, received bi-weekly emails with facts about HPV vaccination, and attended two online webinars about HPV vaccination. These communication strategies mirrored Shoup et al.'s successful social media intervention that facilitated interaction with parents through a newsletter, blog, discussion forum, chat room, and portal to ask questions (19). In the current study, eight bi-weekly emails were distributed through MailChimp (Rocket Science Group, LLC, Atlanta, GA), which tracked newsletter open rate. The research team posted to the private Facebook message board ~5 times each week. Researchers posted information and facts about HPV vaccination, shared current news stories, and promoted engagement through polls and discussion prompts. Participants completed a pretest survey, three online asynchronous focus groups, a posttest survey, as well as a longitudinal follow-up survey at 6 months.

Participants and Setting

Participants included parents living in South Carolina who were committed to increasing HPV vaccination and were *active users* (post at least once per week, log-in at least once per day) of Facebook **and** Twitter. A screening tool was used prior to enrollment in the study. For this feasibility study, we recruited participants who were committed to increasing HPV vaccination and dedicated to starting conversations (online and in-person) and answering questions about HPV vaccination in their social networks. Participants were recruited through word of mouth, email messages, social media posts, and at relevant meetings and events. As a result, snowball sampling occurred when participants recommended additional participants. Participants received an incentive for their time and effort in the study, including \$100 after completing the 3-month training and \$20 for completing the longitudinal follow-up at 6 months. Informed consent was obtained through Qualtrics by all parents prior to participation.

HPV Vaccination Champions Intervention

The development of the intervention was informed by best practices in implementation science (26, 30) and based on a successful technology-mediated HPV vaccination awareness intervention for college students (29). Messages and health education information were adapted for parents based on formative audience research (8, 31, 32). Content was delivered through a private Facebook group, bi-weekly emails with facts about HPV vaccination, and two online webinars about HPV vaccination (see **Figure 1**). Eight emails were sent to participants on a bi-weekly basis that included topics such as: What is HPV? Who is at risk? Can HPV and HPV-related cancers be prevented? (see **Table 1**). Participants attended two live online webinars lasting ~1 h each, which were also archived on Facebook. The first webinar covered "What is HPV Vaccination?" and addressed common misconceptions. The second webinar covered "How to be an Effective Spokesperson for HPV vaccination" online and in-person. Participants engaged in a private Facebook group, responding to polls, posting messages, and asking questions of one another (peer-to-peer), as well as experts on the research team.

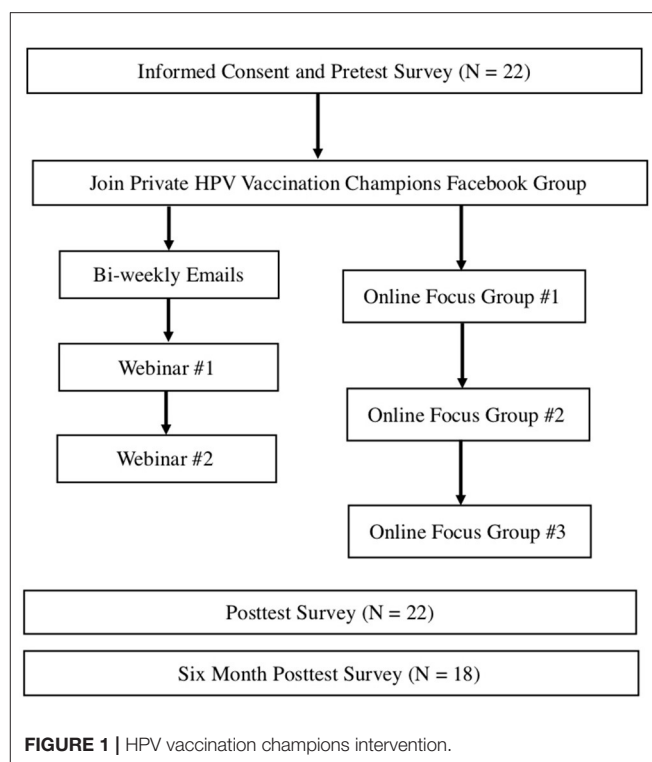


TABLE 1 | Bi-Weekly emails with facts about HPV vaccination ($n = 22$).

Email	Topics	Open
1	What is HPV?	15 (68.2%)
2	Who is at risk for HPV?	7 (31.8%)
3	Can HPV and HPV-related cancers be prevented?	10 (45.5%)
4	Does HPV cause symptoms?	9 (40.9%)
5	What are the risks and benefits of HPV vaccination?	8 (36.4%)
6	Who should get the HPV vaccine?	12 (54.5%)
7	Where is the HPV vaccine available?	8 (36.4%)
8	How can I get involved in HPV vaccination efforts in our state?	14 (63.6%)

The goals of the 3-month online training were to help HPV vaccination champions explain HPV vaccination recommendations, discuss the importance of HPV vaccination and the risks of HPV-related cancers and disease, describe ways an ambassador can increase HPV vaccination by supporting vaccination and overcoming barriers, provide examples of activities to engage in as an ambassador (e.g., letters to the editor/op-eds; social media posts), and understand resources to support champions. The webinars were designed to respond in real time to the questions and concerns participants expressed during online focus groups and the private Facebook group.

Questionnaires

Participants completed a questionnaire at baseline (pretest) and post-intervention at 3 months (posttest) and 6 months (longitudinal follow-up). The questionnaires investigate awareness and knowledge of HPV and the HPV vaccine, attitudes and beliefs about HPV and the HPV vaccine, and behavior/behavioral intention regarding HPV and the HPV vaccine. The measures were drawn from a variety of sources and have proven to be reliable and valid, including the Health Information National Trends Survey (HINTS), the Behavioral Risk Factor Surveillance System (BRFSS), TTM, HBM, and surveys of young adult populations (33–38), which enable comparison of our results from those of prior studies. Baseline demographic characteristics self-reported at pretest included age, gender, race, level of education, health insurance status, income, county of residence, and technology use. Surveys were administered online through Qualtrics (Provo, UT).

Intervention Engagement

Engagement was assessed objectively on web-based platforms (Facebook and MailChimp). Engagement with bi-weekly emails was defined as the number of participants who opened the email, which was obtained from MailChimp metrics. Engagement with the private Facebook group was measured by the number of interactions, including post likes, comments, and original posts.

Treatment Satisfaction

The online focus groups and the posttest and longitudinal follow-up questionnaires assessed how satisfied participants were with the training by rating its overall usefulness and likelihood of recommending it to a friend. Level of satisfaction with specific intervention components (e.g., emails, Facebook group, and webinars) was also reported. All items were rated on an agreement-oriented 7-point Likert scale anchored with strongly agree and strongly disagree.

Statistical Analysis

All data were reported as frequencies and response rates were reported as percentages of the total sample population. Basic descriptive statistics were used to describe the sociodemographic characteristics, participants' use of technology and participant retention rates. For analysis of technology use, cell phone included responses of "receive a text message on a cell phone," "send a text message on a cellphone" and "use a cellphone to make or receive a voice call." Hourly included responses of "about once an hour" and "more than once an hour." Daily included responses of "about once a day" and "several times a day." Weekly included responses of "up to about once a week" and "a few times a week." Friedman's test was used to compare pretest, posttest and 6-month follow-up responses within participants' intention to vaccinate their child against HPV. Responses were ranked in order of 1 = "I am unsure about my intention to get my child vaccinated" to 11 = "My child has received all three shots of the HPV vaccine." Exact McNemar's tests were used to compare pretest and posttest responses for each question of HPV and HPV vaccination knowledge. Responses were recoded as binary to designate correct answers as "1" and incorrect answers or

"don't know" as zero. The overall average of correct responses was analyzed from composite scores calculated from the sum of correct responses per individual. A paired *T*-test was used to compare the pretest and posttest composite score for the overall scale, given the continuous distribution of these data. Wilcoxon Signed-Rank tests were used to compare pretest and posttest responses of HPV and HPV vaccination attitudes. Responses were ranked in order of 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree, and 6 = don't know. For analysis, agree included responses of "strongly agree" and "agree." Disagree included responses of "strongly disagree" and "disagree." For analysis of HPV vaccination influence, influence included responses of "strongly influenced" and "influenced." For analysis of participant intervention experience, extremely included Likert scale responses of "4" and "5." A *p*-value ≤ 0.05 was used to determine statistical significance for all analyses. All data analyses were conducted using SAS statistical software version 9.4 (SAS Institute, Cary, North Carolina).

Focus Groups

Participants were invited to participate in three online asynchronous focus groups. Focus groups allow researchers to better understand socially constructed understandings of HPV and HPV vaccination. The first focus group addressed knowledge, attitudes, and beliefs about HPV vaccination. Questions included myths/misunderstandings about HPV vaccination. The second focus group addressed communicating about HPV vaccination, including challenges and opportunities to improve in-person conversations and constructing media messages. The third focus group asked specifically about the HPV vaccination champions intervention, including visibility of messages in the community, perceptions of messages, needs/preferences for future messaging, successes and opportunities for improvement.

Research shows that online focus groups include many advantages, such as convenience, accuracy of data, low costs, expanded geographic range, and increasing access to specific types of participants (e.g., parents), while preserving the quantity and quality of data collected during in-person groups (39, 40). In line with Levine et al.'s evidence-based approach, during a 5-day period, researchers posted one question per day on the private Facebook group and participants responded within a set time frame at their own pace (39). Since online focus groups require a skilled moderator, the first author moderated all focus groups and relied on response elicitation techniques, such as sharing summaries, offering feedback, and frequently encouraging comments to promote participation and engagement (40). Participants responded to questions at their convenience in the comfort of their homes, which can result in longer and more detailed responses and optimal group discussion than traditional focus groups (39, 40).

Qualitative Analysis

Qualitative data analysis of the online focus groups was conducted using a constant comparative method (41). Researchers with graduate level qualitative training coded line-by-line, which allowed new concepts to emerge. A codebook

TABLE 2 | Baseline characteristics and retention rates.

Characteristic	Total (N = 22)
Age (SD), years	40.2 (6.6)
Sex, n (%)	
Female	21 (95.4%)
Male	1 (4.5%)
Hispanic, n (%)	
No	22 (100)
Race, n (%)	
White	20 (90.9%)
Black or African-American	2 (9.1%)
South Carolina County, n (%)	
Anderson	1 (4.5%)
Berkeley	2 (9.1%)
Charleston	7 (31.8%)
Chesterfield	2 (9.1%)
Darlington	1 (4.5%)
Dorchester	1 (4.5%)
Greenville	3 (13.6%)
Kershaw	1 (4.5%)
Oconee	1 (4.5%)
Sumter	3 (13.6%)
Health Insurance Status, n (%)	
Private Insurance	22 (100%)
Education, n (%)	
High school diploma/GED	1 (4.5%)
Some college education	2 (9.1%)
Undergraduate education	6 (27.3%)
Some graduate education	3 (13.6%)
Graduate degree	10 (45.4%)
Household Income, n (%)	
\$30,000–\$49,999	3 (13.6%)
\$50,000–\$69,999	5 (22.7%)
\$70,000 or more	14 (63.6%)
Technology Use (%)	
Cell Phone ^a	
Hourly Use	30.3%
Daily Use	62.6%
Weekly Use	7.1%
Monthly Use	0%
Never Use	0%
Computer	
Hourly Use	9.1%
Daily Use	45.5%
Weekly Use	22.7%
Monthly Use	9.1%
Never Use	13.6%
Multiple Devices ^b	
Hourly Use	22.7%
Daily Use	59.1%
Weekly Use	13.6%

(Continued)

TABLE 2 | Continued

Characteristic	Total (N = 22)
Monthly Use	4.5%
Never Use	0%
Retention rates, n (%)	
Posttest	22 (100%)
6-month follow-up	18 (82%)

^aCell phone use includes responses of “receive a text message on a cell phone,” “send a text message on a cellphone,” and “use a cellphone to make or receive a voice call.”

^bHourly includes responses of “about once an hour” and “more than once an hour.”

Daily includes responses of “about once a day” and “several times a day.”

Weekly includes responses of “up to about once a week” and “a few times a week.”

was developed based on extant literature and emergent concepts. Axial coding identified cross-cutting themes and concepts in the data. Researchers met frequently throughout the implementation and evaluation of the intervention and reached unanimous consensus on conclusions emerging from the data.

This study was approved by the Institutional Review Board at the College of Charleston.

RESULTS

Participants included 22 parents with a median age of 40.2 ± 6.6 years. Most participants self-identified as female (95.4%) and white (90.9%). Participants lived in counties across South Carolina with representation from each of four regions in the state, including the Upstate Region, Midlands Regions, Lowcountry Region, and Pee Dee Region. All participants reported private health insurance coverage. Participants' education ranged from a high school diploma (4.5%), some college (9.1%), an undergraduate degree (27.3%), some graduate education (13.6%), and a graduate degree (45.4%). All participants reported an annual household income above \$30,000 with the majority reporting \$70,000 or more (63.6%). Among participants, 62.6% reported using a cell phone every day and 30.3% reported using it every hour. Almost half of participants (45.5%) reported using a computer every day with 9.1% reporting hourly use. The majority of participants reported using multiple devices every day (59.1%) with 22.7% reporting hourly use of multiple devices. All participants completed the posttest survey and the retention rate at the 6-month longitudinal follow-up was high (82%) (see **Table 2**).

HPV Vaccination Knowledge, Attitudes, and Behaviors

At baseline, half of participants ($n = 11$; 50%) reported “my child has received all shots of the HPV vaccine series,” 9 participants (40.9%) indicated “I plan to get my child vaccinated at the recommended age,” and 2 participants (9.1%) reported “I am unsure about my intention to vaccinate/I do not plan to get my child vaccinated in the next 6 months” (see **Table 3**). Following the intervention, two participants changed from being unsure to planning to vaccinate at the recommended age. There were no

TABLE 3 | Intention to vaccinate child against human papillomavirus (HPV).

	Pre (n = 22) %	Post (n = 22) %	6-month follow-up (n = 18) %
Action Stage:			
My child has received all shots of the HPV vaccine series	50%	50%	50%
Preparation Stage:			
I plan to get my child vaccinated at the recommended age	40.9%	50%	50%
Contemplation Stage:			
I am unsure about my intention to vaccinate/I do not plan to get my child vaccinated in the next 6 months	9.1%	0%	0%

*Friedman's test compared pre-post and 6-month follow-up responses for intent to vaccinate their child against HPV.

statistically significant differences between pretest, posttest and 6-month follow-up responses within participants (Table 3).

At pretest, all participants (100%) knew that HPV can be spread through sexual intercourse, HPV can cause an abnormal Pap (cervical cancer screening) test, and some types of HPV can cause cervical cancer. Fewer participants were aware that HPV can be spread through contact other than sexual intercourse (77.3%) and that some types of HPV can cause oral cancer (81.8%). Participants reported changes in knowledge from pretest to posttest, particularly learning that "some types of HPV can cause anal cancer," "condom use does not fully protect against the spread of HPV" and "an HPV infection cannot be cured." Overall, there was a statistically significant difference in the average of correct answers from pretest and posttest ($p = 0.0042$) (Table 4).

Participants reported high perceptions of HPV vaccination benefits, barriers and severity; however, they reported low susceptibility. Parents' attitudes about HPV and HPV vaccination

TABLE 4 | Human papillomavirus virus (HPV) and HPV vaccination knowledge.

	Pre (n = 22)		Post (n = 22)		Difference in change at posttest (p-value)*
	n	%	n	%	
Some types of HPV can cause anal cancer. Correct answer: True	17	77.3%	21	95.4%	4 (0.001)
Condom use fully protects against the spread of HPV. Correct answer: False	15	68.2%	19	86.4%	4 (0.0075)
An HPV infection can be cured. Correct answer: False	15	68.2%	19	86.4%	4 (0.0075)
Some types of HPV can cause oral cancer. Correct answer: True	18	81.8%	21	95.4%	3 (<0.001)
HPV can be spread through contact other than sexual intercourse. Correct answer: True	17	77.3%	20	90.9%	3 (0.0007)
Some types of HPV can cause genital warts. Correct answer: True	20	90.9%	22	100%	2 (<0.001)
People who have been infected with HPV might not have symptoms. Correct answer: True	21	94.4%	22	100%	1 (<0.001)
HPV can cause an abnormal Pap (cervical cancer screening) test. Correct answer: True	22	100%	22	100%	0
HPV can be spread through sexual intercourse. Correct answer: True	22	100%	22	100%	0
Some types of HPV can cause cervical cancer. Correct answer: True	22	100%	22	100%	0
Women who get the vaccine still need regular Pap (cervical cancer screening) tests. Correct answer: True	21	95.4%	21	95.4%	0
Overall average of correct responses	9.54	10.50	0.0042		

* Exact McNemar's tests compared pre-post responses for individual items, dichotomized as correct vs. incorrect/don't think. A paired T-test compared pre-posttest score for the overall scale.

TABLE 5 | Human papillomavirus (HPV) and HPV vaccination attitudes.

Health belief model constructs	Pre (n = 22) %	Post (n = 22) %
Benefits:		
“Getting the HPV vaccine would help my child stay healthy.”		
Agree	100%	100%
“Getting the HPV vaccine would benefit a significant other or partner.”		
Agree	100%	100%
“Getting the HPV vaccine would be a benefit to society.”		
Agree	100%	100%
Severity:		
“A vaccine that prevents a sexually transmitted infection is a good idea.”		
Agree	100%	100%
“A vaccine that prevents HPV-related cancer is a good idea.”		
Agree	100%	100%
“A vaccine that prevents genital warts is a good idea.”		
Agree	100%	100%
“Having genital HPV would make it difficult for someone to get a long-term sex partner.”		
Disagree	59.1%	54.5%
Barriers:		
“My healthcare providers would approve of my child getting the HPV vaccine.”		
Agree	100%	100%
“My family would approve of my child getting the HPV vaccine.”		
Agree	95.4%	95.4%
“My religious institution would approve of my child getting the HPV vaccine.”		
Agree	81.8%	77.3%
Susceptibility:		
“My child is likely to get a genital HPV infection in his/her lifetime.”		
Agree	45.4%	50%
“My child is likely to develop HPV-related cancer in his/her lifetime.”		
Agree	18.2%	22.7%
“My child is likely to develop genital warts in his/her lifetime.”		
Agree	18.2%	13.6%

*Wilcoxon Signed-Rank tests compared pre-posttest responses for HPV and HPV vaccination attitudes.

mirrored the constructs of the Health Belief Model except related to perceptions of susceptibility. There were no statistically significant differences between responses (Table 5).

At baseline, participants identified factors that influenced their HPV vaccination decision. “Concerns about my child getting other HPV-related cancer” and “concerns about my child getting HPV” were the most frequently identified statements (Figure 2).

Participants Described Why They Supported HPV Vaccination

Parents supported the HPV vaccination as cancer prevention. According to one participant, “my daughter was immunized for HPV: Vaccine vs. cervical cancer. The choice is clear.” Another parent said, “I support the HPV vaccine because I’m all for cancer prevention.” Among these supporters of HPV vaccination, the parents agreed, “any opportunity to prevent cancer is foolish not to take advantage of.” Some participants shared a personal connection to HPV or HPV-related cancer that increased their commitment to vaccination. According to one participant, “...I’ve seen how devastating cervical cancer is. My aunt’s MIL got it in her forties. She had so many complications from the cancer and treatments and ended up dying within 2 years of being diagnosed.” Another parent wrote, “...being someone who has HPV, I am definitely for the vaccine. My daughter has already had the vaccine and my son will when he is old enough.” Prior to the intervention, participants already knew that HPV was ubiquitous and that it caused precancerous cervical lesions, as well as cancer. For example, one participant wrote, “I support the vaccine because I think it is important! HPV is so prevalent and yet easy to protect yourself.” Another parent supported the vaccine because, “I’ve known too many young women scared because of precancerous cells due to HPV.” Among this group of parents, HPV vaccination was common sense. According to one parent, “it seems obvious to me that if you have a means to protect yourself and your children then you should take advantage of it, therefore, vaccinate.”

Participants Described Barriers to HPV Vaccination Among Parents

Parents discussed conversations they had in their everyday lives about HPV vaccination. Participants revealed the most common barriers to HPV vaccination among parents in their social networks. Misinformation about HPV vaccination emerged related to safety and side effects, gender, understanding of risk, and sexual activity. A number of participants described vaccine hesitancy toward specific vaccines, including the HPV vaccination. According to one parent:

A lot of people I talk to seem to break vaccines down into two groups, the ones that they consider absolutely necessary (tetanus, polio) and the ones that they consider less important/optional (chicken pox, mumps). Often HPV is grouped in the second category and the reasoning is often based on fear of side effects combined with a lack of appreciation of the impacts of the diseases.

Another participant concurred, “while they are generally pro-vax they’ve heard that this one has a lot of documented injuries associated with it.” Parents described hearing comments about injuries and deaths related to the HPV vaccine.

Understanding the HPV vaccine as a gender-specific vaccine was also a prominent theme among parents in the participants’ social networks. According to one participant, “parents of boys don’t see how it applies to their son at all.” Participants also believed that many parents continued to link the vaccine with sexual activity. Parents explained how this opinion impacted vaccine decision-making, “it isn’t relevant for preteens since it

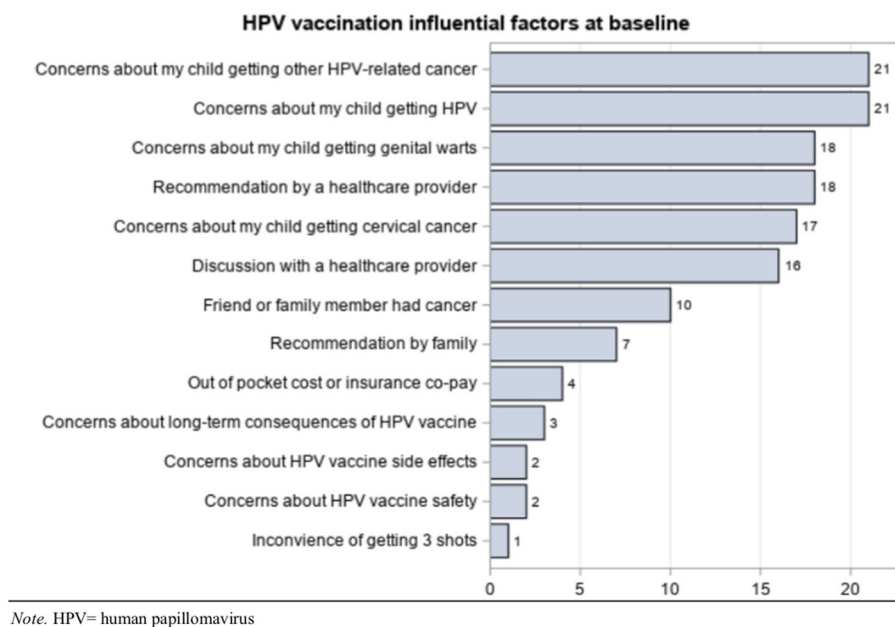


FIGURE 2 | HPV vaccination influence.

is sexually transmitted,” and “their kid is too young for sex yet anyway.” According to one participant, “I usually hear it is because their kid is not sexually active or out of fear that will condone their younger child to become sexually active.” Another parent offered a compassionate response to this concern:

I have heard many mothers say they didn’t want their child to get the vaccine because they weren’t sexually active and didn’t plan to become sexually active for years. A pediatric nurse practitioner that I work with has always had the best response to that with “Your daughter is a princess but she may not marry a prince 1 day.” That usually resonates with parents and they end up choosing to vaccinate.

Participants suggested parents who have opted for the vaccine have not been as vocal about it as those with concerns. The prevalence of the virus itself and HPV-related cancers was also overlooked in parents’ social networks. According to one participant, “as a parent, I know cancer is a worry for pretty much all parents. But I don’t think parents realize how common HPV related cancers are.”

Intervention Engagement and Treatment Satisfaction

The electronic newsletter showed moderate penetration with an average of 47.2% of participants opening the bi-weekly email (see **Table 1**). The majority of participants opened emails about “What is HPV?” (68.2%), “Who should get the HPV vaccine?” (54.5%), and “How can I get involved in HPV vaccination efforts in our state?” (63.6%). On the private Facebook page, all posts had one or more interactions by participants (i.e., like, reaction,

or comment). On average, there were 3.3 comments per post on the private Facebook page.

Overall, participants rated the intervention positively (see **Table 6**). All participants (100%) indicated that they enjoyed participating in the intervention. Almost all participants (90.9%) found the bi-weekly emails and posts on Facebook to be valuable, indicated that the Facebook group was useful in helping them learn about HPV vaccination, and reported that they would recommend the program to a friend. Most participants reported that the bi-weekly emails were useful in helping them learn about HPV vaccination (86.4%) and the majority of parents found the webinars to be valuable (68.2%). Most parents (86.4%) found the training valuable in helping them become more confident in starting conversations (online or in-person) about HPV vaccination).

Participants Reported High Intervention Engagement and Treatment Satisfaction

Through the online focus groups and open-ended responses on the posttest and longitudinal follow-up surveys, parents unanimously described the benefits of the intervention. Participants appreciated the ease of use and convenience of the private Facebook group, which streamlined seamlessly with their existing social media habits. According to one participant, “I liked the interaction and instruction on Facebook.” Participants demonstrated an increase in knowledge about HPV vaccination. One participant wrote, “I definitely know a lot more about HPV and the HPV vaccine (especially with regard to its impact on men).” Parents described improved confidence and the ability to talk more freely with other parents. According to

TABLE 6 | Intervention experience.

Items	Post (n = 22) %
How much participants enjoyed participating in the program.	100%
Extremely	
How useful the Facebook group was in helping participants learn about Human Papillomavirus (HPV) vaccination.	90.9%
Extremely	
How helpful or valuable participants found the posts on Facebook.	90.9%
Extremely	
How much participants would recommend the program to a friend.	90.9%
Extremely	
How helpful or valuable participants found the bi-weekly emails.	90.9%
Extremely	
How useful the bi-weekly emails were in helping participants learn about HPV vaccination.	86.4%
Extremely	
How helpful or valuable the training was in helping participants to become more confident in starting conversations (online and/or in-person) about HPV vaccination.	86.4%
Extremely	
How helpful or valuable participants found the Webinars.	68.2%
Extremely	

one participant, “one of the main benefits to me was getting confident with the facts about the HPV vaccine and HPV vaccination rates in S.C.” Another parent wrote, “it has helped to open conversations and given me the opportunity to educate others.” The longitudinal follow-up showed that participants were still using the training 6 months later by filming videos as advocates, joining advocacy groups, and holding many discussions about HPV vaccination with the people in their lives. The training also offered unexpected opportunities for participants to improve communication about HPV vaccination with their children and their patients. According to one participant, “I am a nurse practitioner and going through this program helped me relay to my patients the importance of the HPV vaccine.” Participants expressed gratitude for the program and emphasized how useful it was to them personally. They particularly enjoyed the aspects of the program focused on improving online and in-person communication and suggested the program include more of this practical skills-based training, such as crafting social media posts.

DISCUSSION

To our knowledge, this is the first evaluation of a collaborative online learning environment to train and support parents to

serve as champions for HPV vaccination. The format and content of this technology-mediated intervention was well-accepted by participants. Results indicate the 3-month training program increased knowledge about HPV and HPV vaccination. Overall, there was a statistically significant difference in the average of correct answers from pretest to posttest ($p = 0.0042$) (Table 4). In line with previous studies, participants reported that the intervention addressed important gaps in knowledge about men’s susceptibility to HPV and the link between HPV and oropharyngeal and other head and neck cancers (42). At the start of the intervention, the majority of participants were in the action stage of intention to vaccinate their child against HPV. Following the intervention, two participants changed from the contemplation stage to the preparation stage. As anticipated in a sample of participants who were already committed to increasing HPV vaccination prior to the intervention, changes in knowledge, attitudes, and behavioral intentions were modest.

Participants’ intervention engagement and treatment satisfaction indicate that this approach provides utility and scalability among parents. All participants (100%) indicated that they enjoyed participating in the intervention. The electronic newsletter showed moderate penetration with an average of 47.2% of participants opening the bi-weekly email. However, this information was repeated in the private Facebook group, offering two ways for participants to engage with the material at their convenience. All Facebook posts had one or more interactions by participants with an average of 3.3 comments per post. Parents reported that Facebook was easy to use, convenient, and provided an optimal platform for instruction and interaction. This finding expands existing research demonstrating that interactive forums empowered parents to express vaccine concerns and offered opportunities to provide answers in real time (16).

Participants described how other parents in their social networks displayed vaccine hesitancy toward the HPV vaccination despite an overall pro-vaccination attitude. This finding builds on limited research aimed at determining different types of vaccine hesitancy (43). Parents reported misinformation about HPV vaccination related to safety and side effects, gender, understanding of risk, and sexual activity that remained prevalent in their social networks. Results reflect recent research that safety concerns were the most common reason parents chose not to start the HPV vaccine for unvaccinated adolescents (44). In line with our formative audience research, this study also identified misinformation related to gender, understanding of risk, and sexual activity as barriers to HPV vaccination (31, 32). Results provide evidence that health communicators and public health professionals should consider using social media platforms to disseminate science-based information about the safety of vaccines (7). In the current study, the majority of participants reported using multiple devices every day (59.1%) with 22.7% reporting hourly use of multiple devices, indicating that parents are reachable online.

Most parents (86.4%) believed that the intervention resulted in improved confidence and the ability to talk more freely about HPV vaccination with other parents in-person and on social media. This finding supports the effectiveness of

connecting vaccine-interested parents with those who are like-minded in order to assist them in countering vaccine hesitancy and misinformation on social media (6). This study offers an innovative approach to effectively address the spread of rumors about HPV vaccination on social media (43). Participants suggested parents in their social networks who have opted for the vaccine have not been as vocal about it as those with concerns. This research answers the call to action by researchers to assist parents who support vaccination to speak out easily and often by providing information that is simple and shareable online (6).

Study Limitations and Strengths

This mixed methods study offers an innovative approach to reach parents to overcome barriers to HPV vaccination. Participants represented counties across four regions of South Carolina. However, the homogeneity of the population and small sample size limit the generalizability of the results. Future studies should purposively sample diverse parents, especially in terms of race and ethnicity. Researchers may consider less stringent screening criteria, increased participant incentives, more targeted recruitment, and a budget for recruitment to improve diversity in future studies. Another limitation of the study is the largely single gender population of mothers. Although future studies may seek to incorporate more fathers, it is important to continue to target women since mothers serve as the primary decision makers for adolescents receiving HPV vaccination (13–15). It is also important to focus on raising the voices of women who support vaccination because the majority of participants on anti-vaccination Facebook pages are women (11).

This feasibility study offers a model of cultivating HPV vaccination champions in a community setting and demonstrates potential for scalability and dissemination of this intervention approach (24–27). In the context of the pandemic, this technology-mediated intervention offers an innovative model to combat the proliferation of anti-science and anti-vaccine messaging. Specifically, the automated delivery of bi-weekly emails and Facebook posts offers an opportunity to scale the intervention among larger groups of parents with limited resources. Participants demonstrated high treatment satisfaction and robust engagement in one of the first technology-mediated HPV vaccination training programs for parents. This study benefited from a high retention rate and longitudinal evaluation, including a 6-month follow-up survey. The use of objective measures and qualitative assessment of the intervention, including online focus groups, were additional study strengths.

CONCLUSION

A technology-mediated intervention for parents increased their confidence and motivated them to speak more freely about HPV vaccination in-person and online with others in their social networks. The collaborative online learning environment cultivated HPV vaccination champions through a 3-month training program that supported parents to serve as proponents and social media influencers to overcome

barriers to HPV vaccination. Participants identified prevalent misinformation about HPV vaccination and learned how to effectively craft messages to address concerns related to safety and side effects, gender, understanding of risk, and sexual activity. Objective measures and qualitative open-ended assessment showed high intervention engagement and treatment satisfaction. The effectiveness of this feasibility study suggests that social media is an appropriate platform to reach parents with HPV vaccination information that is simple and shareable in-person and online. This study combined education and health promotion messages with skills-based communication training to empower parents to raise their voices in support of HPV vaccination.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because the informed consent procedure guaranteed participants in this study that only authorized study staff would have access to the data. Requests to access the datasets should be directed to BLS@cofc.edu.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Institutional Review Board (IRB) at the College of Charleston, Charleston, SC. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BS and KC contributed to conception and design of the study. NR organized the database and assisted with project management. AW assisted with project management and conducted quantitative data analysis. BS performed the qualitative analysis. BS and NR wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Testing Messages on Facebook to Promote Use of an HPV Educational Web-Intervention

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In the US, the human papillomavirus (HPV) vaccine remains underutilized leading to disparities in HPV-related diseases. Latinx have some of the highest rates of cancer caused by HPV. In a previous study, we developed a tailored-messaging based online educational intervention (CHICOS) that was found to increase HPV vaccination intention among Latinx participants. The current research uses Facebook Advertising to test the comparative effectiveness of messages designed using the Extended Parallel Processing Model (EPPM) to promote the use of CHICOS among Latinx young adults and parents of adolescents. We also looked at differences in the effectiveness of messages that highlighted HPV-related cancers, genital warts, or a control condition as well as differences in Spanish vs. English messages. Results found Latinx young adults and parents, were more likely to click on Facebook Advertisements containing messages in Spanish and those that mention cancer risks pertinent to this population compared to those in English or messages that discuss genital warts. Thus, findings suggest that Facebook Advertising has the potential to be a useful tool for motivating information seeking online about HPV vaccination.

Keywords: HPV vaccination, vaccine hesitancy, fear appeals, persuasion, health communication, social media, dissemination & implementation research

INTRODUCTION

Human papillomavirus (HPV) is the most common sexually transmitted infection worldwide (1). Latinx have higher rates of HPV-related cancers compared to other groups in the United States (1). Previous research demonstrates the efficacy of health communication efforts that are customized to include culturally relevant information (2–5). The current study presents a comparison of health messages aimed at promoting HPV information seeking as a means for encouraging HPV vaccination among a Latinx audience.

The burden of HPV infection exacts a significant emotional, financial, and medical toll (6, 7). Although rates of HPV infection are similar across nearly all race and ethnicity groups, there are significant disparities in HPV-associated cancers among Latinx. For example, Latinas have the highest risk of developing cervical cancer when compared to all other US population groups—similarly, Latinos have the highest risk of developing penile cancer (1, 7–10). Additionally, Latinx experience higher rates of other HPV-related illnesses like genital warts, abnormal Pap smears, anal cancer, and oropharyngeal cancer (6).

Although a vaccine for HPV has been available and recommended by the Centers for Disease Control and Prevention (CDC) for the past 10 years for routine use among all adolescents ages 11 years and older, US vaccination rates continue to remain low (11). As of 2019, it is estimated that only 56.8% of girls and 51.8% of boys ages 13–17 nationally were up-to-date on the HPV vaccine series (11). Vaccination series completion rates are even lower among Latinx adolescents (46.2% for girls, 35.0% for boys) and significantly below the national vaccination target level of 80% coverage (12). Without significant increases in HPV vaccination, especially among high-risk populations, disparities in HPV-related cancers and other diseases are likely to continue. Thus, there is an urgent need for interventions that employ culturally-targeted strategies to reduce these disparities.

In a previous study, we developed a web-based educational intervention targeting Latinx parents of adolescents and young adults, called CHiCOS (13). CHiCOS uses responses to a series of survey items to provide personally tailored information about HPV. Results from a randomized controlled study comparing CHiCOS to “usual care” demonstrated that exposure to CHiCOS led to increased intention to vaccinate for HPV. These increased intentions unfortunately did not lead to subsequent increases in vaccination receipt. Later analysis indicated that this lack of effect was most likely due to logistical barriers to receiving the vaccine. Given that positive intentions are recognized as a necessary upstream factor to successful vaccination (14–19), the CHiCOS intervention can be added to the growing list of evidence based communication strategies to improve vaccination intention.

Thus, CHiCOS presents the opportunity to further explore methods for the dissemination of evidence-based communication interventions which increase HPV vaccination intent. Previous attempts to disseminate similar web-based interventions in healthcare office waiting rooms have produced lack-luster results (13)—demonstrating the need to discover alternative methods for disseminating CHiCOS in a manner that stimulates the health information seeking behavior necessary to engage with the website. Health information seeking is particularly relevant as previous research has demonstrated its role in promoting HPV vaccine intentions (20–22). For the purposes of the current study, the primary outcome of interest is to stimulate use of the CHiCOS website—a form of health information seeking specific to HPV vaccination—via social media advertising. As such, the primary aim of the current study is to compare the effectiveness of different messages for promoting HPV information seeking via CHiCOS.

The Extended Parallel Process Model [EPPM; (23)] is a theoretical framework for designing messages that has previously proven successful for promoting HPV vaccination (24, 25). The EPPM posits that message design strategies that highlight risk *severity* and the target audiences' *susceptibility* must be coupled with messages prompting *self-efficacy* and *response efficacy* in order to effectively persuade individuals to take protective action (26). As people may underestimate their susceptibility to and the severity of HPV-related diseases (27–31)—especially cancers outside of cervical cancer including those that affect men (i.e., anal, penile, and oropharyngeal cancers)—the EPPM is a particularly relevant theoretical framework for designing messages to promote HPV vaccination. Previous research on

using the EPPM to design messages related to HPV vaccination has primarily focused on intention to vaccinate as the primary outcome (32). However, other work has demonstrated the utility of the EPPM for promoting health information seeking in areas such as meningitis vaccination (33).

Results of previous studies demonstrate that message content (cervical cancer vs. genital warts) may differently influence parents' vs. young adults' intention to vaccinate [cf. (25)]. However, these messages have not been explicitly tested among a Latinx population—a group with distinct cultural norms and values related to sexual health and healthcare decision making. The current study extends this line of research. We posit the following hypotheses and research questions:

H1: Among Latinx parents of HPV-vaccination eligible adolescents, messages focusing on HPV-related cancers will lead to higher information seeking via CHiCOS (i.e., link click-through rates) than messages focusing on genital warts.

H2: Among Latinx young adults, messages focusing on genital warts will lead to higher information seeking via CHiCOS (i.e., link click-through rates) than messages focusing on HPV-related cancers.

RQ1: Do messages containing EPPM variables lead to higher click-through rates than messages without these variables?

RQ2: Does message language affect click-through rates?

MATERIALS AND METHODS

The current study compared message effectiveness for promoting use and dissemination of CHiCOS, a web-based educational intervention [previously described in detail, see (13, 34)]. We used Facebook Advertising to test nine messages designed using the EPPM (see **Figure 1**) and employed a $2 \times 3 \times 2$ mixed factorial design that compared two key decision-making audiences (Latinx young adults vs. parents of adolescents), three message topic frames (genital warts vs. cancer vs. control), and two message languages (English vs. Spanish). Per the EPPM, messages in the cancer and genital warts frames included *susceptibility* and *severity* information specific to Latinx populations, as well as *response efficacy* statements emphasizing the effectiveness of the HPV vaccine. *Self-efficacy* for seeking information about the HPV vaccine was induced by directing users to a link where more information about HPV could be found (i.e., the CHiCOS website). Messages in the control frame were written to be intentionally vague, did not mention cancer or genital warts, and did not meet criteria for containing all EPPM message components.

Facebook Advertising was chosen as the method of study for its popularity and ability to reach target audience members, the capacity to embed website links to the CHiCOS website in advertising messages, and Facebook's role in facilitating health information seeking (35, 36). Advertisement sets were created for each message frame containing three advertisements, each with a different message from the frame (see **Figure 1**). All advertisements used the same stock photo of multicultural youth. To comply with Facebook's requirements for establishing a source account to sponsor advertisements, we created a Facebook

Messages were also translated into Spanish for a total of 6 messages frames.

Genital Warts

- HPV infection—the leading cause of genital warts—is highest among those ages 14–24. The HPV vaccine is nearly 100% effective at preventing these infections. [Click here](#) to get more info about how you can prevent HPV.
- Most Americans will be exposed to HPV by the time they turn 25. Nearly 90% of genital wart cases can be prevented by getting vaccinated for HPV. [Click here](#) to find out what you need to know about HPV.
- Approximately 3 out of 4 people will get genital warts after having any kind of genital contact with someone infected. The HPV vaccine protects against infections that cause 90% of genital wart cases. [Click here](#) to get answers to your questions about HPV.

Cancer

- This year 4,100 women will die from cervical cancer. The HPV vaccine is 98% effective at preventing infections that cause cervical cancer. [Click here](#) to get answers to your questions about HPV.
- HPV—the leading cause of cervical and penile cancer—will infect 14 million Americans this year. The HPV vaccine is 98% effective at preventing these infections. [Click here](#) to get more info about how you can prevent HPV.
- Hispanic men have higher rates of HPV-associated penile cancer than non-Hispanic men. Getting vaccinated against HPV can prevent more than 60% of incidents of penile cancer. [Click here](#) to find out what you need to know about HPV.

Control

- HPV is a harmful disease. [Click here](#) to get more info.
- You can prevent HPV by getting vaccinated. [Click here](#) to get more info.
- HPV is linked to the development of other dangerous diseases. [Click here](#) to get more info.

FIGURE 1 | Message frames.

Page with information about the CHiCOS website. The account for this page was then used as the sponsoring source for all advertisements (see **Figure 2**). Facebook advertisements ran for 39 consecutive days in October and November 2017.

Subjects

Facebook's advertising settings provided the ability to target different population groups for the study. Messages were targeted to Latinx young adults using the Facebook Advertisement criteria: Ages 18–27, Behaviors: Multicultural Affinity: Hispanic (US - All), and geographically relevant to the study team (i.e., Denver metro area) zip codes with high Latinx populations. Similarly, Latinx parents of adolescents were targeted using the criteria: Ages 28–65 (to exclude overlap with young adult

advertising sets), Behaviors: Multicultural Affinity: Hispanic (US - All), Parents, and Denver metro area zip codes with high Latinx populations. Different zip codes were used for each message frame advertising set (see **Figure 1**) so that users did not overlap between the six message conditions. Using population data for each zip code, we created advertising sets that were estimated to reach 18,000–19,000 unique users each.

Data Sources

Data were collected using Facebook analytics, Google analytics, and CHiCOS website paradata in order to determine the comparative effectiveness of message frames based on each advertisement's performance metrics. The primary outcome of interest was click-through rates to the CHiCOS

FIGURE 2 | Example of facebook advertisements.

website—wherein, for the purposes of our study, information seeking behavior was defined as clicking on a link embedded in each advertisement that led to the CHiCOS website.

Facebook Analytics

Metrics provided by Facebook included: (1) Reach - the number of unique users who saw the ad at least once, (2) Impressions - the number of total times the ad was on screen for the targeted audience, (3) Frequency - the average number of times each user saw the ad, (4) Link clicks - the number of clicks on a link within the ad that led to the CHiCOS website, and (5) Link click-through rate (CTR) - the percentage of times people saw the ad and performed a link click (i.e., link clicks/impressions), (6) Unique link clicks - the number of unique users who clicked on the website link (i.e., removes duplicate link clicks by the same user), and (7) Unique CTR - the percentage of unique users who saw the ad and performed a link click (37).

Since Facebook uses a proprietary algorithm to determine the priority by which it places advertisements in users' timelines, parameters for controlling the reach of ads were not entirely within our control. Our goal was for each ad set to reach at least 3,000 users in order to compare performance of our primary outcome (Unique CTR). However, Facebook does not allow advertisers to place limits on Reach - only on the total amount of money spent for each ad. Thus, for the purposes of this study, Reach serves as an outcome that reflects ad performance as the algorithm adjusts to extend the reach of certain ads that produce more results (e.g., higher engagement) early on and to limit the

reach of ads that produce lower results. This algorithm frequently changes and Facebook does not disclose the exact parameters they use to extend or limit ad reach.

Google Analytics

Metrics provided by Google analytics (which was installed on the CHiCOS website) included: (1) Sessions - the period time a user is actively engaged with the website, (2) Pageviews - the total number of web pages viewed on the website, (3) Avg. session duration - the average time length of a session, (4) Page depth - the average number of pages viewed during a session, (5) Bounce rate - percentage of sessions with only one page view out of all sessions (38). Google analytics tracked the website referral source (Facebook) using unique referral links embedded into different advertising message frames. Thus, we were able to track the above metrics for each message frame.

CHiCOS Website Para-Data

The CHiCOS website reported metrics on the total number of time spent on the website (for users who registered to use the site by clicking the continue button on the landing page), as well as whether or not (True/False) the user completed the survey items used to tailor the educational messaging.

Analysis

Descriptive statistics as well as chi-square tests for categorical data, and z-tests and g-tests for proportions, were used to examine differences between groups (H1-2, RQ 1-2).

TABLE 1 | Facebook analytics for reach, impressions, and frequency by message frame.

Message frame	Reach	Impressions	Frequency	$\chi^2(p)$
Parents				171.16 (<0.001)
Cancer English	4,066	11,101	2.73	
Cancer Spanish	5,465	19,807	3.62	
Control English	4,099	10,672	2.60	
Control Spanish	5,654	18,005	3.18	
Genital Warts English	6,316	18,089	2.86	
Genital Warts Spanish	6,375	17,930	2.81	
Young adults				52.87 ($p < 0.001$)
Cancer English	6,338	25,079	3.96	
Cancer Spanish	6,157	23,480	3.81	
Control English	6,650	22,993	3.46	
Control Spanish	7,719	23,810	3.08	
Genital Warts English	6,894	23,602	3.42	
Genital Warts Spanish	7,348	23,797	3.24	
TOTAL (Reach, Impressions)	73,081	238,365		
AVG. (Frequency)			3.23	

RESULTS

Facebook Analytics

Overall, messages reached 73,081 Facebook users and generated 238,365 impressions for a frequency of 3.23 impressions per user. **Table 1** provides a breakdown of all reach, impression, and frequency data by message frame for parents and young adults.

A chi-square test of independence was performed to examine the relation between language and message frame. For both parents and young adults, the relationship between these variables was significant [parents: $\chi^2(1, N = 31,975) = 171.16, p < 0.001$; young adults, $\chi^2(1, N = 41,106) = 52.87, p < 0.001$]. Across both parents and young adults, advertisements in Spanish reached more users than messages in English—and messages that mentioned genital warts reached more users than messages about cancer or the control condition.

Overall, Facebook advertisements produced 2,159 total link clicks and 1,552 unique link clicks to the CHiCOS website across all message conditions. The overall Unique CTR was 0.9% (per impression) and the unique CTR was 2.12% (per user reached). **Table 2** provides a breakdown of link clicks and CTR by message frame for parents and young adults.

For Latinx parents, messages reached 31,975 users and generated 676 Unique link clicks for an average Unique CTR of 2.10%. Messages mentioning cancer had a significantly higher Unique CTR (2.49) than control (1.89) and genital warts message (1.91, $p = 0.001$)—thus, our hypothesis that cancer messages would produce higher CTR among Latinx parents (H1) was confirmed. Spanish messages had a higher overall Unique CTR (2.35) than English messages ($p = 0.001$, RQ2).

For Latinx young adults, messages reached 41,106 users and generated 876 Unique link clicks for an average Unique CTR of 2.15%. Messages mentioning cancer had a significantly higher Unique CTR (2.55) than control (1.93) and genital warts messages (1.96, $p = 0.001$)—disconfirming our hypothesis that genital wart messages would produce higher CTR among Latinx young adults (H2). There were no significant differences in the overall Unique CTR for English (2.14%) vs. Spanish messages (2.12%).

Google Analytics

Session metrics from Google Analytics demonstrated similar numbers for total new visitor website sessions (1,592; with confirmed referrals from Facebook) when compared to Facebook Analytics' Unique link clicks (1,552). **Table 3** provides a full breakdown of Google Analytics metrics by message frame for parents and young adults. Across both user groups, the bounce rate was high, 92.58%—indicating that the majority of users did not proceed past the first page of the website. For those that did proceed past the first page of the website, the average session duration was 24.64 seconds with a page depth average of 1.21 pages per user session.

Additionally, Google's analytics showed that, in addition to the 1,592 new visitor sessions, 261 users returned the CHiCOS website at least once generating 565 additional sessions (for a total of 2,157 sessions). The bounce rate was similarly high among returning users (92.21%); however, average session duration was considerably longer at 53.01 seconds.

CHiCOS Website Para-Data

While Facebook advertising messages produced 1,552 link clicks to the website, paradata tracking new users to the website showed that only 11 people interacted with the website—and of those, only three people completed the survey items necessary to receive the personally tailored educational materials. The average time among those who interacted with the website was 8:52 minutes.

DISCUSSION

The current study provides evidence that using Facebook advertising was an effective means for promoting information seeking about HPV vaccination via the CHiCOS website. Overall, messages in Spanish were more effective at reaching Latinx young adults and parents of adolescents than were messages in English. Among Latinx parents, messages that mentioned the relationship between HPV and cancer produced higher proportions of information seeking behavior (i.e., unique CTR) than messages that referenced genital warts or the control messages. However, among Latinx young adults, we did not find the reverse trend (as we hypothesized in H2)—that is, messages mentioning genital warts did not generate higher unique CTR than messages about cancer or the control messages.

Messages that contained all four elements as prescribed by the EPPM did not consistently outperform messages without (i.e., the control message frame). This finding provides further support for results of a previous message testing study where survey participants were shown the same messages used here

TABLE 2 | Facebook analytics for link clicks and CTR by message frame.

Campaign name	Link clicks	CTR (link click-through rate)	Unique link clicks	Unique CTR (link click-through rate)	G (p)	z (p)
Parents						
Cancer English	91	0.82	77	1.89		
Cancer Spanish	279	1.41	169	3.09		
Control English	77	0.72	69	1.68		
Control Spanish	155	0.86	119	2.10		
Genital Warts English	155	0.86	119	1.88		
Genital Warts Spanish	166	0.93	123	1.93		
Cancer Avg.				2.49	13.4	
Control Avg.				1.89	(0.001)	
Genital Warts Avg.				1.91		
English Avg.				2.35		0.16
Spanish Avg.				1.82		(0.001)
Young adults						
Cancer English	201	0.80	158	2.49		
Cancer Spanish	267	1.14	161	2.61		
Control English	166	0.72	128	1.92		
Control Spanish	205	0.86	150	1.94		
Genital Warts English	204	0.86	140	2.03		
Genital Warts Spanish	193	0.81	139	1.89		
Cancer Avg.					14.5	
Control Avg.					(0.001)	
Genital Warts Avg.						
English Avg.						0.16
Spanish Avg.						(0.873)
TOTAL (Clicks)	2,159		1,552.00			
AVG (CTR)		0.90		2.12		

containing a hyperlink to “more information” (Reno and Dempsey, unpublished manuscript). Alternatively, participants could choose to continue on in the survey without clicking the hyperlink. In this study, participants who received a control message were more likely to click the hyperlink than those who received either the cancer or genital warts messaging. Furthermore, when asked to report the extent to which a message made them “feel frightened,” participants who received the control messages consistently reported higher levels of fear than those who received the cancer or genital warts messages containing statements of severity and susceptibility designed to induce fear. Thus, further research is needed to understand the role of message design in promoting information seeking, particularly about HPV vaccination. It may be that messages that present a more veiled threat (as opposed to containing explicit susceptibility and severity statements) are more likely to inspire information seeking behavior.

We had 261 users total who visited the website more than once, demonstrating that messages disseminated via Facebook advertising were effective at stimulating initial information seeking behavior (i.e., clicking on a link for more information). However, our study did not produce evidence this information seeking behavior was carried out once users reached the CHiCOS website, as demonstrated by the high bounce rate even among repeat users—although there is some evidence that repeat users

invested more time in information seeking via CHiCOS as their total time spent on the website (i.e., avg. session duration) was longer than new users. This may be due to limitations in the design of the CHiCOS website where users were first instructed to complete a short survey before receiving personalized information about the HPV vaccine. Thus, it stands to reason that users were not compelled to seek information to the extent needed to complete the survey items before receiving more information about the HPV vaccine. Further research is necessary to determine type of message content and format sufficient to engage users in HPV information seeking.

LIMITATIONS

A primary limitation to the current work is the format of the CHiCOS website. We have inferred from the data based on the large discrepancy between those who clicked on the link to the website and those who completed the survey questions necessary to view the educational information about HPV that the design of the website may be a primary barrier to additional information seeking. However, it is also probable that the messages delivered via Facebook advertising were insufficient to inspire prolonged information seeking behavior. The design of the study is limited in its ability

TABLE 3 | Google analytics data.

Shared URL	Sessions	Pageviews	Avg. session duration	Page depth
Parents				
Cancer English	100	118	5.44	1.24
Cancer Spanish	232	284	10.92	1.23
Control English	74	81	2.72	1.08
Control Spanish	125	161	60.37	1.31
Genital Warts English	144	162	12.76	1.11
Genital Warts Spanish	151	197	24.68	1.28
Young adults				
Cancer English	177	197	47.85	1.11
Cancer Spanish	241	285	44.63	1.20
Control English	143	182	19.18	1.26
Control Spanish	217	264	18.24	1.24
Genital Warts English	182	229	34.31	1.26
Genital Warts Spanish	173	204	14.58	1.20
Total (Sessions, Pageviews), Avg. (Session duration, Page depth)	1,959*	2,364	24.64	1.21

*This number is based on direct referrals from Facebook. Google Analytics showed an additional 200 sessions during this time that may be the result of users navigating to the CHiCOS website from Facebook through other pathways instead of directly clicking the link within Facebook advertisements. Thus, they were not counted here as they did not use the unique links we embedded in advertisements to track differences in message frame performance.

to substantively differentiate between these two plausible explanations. Thus, further research is needed to determine the ability of Facebook advertising to promote information seeking and dissemination of web-based interventions for HPV.

Additionally, the limitations inherent to the secrecy of the Facebook algorithm impeded our ability to control for variations in advertisement reach and impressions. Thus, while this approach provided a pragmatic test of comparative message effectiveness for promoting the dissemination and use of CHiCOS, we cannot construe the extent to which variations in reach and impressions were due to aspects of the message or of the function of the algorithm. Future research should further explore the utility of Facebook Advertising for this type of A/B

message testing—a feature that has more recently been added to the Facebook Advertising platform (37).

CONCLUSION

Overall, results suggest that Facebook Advertising is an effective means for disseminating and inspiring interest in web-based health information resources about HPV vaccination. As vaccine hesitancy continues to grow, it is essential to identify effective means to deliver accurate information about vaccines such as the HPV vaccine and other effective practices for promoting vaccination.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Colorado Multiple Institutional Review Board (COMIRB). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

JR was responsible for the overall content as guarantor. Both authors contributed to the planning, conduct, and reporting of the work described in the article.

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

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Understanding Human Papillomavirus Vaccine Promotions and Hesitancy in Northern California Through Examining Public Facebook Pages and Groups

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Human papillomavirus (HPV) vaccination coverage among adolescents is lower in rural regions and remains under the 80% coverage goal by Healthy People 2030. Through both sentiment analysis and topic modeling, this research examines how local health agencies and groups in nine Northern California counties promote HPV vaccines through Facebook and how target populations react to promotion posts in comments that elucidate their sentiments and hesitancy toward HPV vaccination. In January 2021, we identified 2,105 public Facebook pages and 1,065 groups related to health within the counties and collected a total of 212 posts and 505 comments related to the HPV vaccine. The posts were published between 2010 and 2021, with the majority (83%) published after 2017. There were large variations of Facebook activities across counties. We categorized four counties with HPV vaccination initiation rates below 40% as low-coverage counties and five counties with rates above 40% as high-coverage counties. In general, low-coverage counties had fewer Facebook activities in comparison to high coverage. Results showed that, on average, comments about the HPV vaccine exhibited more positive emotion, more negative emotion, and more anger than the posts. Overall, thematic topics that emerged from posts centered around awareness and screening of HPV and cervical cancer, STI testing services, information sources, and calls to action for health services. However, comment topics did not correspond to posts and were mostly related to vaccine hesitancy, discussing vaccine risks, safety concerns, and distrust in vaccine science, citing misinformation. When comparing high- versus low-coverage counties, posts expressed similar sentiments; however, comments within high-coverage counties expressed more anger than in low-coverage counties. Comments from both high- and low-coverage counties expressed concerns with vaccine safety, risks, and injury. It is important to note that commenters exchanged information sources and tried to address misinformation themselves. Our results suggest that the promotion of HPV vaccines from public Facebook pages and groups is limited in frequency and content diversity. This illustrates problems with generalized social media vaccination

promotion without community tailoring and addressing specific hesitancy concerns. Public health agencies should listen to the thoughts of targeted audiences reflected through comments and design relevant messages to address these concerns for HPV vaccination promotion.

Keywords: HPV vaccine, vaccine hesitancy, Northern California, Facebook, social media, topic modeling, sentiment analysis

INTRODUCTION

Human papillomavirus (HPV) vaccination can effectively prevent infection from the HPV types that can cause certain cancers, including almost all cases of cervical cancer (1, 2). The U.S. Centers for Disease Control and Prevention (CDC) recommends routine HPV vaccination at age 11 or 12 years (can start as early as 9 years) and for everyone through age 26 years (3, 4). Despite the public health implications of full vaccination coverage, HPV vaccination rates remain below the Healthy People 2030 goal of 80% (5). Among adults aged 18–26, the percentage who ever received one or more doses of the HPV vaccine increased from 22.1% in 2013 to 39.9% in 2018 (6). In 2019, 54.2% of adolescents aged 13–17 were up-to-date with the HPV vaccine series, and 71.5% received at least one dose of the HPV vaccine (7). Furthermore, regional disparities in HPV vaccine uptake have been well-documented in the literature, with rural adolescents having lower HPV vaccination coverage than their urban counterparts (7, 8). The 2019 National Immunization Survey Teen (NIS-Teen) reported that adolescents living in non-metropolitan statistical areas (MSA) had about a 10% lower HPV vaccination coverage compared with adolescents living inside MSA central cities (7).

Systematic reviews attribute low rates of HPV vaccination coverage to a multitude of factors, such as limited parental knowledge and awareness of the HPV vaccine, lack of a provider recommendation, and concerns about the side effects and efficacy of the vaccine (9, 10). Many of these factors are shaped and influenced by online and offline information exposure and communication about the vaccine. Vaccine hesitancy, generally defined as the “delay in acceptance or refusal of vaccination despite the availability of vaccination services,” (11) has been particularly associated with online communications surrounding vaccines. Because the internet and social media make sharing information, narratives, and opinions easy, bypassing traditional checking, and gatekeeping processes, the resulting information environment is in abundance of contradictory and incomplete information (12, 13). There are extant efforts in vaccine promotions through social media by public health groups and institutions, and research evidence has documented the effectiveness of using social media-based interventions for increasing vaccine knowledge and acceptance (14, 15). While, on the contrary, exposure to anti-vaccine information, including misinformation, has been shown to negatively influence vaccination attitudes, and decisions (16, 17). Social media has facilitated the spread of misinformation, and several studies have documented the

prevalence of anti-vaccine sentiments (18, 19). The major types of HPV vaccine misinformation include conspiracy theories, unsubstantiated claims, and risk of vaccine injury (20). In addition, technical infrastructures, including social media recommendation algorithms, interaction designs, and social network structures, can create and reinforce anti-vaccine communities (21, 22), leading individuals to be more extreme in their misbeliefs.

Effective pro-vaccination communication on social media is urgently needed to promote HPV vaccination through targeted social media channels to combat growing Internet HPV misinformation. Few research studies have investigated HPV vaccination promotions by local organizations and groups on social media, and even less is known about the dynamics of how social media users respond to different kinds of promotional messages. Recent research has shown that user reactions and comments are likely to deviate from the purposes of the original messages, and their different opinions can influence the opinions of other viewers toward vaccines (23). Thus, it is important to examine the distributions of user engagements to targeted public vaccine promotion messages.

This research examines how local health agencies and groups in nine counties of Northern California (i.e., Alpine, Amador, El Dorado, Merced, Nevada, Placer, San Joaquin, Stanislaus, and Yolo counties) promote HPV vaccines through Facebook. These nine counties were selected because HPV vaccination coverage in this region is below the state and U.S. (24), and a previous study revealed a great extent of hesitancy toward HPV vaccine among these communities (25). Through examining location-specific Facebook public pages and groups, we examine how target populations react to promotion posts in comments that reveal their sentiments and their hesitancy in terms of different discussion topics toward HPV vaccination. In addition, we compare how online posts and comment discussions differ between counties with higher vs. lower HPV vaccine initiation rates. Findings have significant implications for guiding the public promotion and communication of HPV vaccination on social media.

LITERATURE REVIEW

Despite national and state-wide efforts to increase adolescent HPV vaccination coverage to 80% (26), data from the California Immunization Registry (CAIR), the statewide immunization information system, revealed that, in 2018 only, about half of adolescents in California completed the HPV vaccine series

by their 13th birthday; and coverage varied greatly by county (26). Previous research found HPV vaccine hesitancy sentiments expressed by agricultural workers, rural communities, and Slavic communities residing in Northern California, and, analogously, CAIR has documented lower HPV vaccination rates in counties with a larger proportion of these communities. For example, based on data from CAIR, only 8.0–23.4% of preteens aged 13 years old in California rural counties have been documented as having completed their HPV vaccine series. Among the counties with the largest agricultural productions, HPV vaccine series completion ranged from 22.7–37.4%, and, among the counties with the largest Slavic communities, HPV vaccination series completion ranged from 28.0–38.2% (USDA) (27). These findings indicate that there is a need to examine why rates are low among some Northern California counties, especially those with communities that have expressed increased HPV vaccine hesitancy. In addition, it is important to understand the perceptions of these communities regarding the HPV vaccine to provide recommendations for health providers and public health professionals to address these disparities in coverage.

To understand perceptions and feelings about HPV vaccinations, traditional methods may be difficult for reaching diverse target audiences, in addition to social desirability biases relating to self-report (28). One approach to reach specific populations, as well as to obtain unobtrusive and naturalistic data, is through examining emergent discussions on social media. Most U.S. adults have used at least one social media platform, and Facebook remains to be one of the most popular social media sites; about 69% of U.S. adults report using Facebook (29). Furthermore, the majority of U.S. adults use Facebook regardless of race, income, and urban/rural residence (29), among which certain demographic factors have been associated with vaccine hesitancy.

For the current research context, previous research showed that Facebook was cited as the most utilized social media platform among the nine California counties, and addressing social media misinformation was identified as a strategy for combating HPV vaccine hesitancy in these communities (25). With the ability to utilize online geolocation tools to pinpoint community public pages and groups, we aim to hone in on examining areas with low vaccination rates. Analyzing the communication dynamics within Facebook groups and pages would enable researchers to examine the attitudes and opinions of users toward HPV vaccination.

Content analysis, using both qualitative and computational quantitative methods, has been conducted to document the content characteristics of social media data. Several studies revealed that users have often expressed negative sentiments over the vaccine, as well as posting and sharing misinformation on social media. For example, Luisi (30) analyzed 6,506 public HPV vaccine-related Facebook posts published within the first decade, following the FDA's first HPV vaccine approval, and found negative sentiments dominated the posts, and negative posts received significantly more user engagements. Furthermore, time effects suggest that few anti-HPV vaccine posts have encouraged more anti-HPV vaccine posts. Kearney et al. (31) analyzed 360 Instagram posts about the HPV vaccine and found a higher

proportion of posts were pro-vaccine compared with anti-vaccine. However, anti-vaccine posts were liked significantly more than pro-vaccine posts. Less than 30.0% of the posts came from health-related sources.

While most content analyses are focused on examining social media posts, very few examine the comment sections, which can reflect more of the reactions and opposing thoughts of the target audiences to the posts. The tendency for social media users to express more negative sentiments and engage with anti-vaccine information will likely be observed in the comment section. In many cases, the comments may drive audiences away from understanding and engaging with the promotional messages from the original posts (23). Therefore, one direction to move this line of research forward is to examine the interactions between posts and comments and to document empirically how they diverge in contents regarding the HPV vaccine. Specifically, posts created on Facebook relating to HPV vaccination may elicit emotional comments from the community, and posts may or may not address or influence the discussion agenda of the views and questions of the target audiences about the vaccine. Thus, understanding the sentiments and contents of both posts and comments are important to gain a full picture of how audiences react to information relating to the vaccine. Furthermore, findings can better inform public health professionals on how best to construct messaging for HPV vaccination promotion and for reducing hesitancy toward the vaccine.

In addition to examining the differences between posts and comments, it is also important to understand differences between counties with high or low HPV vaccination coverages. Research suggests that U.S. regions that have expressed negative views about the HPV vaccine on social media, including discussions of misinformation and safety concerns, may have contributed to low HPV vaccination coverage in that region (12). Using similar computational approaches, Zhang et al. (32) demonstrated that the thematic topics discovered from Twitter discussions were significantly associated with vaccination behavioral indicators collected from national surveys. Differences in discussions surrounding the vaccine, as well as differences in strategies to promote the HPV vaccine, may indicate why there are disparities between high- and low-coverage counties. Analyzing the content topics of posts from high-coverage counties may provide insights into constructing effective vaccine promotion strategies. Furthermore, examining the sentiments and the topics of posts and comments within low-coverage counties may inform future messaging interventions to tackle these issues and promote positive attitudes toward the HPV vaccine.

Lastly, another angle to understand the social media space is to examine HPV vaccination promotion efforts across public pages and groups. Public pages are often set up by organizations or institutions to broadcast messages to their audiences. For example, a county public health page may post about an upcoming vaccination clinic. In contrast, public groups are often set up by individuals and act as a group of individuals that discuss issues relating to their own interests. Previous research examining social media posts related to cervical cancer suggests that organizational senders are often more successful in spreading vaccine-promoting information than individual

users (33). We thus expect different sentiments and thematic topics across the public pages and groups, given their different motivations and interests in vaccine discussions.

In sum, we address the following research questions. First, how do posts and comments about HPV vaccination differ in terms of sentiments and thematic topics? Second, how do counties with high vs. low HPV vaccination initiation rates differ in posts and comments on dimensions of sentiments and thematic topics? Third, how do public pages and groups differ in posts and comments on dimensions of sentiments and thematic topics? While examining the datasets, we also documented additional observations that may be insightful for understanding local HPV vaccine hesitancy and discussing social media messaging strategies for the target communities.

METHODS

Data Collection

To systematically trace the HPV vaccine promotions on Facebook in the targeted regions, we designed multiple data searching and collection strategies. The first step was to compile a list of keyword combinations of locations and public health interests to identify location-specific health-relevant public pages and groups where HPV vaccine discussions were likely to occur. On locations, because there are multiple cities and census-designated places located within a county, we considered both county-level and city/place-level searches and compiled a list of 60 location keywords across the nine counties (see **Supplementary Material**). On public health interests, we used a list of eight keywords (e.g., health, hospital, community clinic, see **Supplementary Material**). In total, the combinations yielded 480 unique search terms. We performed the searches on Facebook, using a web scraping tool, Selenium Python (34). Then, a team of four trained research assistants screened the relevance of the resulting pages and groups. Pages and groups were excluded if (1) they were private or closed (i.e., not public); (2) they were not related to the specific location (e.g., cities with the same name but in another county or state); (3) their languages were non-English; and (4) they were about pets or animals, but not human (e.g., animal vaccination). This careful screening yielded 2,105 public pages and 1,065 public groups.

Next, we leveraged Facebook's CrowdTangle data monitoring platform to search within the pages and groups for HPV vaccine-related posts (35). We compiled the initial sets of search keywords to be broadly relevant to all vaccines, expecting that some comments may contain HPV vaccine discussions even when the posts did not directly address them. The search terms included 40 keywords, covering vaccines, in general (e.g., vaccine, vaccination, vax, shot), and specific types of vaccines, in particular (e.g., cancer vax, Gardasil, flu shot, MMR vax) (see **Supplementary Material** for the full list). As expected, a significant number of retrieved posts contained information about other vaccines, especially with a large increase of COVID-19 vaccine posts since December 2020. Therefore, for the focus of the current project, we applied careful human checking on the relevance of the posts to HPV discussion. The four trained research assistants screened the posts and the comments, and the

posts were excluded (1) if they were about general vaccination or other specific vaccines but did not mention HPV or the HPV vaccine and (2) if they were about pets or animals, but not humans (e.g., animal vaccination). After irrelevant posts were removed, we retained a total of 212 posts on HPV vaccination and 505 comments. All data searches and collection were conducted in January 2021.

Statistical Analyses

We first used descriptive statistics to summarize the number of posts and their engagements in terms of comments, likes, and shares across the nine targeted counties. Then, we used the Linguistic Inquiry and Word Count (LIWC) program to analyze the sentiment and specific negative emotions of the posts and comments (36). LIWC is a computerized text analysis tool and has been widely used to examine sentiment, emotions, and psychological and linguistic styles by analyzing word usage (37).

Sentiment and emotions were measured by the percentage of affective lexicons extracted from the texts of each post or comment. We focused on two general sentiment indicators, positive sentiment (indicating the level of positive emotional expressions of the texts), and negative sentiment (indicating the level of negative emotional expressions of the texts), and three specific negative emotions, including anxiety, anger, and sadness, that are commonly represented when contextualizing vaccine hesitancy. Several studies examining social media vaccine contents have used LIWC (38, 39). For example, Faasse et al. (38) used LIWC to compare language usage in pro- and anti-vaccination comments in response to a high-profile Facebook post. The study analyzed 1,489 comments and analyzed similar emotional dimensions, including positive sentiment, anger, and anxiety. Similarly, Himelboim et al. (39) used LIWC to extract positive sentiment and negative emotions, including anger, anxiety, and sadness.

The sentiment and emotion indicators from LIWC range from 0 to 100%. Based on previous studies of social media data, the average levels for positive sentiment and negative sentiment are 5.48 and 2.14, respectively. The average levels for anxiety, anger, and sadness are much lower, i.e., 0.24, 0.75, and 0.43, respectively (36). We calculated the percentage of positive sentiment, negative sentiment, anxiety, anger, and sadness for each post and comment.

We conducted a series of Welch's unequal variance *t*-tests to compare the sentiment and emotion indicators between the sample of posts and the sample of comments. This test is appropriate for comparing samples with unequal sizes and/or variances. Using the same analytical approach, to explore regional variations, we then compared the indicators between the counties with higher vs. lower HPV vaccine initiation rates. Based on the statistics of HPV vaccine initiation rates, we divided the nine counties into two groups, one with five counties with initiation rates above 40% (including Merced, Placer, San Joaquin, Stanislaus, and Yolo) and the other of four counties with initiation rates below 40% (including Alpine, Amador, El Dorado, and Nevada). Last, to explore whether organizational accounts and individual accounts differ in their sentiment and emotion on HPV vaccine discussions, we compared the indicators of posts

and comments coming from the public pages that represent organizational accounts vs. the public groups consisting of individual accounts.

After analyzing sentiments, we used topic modeling, a statistical natural language processing approach to identify thematic topics from the datasets. We used Latent Dirichlet Allocation (LDA) (40), a widely used computational tool for finding underlying abstract topics, to identify thematic topics in the posts and the comments. In LDA, each post/comment is modeled as a mixture of topics, and each topic is a probability distribution over words. The LDA algorithm exploits word co-occurrence patterns to discover underlying topics. We used the package *gensim* in Python (41) to run the topic modeling. We extracted the number of topics based on optimized model perplexity (41). LDA reported the number of topics with keywords and their relative weights contributing to each of the topics. Two authors qualitatively analyzed the prominent keywords and their referent texts to arrive at meaningful interpretations of the latent thematic topics. To address the three research questions, we qualitatively compared differences in latent topics between posts and comments, between counties with higher vs. lower HPV vaccine coverage rates, and between public pages and groups.

RESULTS

HPV Vaccination Promotions and Engagements on Facebook Across the Nine Counties

We identified more than 3,000 public pages and groups relevant to health discussions in the targeted locations. However, the number of HPV-vaccine-related posts was small. In total, we retrieved 212 posts, with 505 comments, 1,239 likes, and 343 shares. **Figure 1** presents the number of posts and comments published over time. The posts were published between 2010 and 2021, with the majority (83%) published after 2017. It is worth noting that a large number of comments were from 2018 due to a highly engaging post from Placer county that generated 334 comments. This post was a standard educational post for the Preteen Vaccine Week, encouraging Placer residents to learn about crucial vaccines to protect their children. Like other similar posts from the identified pages, the post highlighted the HPV vaccine protects against cancer-causing infections for girls and boys. However, the comment section saw a heated debate between the anti-vaccine and pro-vaccine voices and involved sharing and correcting misinformation about the HPV vaccine.

Table 1 presents the summary statistics of posts and their engagements. The majority of posts (208, 98.11%) and comments (450, 89.11%) are from public pages. There were large variations of Facebook activities across the counties. The number of posts ranged from 0 to 71 ($M = 26.50$, $SD = 23.77$), and the number of comments ranged from 0 to 338 ($M = 2.38$, $SD = 23.21$). Besides, the number of likes was significantly correlated with the number of comments ($r = 0.21$) and shares ($r = 0.67$), and the number of comments and shares was also positively correlated ($r = 0.35$).

The lower-coverage counties only accounted for 15.09% of the total posts, 11.29% of the comments, 6.46% of likes, and 7.87% of shares. These suggest that locations with lower vaccination rates also experienced much lower levels of social media promotions and engagements concerning HPV vaccination.

Sentiments and Negative Emotions in Posts and Comments

Table 2 reports the summaries of average sentiments and negative emotions of posts. **Table 3** reports the same statistics regarding comments. We identified significant differences in sentiments in posts and comments. There was significantly more positive sentiment in comments ($M = 4.52$) than in posts ($M = 1.41$, $p < 0.001$), more negative sentiment in comments ($M = 1.91$) than in posts ($M = .49$, $p < 0.001$), and more anger in comments ($M = 0.56$) than in posts ($M = 0.02$, $p < 0.001$). These suggest user comments show higher levels of sentiment overall, both on the positive and negative dimensions. Importantly, the comments also express a significantly higher level of anger.

Latent Thematic Topics in Posts and Comments

From among all posts, we extracted seven topics. **Table 4** summarizes the thematic topics with keywords and associated example post texts. The topics covered overlapping themes with different emphases. Topic 1 centered on the promotion of STI testing for sexually active teens. Example posts called for STI testing and provided detailed information about testing sites. Topics 2 and 5 both revolved around raising awareness of HPV and cervical cancer, especially during January, the Cervical Health Awareness Month. Topic 2 emphasized more on educating women about HPV and cervical cancer, whereas, Topic 5 discussed more about cervical cancer prevention and provided information with frequent references to external websites. Topic 3 emphasized on cervical cancer screening as well but also called on actions for other types of cancer screening. Topic 4 seemed to involve more scientific explanations, aiming to explain disease transmission, and causes with keywords such as disease, transmit, and cause. Topic 6 was characterized by highlighting information sources related to the HPV vaccine, especially referring to government sources, with keywords such as *https*, *gov*, and *CDC*. Finally, Topic 7 aimed for calling for action and directing viewers to clinic locations and health services.

These seven topics in posts can be thematically categorized into two groups: the first group of posts aims to promote tests, screenings, and vaccination related to cervical cancer, such as Topics 1 (promotion of STI testing), 3 (cancer screening), and 7 (a call for action). The second group of posts aims to introduce more scientific information related to HPV, cervical cancer, and the HPV vaccine, such as Topics 2 (awareness of cervical cancer), 4 (HPV virus and disease transmission), 5 (awareness of cancer prevention), and 6 (information sources and links). The vaccine promotion strategies here are 2-fold: first, to rely mostly on delivering scientific and health information to

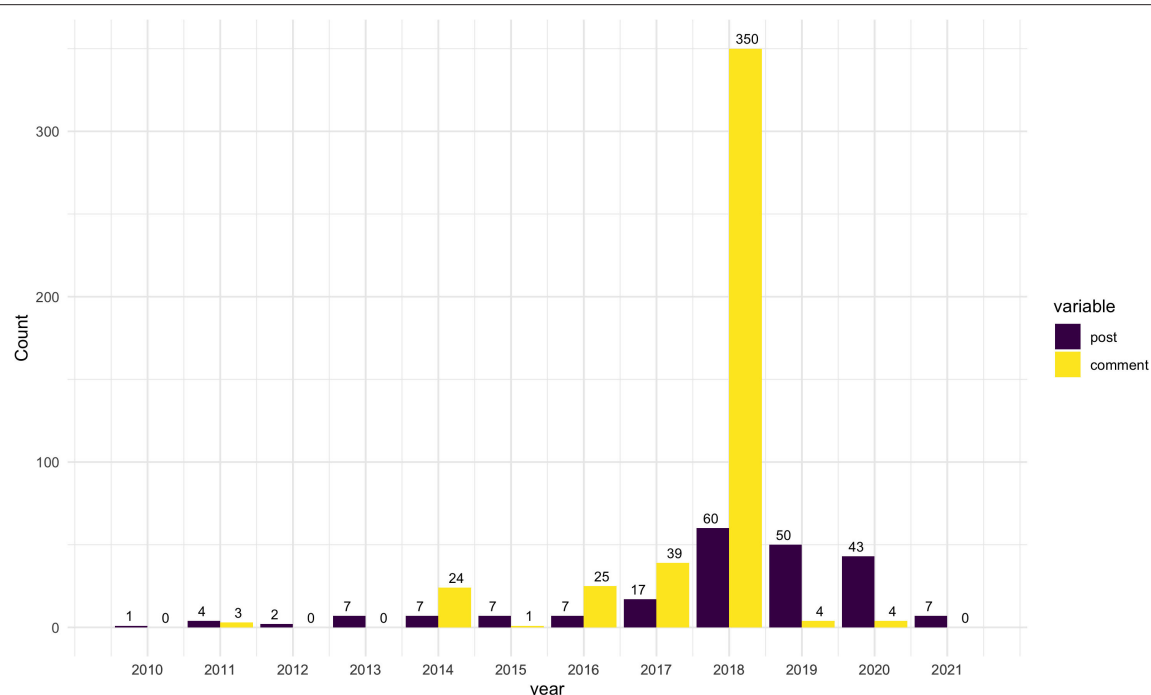


FIGURE 1 | The number of HPV vaccination-related posts and comments on Facebook per year from 2010 to 2021.

TABLE 1 | Summary statistics on HPV vaccination rates, the number of Facebook pages, groups, posts, and their engagements across the nine counties.

County	HPV vaccine initiation rate	HPV vaccine completion rate	Page (n)	Group (n)	Post (n)	Comment (n)	Like (n)	Share (n)
Alpine ^a	34.40%	17.30%	36	28	0	0	0	0
Amador ^a	34.40%	17.30%	70	67	2	0	4	0
El Dorado ^a	36.90%	19.60%	251	65	20	17	51	24
Merced	45.30%	22.70%	341	127	18	0	27	9
Nevada ^a	30.90%	15.20%	215	81	10	40	25	3
Placer	49.00%	27.60%	272	131	55	338	85	24
San Joaquin	53.50%	30.30%	289	162	14	2	85	21
Stanislaus	42.20%	21.60%	349	162	22	91	506	120
Yolo	46.20%	28.00%	282	242	71	17	456	142
Total	-	-	2,105	1,065	212	505	1,239	343

^aCounties with underlined HPV vaccine initiation and completion rates were classified as low-coverage counties.

educate the audiences on the benefits of the HPV vaccine and to raise awareness of cancer prevention and, second, to communicate timely and local service information about testing and vaccination.

Among comments, we also identified seven topics, which are completely different from the post topics. **Table 5** summarizes the thematic topics with keywords and associated example post texts. Six out of seven topics related to vaccine hesitancy. Topic 1 mentioned vaccine safety and injuries among children, and a few comments claimed that many pediatricians do not recommend the HPV vaccine, adding references to the VAERS website. Topic 2 was very specific about discussing the HPV vaccine package insert. While we observed anti-vaccine

commenters using the texts on vaccine side effects as evidence for vaccine risks and dangers, we also saw comments from pro-vaccine people on correcting the misinterpretation of the insert and asserting vaccine safety. Topic 3 focused on discussing scientific evidence for and against the HPV vaccine, with frequent debates on scientific studies. Some comments also contained multiple external websites and the misinformation that the HPV vaccine is banned in Japan. Topic 4 involved questioning information sources of the people and the validity of the source, with keywords such as source, time, post, and link. Topic 5 was more specific about addressing anti-vaccine claims, with keywords such as kill, insert, report, and article. Some comments mentioned anti-vaccine

TABLE 2 | Average sentiments and negative emotions of public Facebook posts about the HPV vaccine.

County	N (212)	Positive sentiment	Negative sentiment	Anxiety	Anger	Sadness
		M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Amador	2	2.28 (3.22)	0 (0)	0 (0)	0 (0)	0 (0)
El Dorado	20	0.64 (1.33)	0.60 (1.18)	0.25 (0.62)	0 (0)	0.11 (0.40)
Merced	18	2.76 (2.91)	0.31 (1.04)	0.16 (0.67)	0 (0)	0.08 (0.34)
Nevada	10	0.83 (1.75)	0 (0)	0 (0)	0 (0)	0 (0)
Placer	55	1.05 (1.44)	0.61 (1.25)	0.36 (0.90)	0 (0)	0.19 (0.67)
San Joaquin	14	0.94 (1.65)	0.65 (1.49)	0.42 (1.31)	0 (0)	0 (0)
Stanislaus	22	1.79 (3.82)	0.46 (1.32)	0 (0)	0.21 (0.97)	0 (0)
Yolo	71	1.60 (2.26)	0.47 (1.06)	0.34 (0.91)	0 (0)	0.11 (0.55)
Average	26.50	1.41 (2.27)	0.49 (1.15)	0.27 (0.82)	0.02 (0.31)	0.10 (0.49)

TABLE 3 | Average sentiments and negative emotions of public Facebook comments about the HPV vaccine.

County	N (505)	Positive sentiment	Negative sentiment	Anxiety	Anger	Sadness
		M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
El Dorado	17	17.26 (32.19)	0.82 (1.41)	0.17 (0.38)	0.13 (0.45)	0.14 (0.32)
Nevada	40	4.44 (8.21)	2.00 (3.45)	0.09 (0.38)	0.55 (2.25)	0.63 (2.32)
Placer	338	3.11 (5.49)	1.96 (3.16)	0.37 (1.23)	0.54 (1.69)	0.23 (1.53)
San Joaquin	2	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Stanislaus	91	6.97 (16.88)	2.26 (6.9)	0.20 (0.82)	0.87 (4.10)	0 (0)
Yolo	17	7.42 (13.31)	0.17 (0.71)	0 (0)	0 (0)	0.17 (0.71)
Average	85.83	4.52 (11.09)	1.91 (4.04)	0.30 (1.08)	0.56 (2.31)	0.21 (1.42)

articles with external links. Topic 6 emphasized vaccine and autoimmune diseases, with keywords of autoimmune, condition, and incidence. Comments discussed whether the HPV vaccine causes autoimmune diseases. Topic 7 was not related to vaccine concerns but rather characterized by frequent keywords used in communication interactions of commenters, such as saying “thank you” or agreeing with the other person with a yes.

Overall, we found the comment section covered prominent discussion topics around vaccine hesitancy. Topics 1 (vaccine safety and injuries), 2 (vaccine package inserts), and 6 (vaccine and autoimmune diseases) were all specifically about safety concerns, citing injuries, and harms. Topics 3 and 4 went beyond specific claims and engaged in more general concerns about scientific research evidence and the study information sources. These two reflect the root skepticism toward science that challenges the confidence of the public toward vaccination. Topic 5 was about addressing anti-vaccine information. While some commenters referred to anti-vaccine articles, others tried to counterargue them. It is interesting to note that Topic 7 reflected on the frequent communication exchanges among the commenters. It is clear that, although some commenters expressed vaccine skepticism or anti-vaccine attitudes, the comment section was not unidimensional, and some commenters were able to confront misleading or false information.

Differences in Sentiments, Negative Emotions, and Thematic Topics Between High-Coverage and Low-Coverage Counties

As discussed above, we divided the counties into high-coverage counties with an HPV-vaccine initiation rate of over 40%, including Merced, Placer, Stanislaus, San Joaquin, and Yolo, and low-coverage counties, including Alpine, Amador, El Dorado, and Nevada. There were fewer posts on HPV vaccination in low-coverage counties than in high-coverage counties. On average, posts in the low-coverage counties received fewer likes ($M = 2.50$) than the high-coverage counties ($M = 6.44$, $p = 0.01$) and, similarly, fewer shares ($M = 0.84$) than their counterparts ($M = 1.76$, $p = 0.03$).

Posts and comments in both groups of counties tended to have similar levels of sentiments. For posts, there were no significant differences across all dimensions of sentiment and emotions. However, for comments, there was a significantly higher level of anger in high-coverage counties ($M = 0.63$) than in low-coverage counties ($M = 0.23$, $p = 0.02$).

There were differences in the number of themes identified for HPV-related posts and comments in the two groups of counties. For low-coverage counties, there was only one topic in posts and five topics in comments; for high-coverage counties, there were four topics in posts and eight topics in comments (see **Supplementary Tables 1, 2**). The one topic of posts

TABLE 4 | Thematic topics, keywords, and example Facebook posts about the HPV vaccine.

Post topic	Keywords	Example
1. Promotion of STI testing	HPV, test, https, vaccine, free, parent, STI, www, need, sexually	...There is a teen health clinic at all CommuniCare locations. We offer STI testing, contraceptives and family planning. If you are sexually active, it is time to #GetTested.
2. Awareness on cervical cancer	cervical, health, HPV, cancer, awareness, women, https, month, january, papillomavirus	Cervical cancer was once one of the most common causes of cancer death for American women, but today the death rate is down by more than 50%, thanks to increased cancer screenings and human papilloma virus (HPV) vaccinations. This month, help spread awareness about the importance of the HPV vaccine for cancer prevention.
3. Cancer screening	cancer, HPV, screen, https, neck, vaccine, head, cancers, virus, risk	Do you smoke, drink alcohol, or are sexually active? If so, you may be at risk for cancer, and this FREE 10-min screening could save your life.
4. HPV virus and disease transmission	HPV, cancers, https, cancer, papillomavirus, human, vaccine, www, diseases, sexually	Human papillomavirus (HPV) is the most common sexually transmitted infection in the US according to the Centers for Disease Control and Prevention (CDC). Researchers report that throat cancers caused by the human papillomavirus, transmitted during oral sex, have increased significantly in the United States.
5. Awareness on cancer prevention	cancer, HPV, cervical, awareness, health, https, month, national, vaccination, risk	Your Cervical Health Begins with Prevention Awareness January is Cervical Health Awareness Month, and CommuniCare Health Centers wants you to know that there's a lot you can do to prevent cervical cancer. [link]
6. Information sources and links	HPV, vaccine, www, cancer, https, unite, gov, prevent, cervical, CDC	To learn more about cervical cancer screenings and the HPV vaccine, schedule a visit with your medical provider or click the following link: https://www.cdc.gov/cancer/cervical/basic_info/screening.htm
7. Call for action	cancer, HPV, cervical, vaccine, virus, test, years, women, oral, cause	January is Cervical Cancer Awareness Month. Have you gotten your Pap or HPV test yet this year? Call to schedule a screening today at a Valley Health Team location near you! Check out the link to learn more: https://www.cdc.gov/cancer/cervical/basic_info/screening.htm Did you know? "Two doses of the HPV vaccine are recommended for all boys and girls at ages 11–12; the vaccine can be given as early as age 9..." ~CDC Call Marshall Pediatrics for your vaccinations at (530) 626–1,144

The topics were ordered by the topic importance calculated with LDA. Keywords included top 10 keywords with the highest weights in a topic, ordered by weights. Examples were partially extracted from representative posts on this topic.

in low-coverage counties centered on providing HPV-related information and promoting testing. Whereas, the four topics of posts in high-coverage counties covered a more diverse set of information, including awareness of cervical cancer, HPV virus and disease transmission, educational information for women, and a call for action.

Comments in both groups of counties concerned with vaccine safety, risks, and injuries. In low-coverage counties, we extracted five topics. Topic 1 concerned vaccine package inserts, and Topic 3 was on vaccine scientific evidence. Interestingly, we extracted three slightly new topics from this sub dataset. Topic 2 mentioned alternative treatments for cancer, such as promoting natural remedies and downplaying vaccination. Topics 4 and 5 centered on child vaccination, with Topic 5 focus on vaccination especially for boys. These two topics reflect how people debate about the necessity for getting children the HPV vaccine and the confusion or doubts about HPV vaccination for boys. In contrast, the eight topics identified from comments of the high-coverage counties did not refer to specific concerns of children or boys; rather, they emphasized vaccine risks, autoimmune diseases, and questioning of information sources. Interestingly, although, the posts were all about HPV vaccination, some comments digressed to discuss mask-wearing for the COVID pandemic.

Differences in Sentiments, Negative Emotions, and Thematic Topics Between Public Pages and Public Groups

There were significantly more HPV-related posts by public pages ($N = 208$) than in public groups ($N = 4$). All public page posts were posted by the local government agencies or organizations setting the pages, and all group pages were by individual users. Regarding sentiments, public page posts tended to express more positive emotion ($M = 1.43$) than group posts ($M = 0.17$, $p < 0.001$). Besides, public page posts showed significantly more anxiety ($M = 0.28$) than group posts ($M = 0$, $p < 0.001$), and more sadness ($M = 0.10$) than group posts ($M = 0$, $p = 0.003$). Comments attached to public page posts tended to show more anxiety ($M = 0.32$) than those for group posts ($M = 0.10$, $p = 0.003$).

There were four topics identified for page posts and five topics identified for their comments (see **Supplementary Table 3**). For group posts, there were only two topics for posts and four for comments (see **Supplementary Table 4**). Public page posts mostly centered on awareness and knowledge promotion, STI testing, and screening. Group posts, in contrast, did not mention anything addressing cancer awareness nor promoting the HPV vaccine but rather digressed to discussing different types of

TABLE 5 | Thematic topics, keywords, and example Facebook comments about the HPV vaccine.

Comment topic	Keywords	Examples
1. Vaccine safety and injuries	vaccine, HPV, know, vaccines, CDC, injuries, children, want, doctor	Even many pediatricians don't recommend this vaccine. Linked to way too many injuries and deaths. Check the CDC and VAERS website. Very irresponsible post Placer County-I'm so saddened by this!
2. Vaccine package inserts	insert, information, vaccine, risk, report, efa, HPV, know, vaccines, CDC	If anyone has read an insert, what is the first line of section 6.1 and 6.2? Do you not know what the insert is? It only has premarketing information and it's a legal document. Current studies do prove the safety and efficacy of the vaccine. We want to see the insert and that is 100 % accurate and safe.
3. Scientific evidence on vaccines	HPV, https, base, study, vaccines, time, look, shoot, data, science	I understand some people are troubled by science based information. But you do not have a basis to assume others don't want facts and evidence. There's plenty of evidence. I personally know a court reporter who has sat in on multiple of these cases. Its everyone's choice obviously, I am just saying do some research before you start giving it to your kids. I can't speak to why an Irish politician called to ban a vaccine. But I expect most people understand that is not scientific evidence.
4. Questioning information sources	people, read, vaccines, vaccine, get, HPV, source, time, post, link	Again I ask for where you got your information. I personally have gotten vaccines with a patient information sheet which mentioned POSSIBLE risks. So again, this is false information. What are your sources?? Cancer is a virus. Read Dr Mary's monkeys some weeks ago I read possible natural cure which was guarantee And I ordered the treatment after 1 week I got 100% cure. I'm so excited to shear this testimony to every article for others living with HPV there is possible natural treatment to eliminate the virus email Dr Onokun, his herbal clinic address.
5. Discussing anti-vaccine information	vaccine, people, cancer, like, source, good, insert, study, HPV, link	Anyone watching the full video mentioned in the article above - from a panel organized by the National Meningitis Association, an organization of parents whose children were killed or disabled by vaccine preventable meningitis - would see the characterization of it in the antivaccine article is incorrect.
6. Vaccine and autoimmune diseases	vaccine, HPV, study, autoimmune, condition, people, group, disease, incidence, receive	Studies show HPV vaccines don't cause autoimmune diseases and paralysis. See my link above. Jennifer Robi is a 24-year-old former athlete and scholar who has been confined to a wheelchair since receiving her third Gardasil vaccines at age sixteen. She suffers continual uncontrolled neuro/muscular contractions (jerking) and postural orthostatic tachycardia syndrome (POTS) and many other symptoms of systemic autoimmune dysregulation.
7. User interactions within comment section	vaccine, CDC, read, yes, post, cancer, doctor, HPV, people, know	Thank you for sharing. Your link is terrific. Thanks.

The topics were ordered by the topic importance, calculated with LDA. Keywords included top 10 keywords with the highest weights in a topic, ordered by weights. Examples were partially extracted from representative posts on this topic.

viruses and vaccines, such as mentioning the COVID-19 and SARS in topic 1. Importantly, Topic 2 argued that the Gardasil vaccine caused death.

Given the large data size of comments from the public pages, it is the case that comment topics from the public pages were aligned mostly with the comment topics identified from the overall comment dataset, mentioning vaccine injury, the package inserts, and relevant evidence and information sources. In contrast, comment topics from the groups emphasized vaccine allergic reactions, mask-wearing, HPV vaccine injuries for children, and distrust toward vaccine science.

DISCUSSION

Social media and Facebook in specific should be used more often to inform and educate the public about HPV vaccination for disease and cancer prevention. Furthermore, given the interactive nature of social media, it is crucial to monitor public sentiments and concerns about the vaccine. As research has advocated for a long time, online health communications

cannot just deliver information one-way, assuming that the audiences will accept and be influenced by the messages (14, 42–44). Rather, effective communications need to be two-way interactive so that negative emotions, counterarguments, and concerns of the audiences can be addressed. Social media can afford meaningful asynchronous conversations between the poster and the audience and thus is a potential channel for addressing vaccine hesitancy. As demonstrated by Pedersen and colleagues (14), addressing both cognitive and emotional factors in HPV vaccine hesitancy and devoting resources for community management in terms of creating community dialogues are the keys to restore confidence in HPV vaccination.

Despite the potential, observational accounts of the Facebook public health pages and groups set up within nine counties in northern California do not show adequate two-way communications that respond to the emotional experiences of the target audiences and their specific concerns and worries about HPV vaccination. First, the overall promotion of HPV vaccines from public pages and groups on Facebook is limited

in both frequency and content diversity. Most posts focused on general information to raise awareness of cervical cancer, the availability of the HPV vaccine, advocating for HPV vaccination, and direct audiences to external information links. In contrast, the comments did not engage much with such promotional messages and showed significantly higher levels of both positive and negative emotions and, specifically, anger. This finding is in line with a previous study on Twitter data of HPV vaccine conversations, which identified anger from many individual tweets commenting on HPV vaccines (39). Such anger emotion in user comments could further negatively impact the pro-vaccination attitudes of the people (16). This suggests that communication efforts to reduce HPV vaccine hesitancy are needed to strategically address angry reactions of the people.

The topics identified in the comments pertained to discussions about the safety and efficacy of the vaccine (i.e., side effects and reactions) and about HPV vaccine misinformation (e.g., the connection between the HPV vaccine and autoimmune diseases and the banning of the HPV vaccine in other countries), which included further questioning of the information sources and online information sharing attitude of people. In contrast to previous research examining Twitter topics of HPV vaccines that identified a broader spectrum of topics (including conspiracies and policy debates) (45), our data focused on Facebook user comments centered primarily on the direct concerns of the users with side effects and vaccine safety. It suggests that the target audiences of these social media posts do actively participate in the discussions but also try to expand the topics to highlight vaccine hesitancy concerns by exchanging comments. It is also frequent that pro-vaccine people correct misinformation or question the credibility of the information. Here, we need to point out that there is a lack of direct communication by public health pages and group leaders to dispel misinformation and directly address vaccine hesitancy within the comment space.

These observations are best illustrated by the most engaging post from Placer county in our dataset. Although, the post itself was a regular educational message with an attached infographic, it sparked heated debates in its comment section where both pro- and anti-vaccine opinions were expressed, involving sharing, and correcting misinformation about the HPV vaccine. The following two adjacent comments directly illustrated the nature of responses: “Oh great, the anti-vaxxers are out in force tonight. Better go grab my bingo cards.” and “Oh boy, the pro-vaxxers are out in full force tonight. But they don’t know HPV vaccine is banned in other counties” (paraphrased quotes). One speculation is that this post included an infographic that might have boosted initial attention from the audience. The other reason may be that Placer county shares a strong conservative base, and vaccine topics incur political concerns. For example, one user commented, “We are a predominantly conservative county and we want to maintain medical freedom, but we are slowly losing it” (paraphrased quotes). This post-comment dynamic is exceptional in the sense that stochastic processes generate very few “black swans” of highly engaged posts in social media (33). However, such

post-comment dynamics can be highly influential and provide great insights into vaccine hesitancy. These findings are also in line with another research examining pro- and anti-vaccination comments in response to a high-profile Facebook post, which found that both camps cited external resources and evidence to support their arguments (38).

Furthermore, we observed different patterns in social media promotion and discussion between regions with high vs. low HPV vaccine coverage rates. High-coverage counties devoted more posts to raising awareness and increasing knowledge of the disease causes and transmission and prevention measures, and they also focused on targeting women and directly calling people to take actions for tests and vaccinations. In contrast, low-coverage counties posted more on cancer awareness and general cancer screening. Although, in general, comments from all counties are pertinent to vaccine hesitancy, the differences across the high- and low-coverage counties are important to discuss. Commenters in high-coverage counties focused more on specific topics about vaccine risks and safety concerns (e.g., package inserts and autoimmune diseases), whereas commenters in low-coverage counties discussed more about HPV vaccination for children, especially boys. This might suggest that people in low-coverage counties were mostly concerned with vaccine recommendations for children and may likely be due to the lack of knowledge about how the vaccine works or issues with the false perception that the vaccine encourages sex among youth. Communities in the high-coverage counties likely have higher vaccine acceptance, so most issues pertaining to the HPV vaccine relate to specific misinformation and discussions among those who are still skeptical or anti-vaccine. In perspective of the diffusion of innovation theory (46), this suggests that for counties with fewer adoptions, communicating vaccine recommendations, and explanations of vaccine benefits is more crucial to move people toward accepting the vaccine. In contrast, for high-adoption counties, public communications need to shift to focus on addressing vaccine hesitancy among people who are already aware of the basic information but holding strong misinformed beliefs. This is reflected best in the Placer county case, which contributed 338 comments that included a lot of strong anti-vaccination voices.

Lastly, we observed significantly more public page posts from organizations than group posts by individuals. Page posts and comments were largely focused on the common topics surrounding HPV vaccination promotion or hesitancy concerns, while groups posts and comments sometimes lost focus and digressed to discussing other vaccines for COVID-19 and mask-wearing in general. This suggests that public pages may work more efficiently to have targeted vaccine campaigns for organizations or institutions than setting up public group discussions. Echoing a previous study that found that people are likely to share more organizational messages than individual messages regarding cervical cancer prevention (33), more Facebook public page posts for promoting HPV vaccinations and addressing hesitancy concerns are needed and are expected to be shared more through the social networks of the target audiences.

Strengths and Limitations

There are several strengths and limitations to be discussed for evaluating the findings. First, in comparison to previous studies that used random sampling of data from social media, this research used precise geolocation searches and rigorous human checking within the platform to zoom into examining the local public pages and groups. Findings from the analyses provide more accurate depictions of the emotional experiences and concerns of the local communities about HPV vaccination. Future research can consider replicating this approach and extend the scope of research to cover more regions and states and explore broader comparisons.

Second, we utilized topic modeling to examine both the posts and comments and illustrated the wide discrepancies in focuses between vaccination promotion messages and reactions of the audiences. The automated modeling approach could increase the comparability of the findings to other analyses, using social media datasets. Given the relatively small sample size, LDA, coupled with qualitative interpretations, provided a high-level extraction of the topics. Future research can further apply the topics to label each post or comment to quantify the percentages of each topic's presence in the data.

We need to point out that this research is exploratory in nature, so we cannot draw clear causal implications of how social media vaccine discussions could impact the target communities. It is also known that social media is not representative of all populations. Given ethical and privacy concerns, we could not extract more information from the individual commenters to describe their demographic backgrounds, such as age, gender, parental status, or race. Knowing this information can help provide a clearer understanding of the active participants and their vaccine stances, future research may consider supplementing social media analyses with surveys.

In addition, while we had two authors qualitatively reading the topic modeling outputs, given the often-fragmented social media comments, we could have under-interpreted or overinterpreted some expressions regarding vaccine hesitancy. The topic modeling results contained overlapping themes, so the demarcation among different topics may not be clear-cut. We attempted to explain the topics with common emphases.

Lastly, we did not harness a lot of data from public groups, since public groups as a feature of Facebook are not popular venues for engaging with health topics. This may be because the most active groups on Facebook are private, and we could not access those. Future research needs to address the challenges of researching private groups, which can provide more insights into vaccine hesitancy in local communities.

CONCLUSIONS AND IMPLICATIONS

Public health agencies working for vaccine promotion should expand on social media campaigns and make efforts to improve communications between their page contents and the comments from the targeted audiences. This two-way interactive approach not only leverages the capabilities of social media but allows for an engaged and informed audience in which emotions, concerns, and misinformation surrounding the vaccine can be

addressed. Previous research suggests that corrections from reputable sources may help reduce the negative effects of vaccine misinformation (47–49). Public health agencies thus need to first listen to thoughts and misperceptions of targeted audiences reflected through their comments and design relevant messages by citing external expert sources to address the concerns. Formative research to examine concerns about vaccinations in the counties may provide a clear picture for developing future message strategies, a task that is currently being undertaken by our team. This way, agencies can build trust with their communities and foster positive relationships and more effective health communication (44).

Furthermore, public health pages and groups should develop messages that go beyond just providing information and knowledge. This is especially true for the low-coverage counties, where the discussions mostly focus on concerns about the age and gender of administering the vaccine. Developing messages that inform the public on why the HPV vaccine is administered at a younger age, such as how it is more effective when administered before any sexual activity, and messages that address why both boys and girls should get the vaccine, such as how it is used as cancer prevention (and not only cervical cancer), would be particularly useful. In addition, developing more tailored messaging is also important for high-coverage counties because it allows for addressing specific concerns that are brought up as new issues and misinformation are spread. Because emotions are higher among those who exhibit concerns with vaccines, messages can be constructed by leveraging fact-checking labels (49), refutational arguments (16), and narratives that address emotions (50), which have proved to be effective in reducing misinformation impacts.

It is important for public health agencies to examine social media groups and pages within their state and local health department areas to understand the sentiments and contents expressed by their communities. Especially because HPV vaccine skeptic individuals are often within communities that may be hard to reach, public health agencies need to evaluate the roles of social media and allocate resources to their social media communication management. This study provides insights by examining Facebook pages and groups among counties within Northern California. Given that the social media landscape is fast evolving, and young adults and parents under 30 are increasingly using Instagram, Snapchat, and TikTok (29), future research and targeted health promotion campaigns need to examine contents and conversations from these audiences and leverage those platforms for HPV vaccine promotion and communications.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors upon request.

AUTHOR CONTRIBUTIONS

JZ conceptualized the study. JZ and HX managed the project and conducted thematic interpretations. HX conducted the quantitative analyses and initiated the first draft manuscript

with substantial contributions from JZ, CC, and JD. HX, CC, and HC performed data cleaning and coding. All authors contributed to manuscript revision and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fdgth.2021.683090/full#supplementary-material>

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A Digital Personal Health Library for Enabling Precision Health Promotion to Prevent Human Papilloma Virus-Associated Cancers

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Human papillomavirus (HPV) causes the most prevalent sexually transmitted infection (STI) in the United States. Sexually active young adults are susceptible to HPV, accounting for approximately 50% of new STIs. Oncogenic HPV subtypes 16 and 18 are associated with squamous intraepithelial lesions and cancers and are mostly preventable through prophylactic HPV vaccination. Accordingly, this study's objectives are to (1) summarize SDoH barriers and implication for low HPV vaccination rates among young adults (18–26 years), (2) propose a digital health solution that utilizes the PHL to collect, integrate, and manage personalized sexual and health information, and (3) describe the features of the PHL-based app. Through the application of novel techniques from artificial intelligence, specifically knowledge representation, semantic web, and natural language processing, this proposed PHL-based application will compile clinical, biomedical, and SDoH data from multi-dimensional sources. Therefore, this application will provide digital health interventions that are customized to individuals' specific needs and capacities. The PHL-based application could promote management and usage of personalized digital health information to facilitate precision health promotion thereby, informing health decision-making regarding HPV vaccinations, routine HPV/STI testing, cancer screenings, vaccine safety/efficacy/side effects, and safe sexual practices. In addition to detecting vaccine hesitancy, disparities and perceived barriers, this application could address participants' specific needs/challenges with navigating health literacy, technical skills, peer influence, education, language, cultural and spiritual beliefs. Precision health promotion focused on improving knowledge acquisition and information-seeking behaviors, promoting safe sexual practices, increasing HPV vaccinations, and facilitating cancer screenings could be effective in preventing HPV-associated cancers.

Keywords: precision public health, health promotion, human papillomavirus, vaccine, screening, cancer prevention, personal health library

INTRODUCTION

Human papillomavirus (HPV) causes the most prevalent sexually transmitted infection (STI) in the United States (1). Each year, the Centers for Disease Control and Prevention (CDC) reports an estimated prevalence and incidence of 42.5 million and 13 million HPV infections, respectively (2). Likewise, STIs are on the rise with approximately 20 million incident cases recorded each year (3, 4). Almost half of all new STIs diagnosed annually affect young adults (15–24 years), who are disproportionately impacted by HPV and other STIs due to risky behaviors such as unprotected sexual intercourse, multiple sexual partners, and reluctance to utilize sexual health services (5, 6). Accordingly, about one in every four sexually active young females become infected with an STI, primarily HPV and chlamydia (5), while approximately half (46.5%) of all young males (23–27 years) report being infected with HPV (7). In 2018, the direct healthcare cost attributed to new STIs had far-reaching financial implications, being estimated at \$16 billion (2).

While most HPV infections are asymptomatic or transient due to being cleared by the immune system, the persistence of oncogenic HPV subtypes 16 and 18 is associated with cervical, vaginal, vulvar, anal, penile, and oropharyngeal cancers (8, 9). In the U.S., over 35,900 incident cases of HPV-associated cancers are recorded annually: cervical, 12,143; oropharyngeal, 19,775; anal, 7,083; and vulvar, 4,114 (10). The available HPV vaccines are recognized as primary prevention tools that are effective and protective against approximately 92% of HPV-associated cancers and genital warts (11). Consequently, the Advisory Committee on Immunization Practices recommends that a 9-valent HPV vaccine effective against 9 high- and low-risk HPV subtypes be administered in a two-dose vaccination schedule to females and males 11–12 years old (11). For those without prior vaccination, the Advisory Committee endorses catch-up HPV vaccinations for females and males aged through 26 years (12, 13). Aside from being more susceptible to HPV and STIs, college-age adults (18–26 years) should be targeted for catch-up HPV vaccination interventions because at this age they are making their own health decisions independently of their parents.

Previously, we proposed to develop the Personal Health Library (PHL) that will support chronic disease self-management (14, 15). The PHL is also able to combine and utilize clinical, biomedical, reproductive and sexual health, and social determinants of health (SDoH) data from multi-dimensional sources. These sources include needs assessment surveys, the U.S. Census Bureau American Community Survey, electronic medical records (EMR), wearable/mobile devices, the websites of governmental and public health agencies such as the CDC and World Health Organization (WHO), scientific literature, and data collected via social media platforms. Overall, the PHL can facilitate precision health promotion for HPV vaccine uptake, empower individuals to seek health information, and enable better health decision-making.

The objectives of this article are to (i) summarize SDoH barriers and implication for low HPV vaccination rates among susceptible young adults (18–26 years); (ii) propose a digital health solution that utilizes the PHL to collect, integrate, and

manage personalized sexual and health information; and (iii) describe case scenarios and features of the PHL-based app based on ease of use, clinical content, and requirement gathering. The rest of the paper is organized as follows: section 2 describes the role of SDoH barriers in decreasing vaccination rates, section 3 elucidates on health information-seeking and decision-making behaviors, section 4 depicts the application of digital PHL to facilitate precision health promotion, section 5 describes the integration of multi-dimensional data sources to implement the PHL while section 6 characterizes the structure and features of the proposed PHL.

ROLE OF SDOH BARRIERS IN DECREASING VACCINATION RATES AMONG SUSCEPTIBLE YOUNG ADULTS

The 2017 Behavioral Risk Factor Surveillance System survey reports that the number of young adults 18–26 years who initiated (21%) or completed (18%) the HPV vaccination series was very low, particularly when compared with the Healthy People 2030 target of 80% for HPV vaccine uptake by ages 13–15 years (16). Therefore, within a college/university setting, it is likely that a significant number of sexually active young adults are unvaccinated. Given their potentially greater propensity for unsafe, at-risk behavioral practices compared with other age groups, these young adults are vulnerable to HPV infections and therefore susceptible to HPV-associated cancers. The 2017 survey also indicates that 18–26 year-old men were least likely to be vaccinated (16). It is of concern that men who have sex with men or identify as gay or bisexual have an increased prevalence of HPV infection (17).

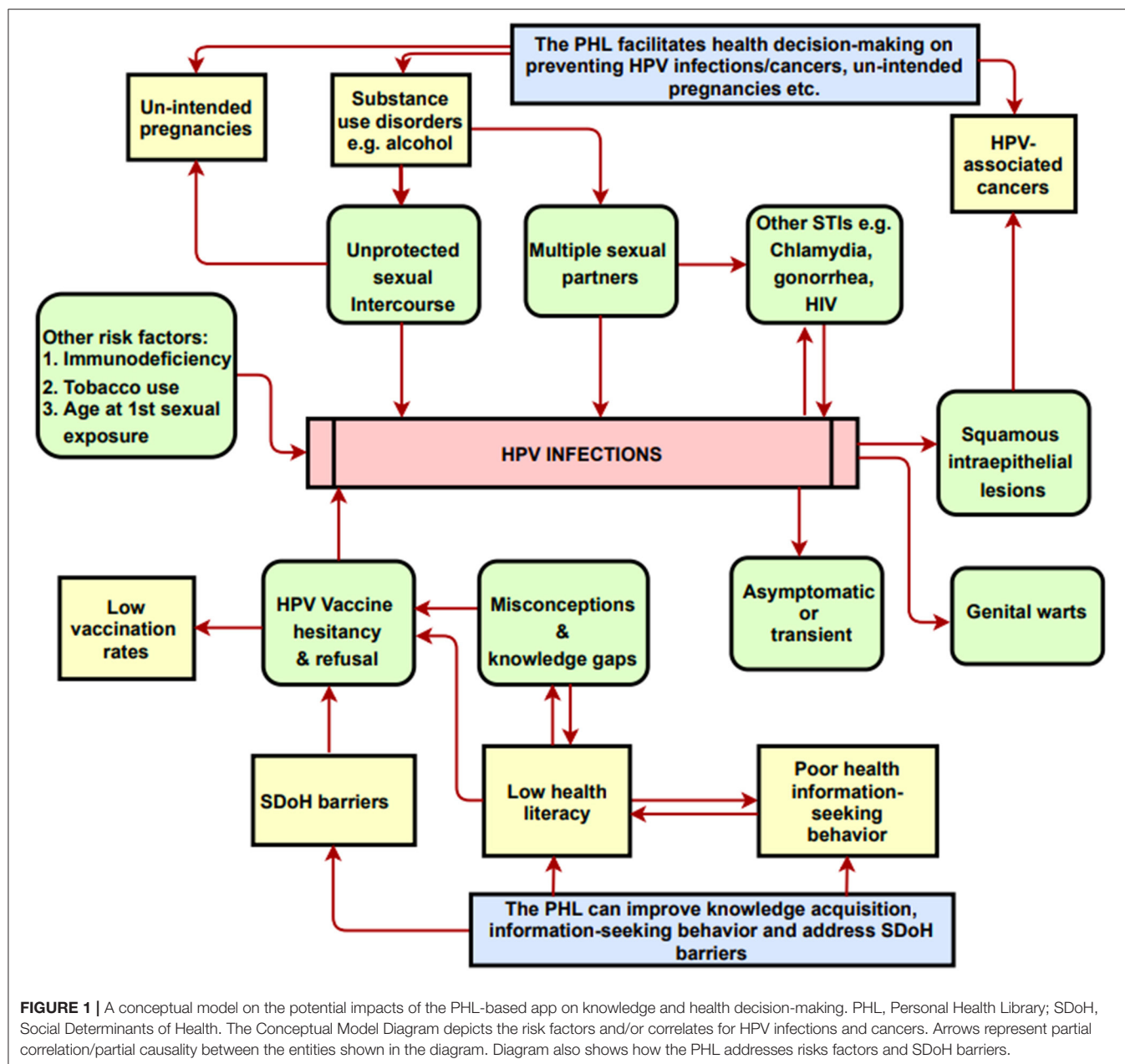
Sociocontextual determinants can hinder HPV vaccine uptake behavior. SDoH embodies the characteristics of neighborhoods, communities, and the environments in which individuals are born, reside, learn, work, and worship. Specifically, SDoH are influenced by the availability of resources that improve quality of life and public health outcomes, including income, access to education, affordable housing and basic amenities, health services, public safety, and food security (18). Among young adults, SDoH barriers adversely influence HPV vaccine acceptance and ultimately lead to vaccine delay, hesitancy, and refusal (19). These barriers include lack of health-related knowledge, low health literacy regarding vaccine safety/efficacy/side-effects, disparities in health information-seeking behaviors, out-of-pocket vaccine cost, poor healthcare access, inadequate or absent health insurance, limited access to healthcare providers' recommendations, language barriers, sub-optimal digital literacy level, peer influence, and parental religious and moral viewpoints (Table 1 and Figure 1).

HEALTH INFORMATION-SEEKING AND DECISION-MAKING IN THE DIGITAL AGE

Several studies have shown that access to education and to clear, unequivocal recommendations/policies serve as predictors for increasing vaccine uptake (20). However, young adults

TABLE 1 | Barriers to vaccine uptake based on the CDC's classification of the SDoH domains.

SDoH domains	Contents
Education	Educational attainment, health-related knowledge, health literacy, health information-seeking behavior, language development, technical skill.
Health and healthcare	Healthcare access, health insurance coverage, health literacy, proximity to healthcare facility, availability of healthcare provider.
Economic stability	Poverty, employment, safe and affordable housing, out-of-pocket vaccine cost, internet access.
Neighborhood and built environment	Environmental conditions, access to transportation, proximity to a healthcare facility, average household size, neighborhood crime and violence.
Social and community context	Health providers' recommendations, patient-provider communication, peer influence, parental religious and moral viewpoints, stressful life event impacting the family/household, incarceration.



report a lack of knowledge and awareness of HPV, its transmissibility through skin-to-skin contact, the existence of HPV-associated cancers, and HPV vaccine efficacy and

protocols (21–23). Additionally, most college-age students did not perceive themselves to be at risk of acquiring HPV (24). In today's internet era, people are increasingly knowledgeable

about navigating digital and mobile devices, online social media platforms to seek and control their own health information, given the proper motivation to do so (25). Moreover, several studies have demonstrated that digital health technologies can increase knowledge, inform health decision-making and change HPV vaccination behaviors (26, 27). Therefore, digital health technologies are uniquely and ideally suited to disseminating information and to facilitating social support that could increase vaccine uptake. As depicted in **Figure 1**, digital health technologies and applications could serve as resource hubs for promoting HPV education, awareness, vaccination services, cancer prevention measures, and for addressing vaccine hesitancy and misinformation, thereby ultimately reducing the incidence of HPV-associated cancers.

THE APPLICATION OF DIGITAL PHL TO FACILITATE PRECISION HEALTH PROMOTION

Precision health promotion, one of the main pillars of digital precision health (28), is defined as, “the personalized design of lived experiences that foster improved health and well-being for individuals within the context of families, organizations and communities” (29). Therefore, an education-focused intervention with strong, tailored, and consistent health messaging communicated through a digital health application could play an important role in facilitating the voluntary behavior of getting vaccinated against HPV. The PHL is a digital tool that could facilitate informed health decision-making and lifestyle choices through customized health information that is collected, integrated, organized, managed, and retrieved through the application of novel techniques. Technologies such as artificial intelligence, knowledge representation, semantic web capabilities, and natural language processing could be used to design the PHL resource.

The proposed PHL-based application has the potential to leverage the following capabilities: (i) integrating individual- and population-level data and evidence; (ii) custom-building to each individual’s specific needs with a patient-centered design; (iii) enabling knowledge acquisition, exchange, validation, and visualization; (iv) promoting healthy behaviors and improving health-information-seeking behaviors; (v) utilizing patient reminder and recall systems; and (vi) learning usage patterns to incorporate an individual’s spiritual, moral and cultural preferences. As shown in **Figures 1, 2**, the application provides intelligent, personalized health education and promotion that address knowledge gaps and misconceptions regarding sexual health; the safety, efficacy, side effects, and cost associated with HPV vaccines; and other cancer-preventive measures such as routine testing for HPV and other STIs and Pap testing to screen for atypical cell morphologies in cervical and other tissues. Overall, this could serve as an individual-centered digital tool tailored for tracking and exchanging information to inform health decisions regarding HPV, STIs, and cancer prevention. It can also be adapted to include other health-related issues

among adults of all ages such as substance use and mental health disorders.

INTEGRATING DATA FROM MULTI-DIMENSIONAL SOURCES FOR THE PHL

To implement the proposed PHL, complex multi-dimensional health information (e.g., clinical, biomedical, and SDoH characteristics) is compiled and integrated from multiple heterogeneous sources at individual- and population levels and from trusted domains. Below, we discuss the PHL sources and types of data and information that are included in further detail.

Individual-Level Data

Electronic Health Records

Electronic health records (EHRs) systematically collect patients’ data that are captured in a clinical setting and stores it in a digital format. EHRs capture a wide range of information including health histories, prescriptions, biomedical and laboratory results, immunizations, demographics including age and home address, and information about disease progression and medical treatments. This data can be complex and multilayered, so the application of artificial intelligence techniques to identify patterns and generate organized data for analysis could facilitate greater insight to inform individual’s health decision-making.

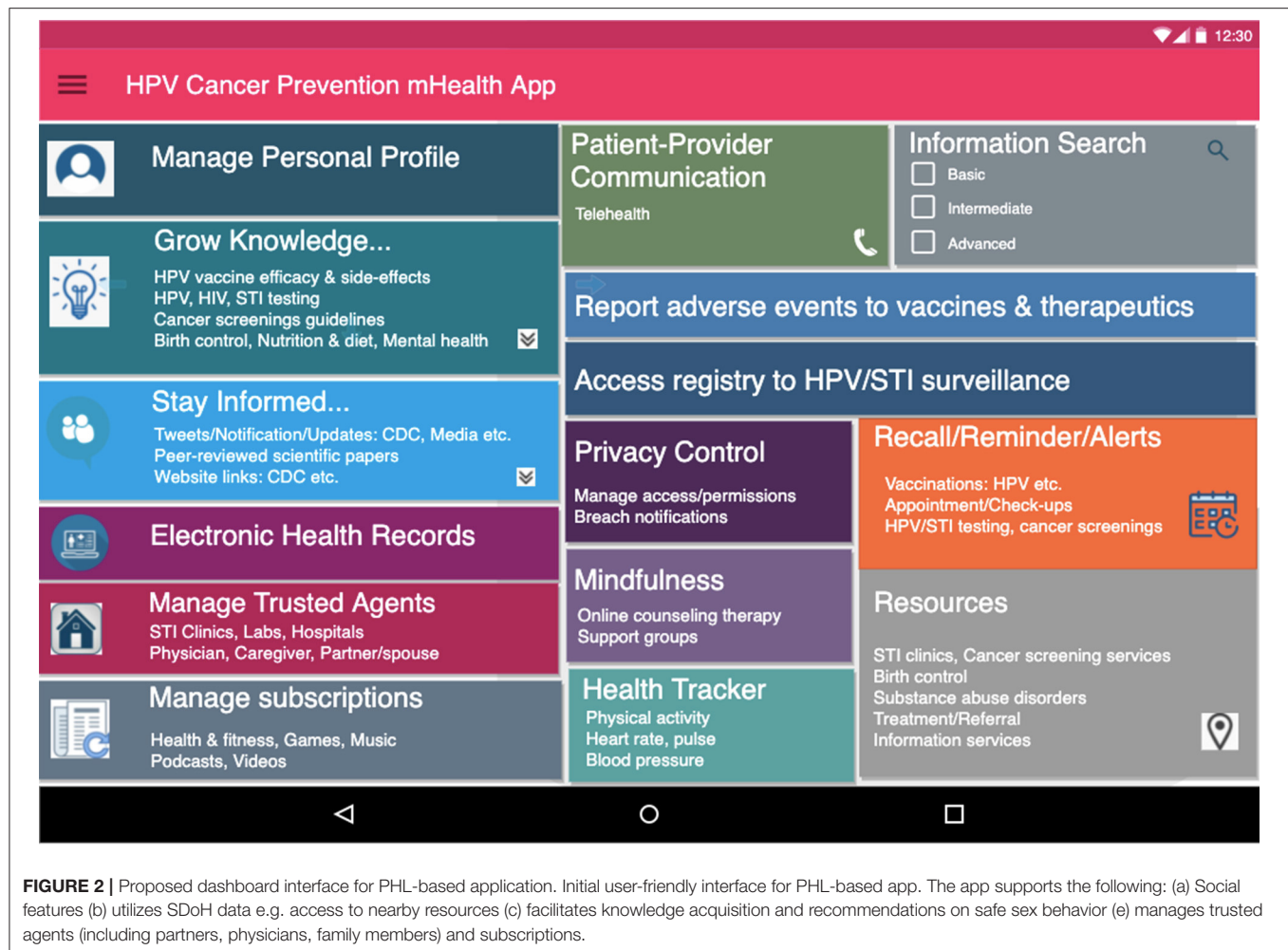
Patient-Generated Health Data and Observations of Daily Living

Patient-Generated Health Data (PGHD) and Observations of Daily Living (ODL) are generated from consumer-health apps, sensors, and wearable devices. Compared with clinical EHR data, the PGHD records of health-related data (e.g., glucose and cholesterol monitoring, medical history, feedback on medication, and adverse drug reports) are gathered, distributed, and controlled by the patients themselves. Studies have revealed that these wearable devices are relatively accurate for remotely monitoring, tracking and measuring physiological metrics (e.g., heart rate, temperature, blood saturation level) and behavior (e.g., physical activity, sleep) (30). ODLs incorporate data on the overall well-being, health, and fitness of an individual, including physical activity, heart rate and pulse. Records from PGHD and ODL can be used to enable and promote healthy behaviors by generating “personalized” information and data.

Population-Level Data

SDoH Characteristics

The adoption of SDoH factors to facilitate catch-up HPV vaccinations represents a novel approach. SDoH data and neighborhood characteristics are obtained and curated at the zip code/census tract level from the Census Bureau and local partners. The Census Bureau utilizes the American Community Survey as its source of information to depict changing U.S. demographics (e.g., housing, average household size, employment, and internet access). This population-level data are integrated with individual-level characteristics to design the PHL-based application.



Needs Assessment Survey

The primary target population for this survey is a diverse, representative sample of young adults (18–26 years) affiliated with U.S. universities and colleges. The recruitment will be conducted via groups on Facebook (and potentially other social media platforms as needed) and will incorporate invitations for participation that include web link access to the needs assessment survey. A structured online questionnaire will be administered to determine individuals' specific needs for a digital application within a socio-cultural context including multilingualism, home access, internet connectivity, and digital tool proficiency. Data will also be collected about knowledge and attitudes regarding HPV, HPV vaccination and vaccine hesitancy. Together, these results will inform the design of the PHL-based application.

Other Trusted Sources of Data and Resources

Public Health Agency Websites and Peer-Reviewed Scientific Literature

To enhance the usability of the PHL platform, science-based evidence and data from public health agency websites (governmental such as CDC and non-governmental) and

scientific literature from peer-reviewed journals will be incorporated. The CDC, the U.S. National Cancer Institute, and WHO serve as research data archives that enable public access to information on reproductive and sexual health, HPV and STIs, vaccinations, screenings, cancer prevention, and surveillance. Additionally, the Substance Abuse and Mental Health Services Administration offers confidential free information services for treatment and referrals to address mental health crises, substance-use disorders, and other behavioral health disorders.

Social Media, Web Blogs, and Podcasts

Behavioral health data, spiritual and cultural viewpoints, general beliefs, and opinions presented in formats such as posts, messages, blogs, podcasts, and video recordings on online social media all serve as valuable sources of information for the PHL.

THE STRUCTURE AND FEATURES OF THE PROPOSED PHL-BASED APPLICATION

We would create an integrated dynamic knowledge base using these multiple data sources to enable PHL to generate

real-time hybrid recommendations that are based on both context and content. To capture context, the PHL integrates individual-level ODL and PGHD data, and population-level data such as SDoH and neighborhood characteristics. The PHL subsequently transforms this information into a machine-readable format using semantic web technologies and natural language processing. This in turn facilitates interoperability between the PHL and other platforms via ontologies and semantic networks of knowledge types that are related to HPV and STIs prevention and cancer screenings, our domain of interest. The technical details underlying the PHL infrastructure have been described and previously published (14, 15, 31).

Proposed PHL-Based Application in Action: Case Scenarios

Here, we present sample scenarios to demonstrate the features, ease of use, clinical content, and requirement gathering already implemented in the initial prototype design of the PHL-based health promotion app. It is important to note that the case scenarios and user features illustrated below should be supported and justified by empirical data from our future work.

- **Scenario 1:** A 19-year-old college sorority female member wants to use the app to acquire knowledge so she can establish appropriate norms to discourage sexual risk during a party she plans to organize.
- **Scenario 2:** A 22-year-old male who newly identifies as gay distrusts the healthcare system and fears discrimination because of his lifestyle choices. He is a recent immigrant with little English proficiency. He seeks social support and information on the PHL-based app to learn how he and his new partner can engage in safe sex practices within their relationship, thereby preventing HPV and STIs.
- **Scenario 3:** A 20-year-old male college athlete who has not been vaccinated for HPV has poor health-seeking behavior. However, he feels he is invincible and immune to getting HPV and STIs despite having multiple sexual partners and engaging in unprotected sexual intercourse. His friend suggests that he sign up to receive daily messages on his phone through the PHL-based app for information about HPV and STIs prevention measures including condom use, vaccinations, and STI testing.
- **Scenario 4:** A 19-year-old female undergraduate student engaged in unprotected sexual intercourse the previous night. She fears she may have contracted HPV or an STI and seeks privacy as she remotely consults a nurse using the PHL-based app. She also utilizes the app's sexual health information to inform her decisions about HPV and STI testing, catch-up HPV vaccinations, and emergency birth control measures.

PHL-Based Application Features and Thematic Assessment of Requirements

The PHL-based app requirements for these case scenarios are listed below, derived mostly from HPV-associated cancer preventive measures, i.e., safe sexual practices, HPV vaccine uptake, routine HPV testing, and cancer screenings. Each

requirement is also mapped to features that would be part of the proposed PHL-based app, as seen in **Figure 2**.

Scenario 1

- **PHL-based app features:** (i) social features: chatting channels, blogs, applications, and podcasts, (ii) web links to CDC, etc., and (iii) recommendations on safe sexual behaviors and safer sex guidelines.
- **Requirements addressed:** (i) safe-sex practices such as condom use, (ii) avoidance of alcohol and drugs, (iii) routine HPV/HIV/STI testing, and (iv) peer support.

Scenario 2

- **PHL-based app features:** (i) social features: chatting channels and shared notepads, (ii) SDoH characteristics: access to nearby sexual health resources and information, (iii) management of trusted sex partners, (iv) recommendations on safe-sex behavior and safer-sex guidelines, (v) recalls and reminders for vaccinations, STI tests, and cancer screenings, (vi) privacy and confidentiality, and (vii) language preferences.
- **Requirements addressed:** (i) Safe sexual practices including condom use, (ii) HPV vaccine uptake, (iii) routine HPV/HIV/STI testing, (iv) cancer screenings, and (v) privacy and confidentiality.

Scenario 3

- **PHL-based app features:** (i) knowledge acquisition, (ii) facilitation in seeking health information, (iii) integration with global web knowledge, (iv) recommendations on safe sex behavior and safer sex guidelines, and (v) incorporation of spiritual and cultural viewpoints.
- **Requirements addressed:** (i) safe sex practices including condom use, (ii) HPV vaccine uptake, (iii) vaccine hesitance, (iv) routine HPV/HIV/STI testing, and (v) peer support.

Scenario 4

- **PHL-based app features:** Social features: chatting channels, shared notepads, (ii) video conference and telehealth, (iii) recommendations on safe sex behavior, (iv) reminders for cancer screenings and testing, (v) manages trusted sex partners, thereby facilitating contact tracing, and (vi) privacy and confidentiality.
- **Requirements addressed:** (i) Safe sex practices including condom use, (ii) HPV vaccine uptake, (iii) routine HPV/HIV/STI testing, (iv) birth control options, (v) privacy and confidentiality, and (vi) contact tracing.

CONCLUSIONS AND FUTURE DIRECTIONS

The immune response elicited by HPV vaccines is effective in preventing infections from the high-risk HPV subtypes (16 and 18) responsible for 92% of HPV-associated cancers. Primary prevention including HPV vaccine uptake and use of safe sex practices, secondary prevention, early detection through HPV testing and cancer screenings, and lifestyle changes such as smoking cessation and reduced consumption of alcohol

could prevent approximately 400,000 HPV-associated cancers annually (32). Overall, we aim to increase catch-up HPV vaccinations and address vaccine hesitancy through precision health promotion, thus ultimately reducing the prevalence of HPV-associated cancers.

In this article, we discuss the utility of personalized digital health solutions for facilitating and promoting healthy behaviors focused on HPV vaccine uptake and cancer screenings. We also propose to continue our research on the design and development of an intelligent PHL-based application that improves health-seeking behavior and decision-making by disseminating personalized recommendations through a user-friendly interface. We will use the results from the needs assessment survey to implement, optimize, and tune the PHL-based app, which will facilitate the gathering, managing, and use of personalized health information. Moreover, we define a series of case scenarios to highlight the features and user requirements implemented in the app.

Future work will entail the completion and incorporation of a formal needs assessment survey results into developing the PHL-based app as well as the evaluation of the PHL prototype by a panel of subject matter experts for clarity, ease of use, workflow, content, and omission. The evaluation will be conducted in the form of (i) semi-structured interviews to obtain qualitative data and (ii) review of case scenarios to simulate the cognitive process of individuals interacting with the app and attempting to make health decisions. Moreover, when fully implemented, a formal usability assessment with a specific focus group will be performed. Future studies should expatiate on the potential impact of the proposed app in quantitative measures, (e.g., what is the impact of the app on HPV vaccination rates and other behavior change outcomes, what is the satisfaction rate for the app?) among different demographic groups and varying

disease conditions. Anticipated limitations to fully implementing the PHL-based app include concerns and challenges about data privacy and data breach. Concerted efforts should be made to enforce privacy-preserving mechanisms at multiple levels (33) as well as to utilize anonymized data from willing participants only.

A comprehensive novel intervention that is education-focused and employs a digital health application to collect, control, and utilize contextualized personal data and information would be empowering and impactful for promoting HPV-associated cancer preventive measures. Importantly, this intervention will be vital in reducing the burden of HPV-associated diseases among young adults.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

OO: conceptualization, writing the draft, review, and editing, visualization. NA: conceptualization, review and editing. RD and RB: review and editing. AS-N: conceptualization, writing, review and editing, obtained funding, supervision. All authors contributed to the article and approved the submitted version.

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Development of Personas to Communicate Narrative-Based Information About the HPV Vaccine on Twitter

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Introduction: Personas are based on real-life typologies of people that can be used to create characters and messages to communicate important health information through relatable narrative storylines. Persona development is data-driven and can involve multiple phases of formative research and evaluation; however, personas are largely underutilized in digital health research. The purpose of this study was to create and document persona development to deliver narrative-focused health education for parents on Twitter with the goal of increasing uptake of HPV vaccination among adolescents.

Methods: Leveraging data from a mixed-method study conducted in the U.S. with a diverse population of parents with adolescents ages 9–14, we used both qualitative and quantitative data (e.g., the National Immunization Survey—Teen, focus groups, and social media) to create personas. These data sources were used to identify and develop key characteristics for personas to reflect a range of parents and their diverse understandings and experiences related to HPV vaccination. A parent advisory board provided insight and helped refine persona development.

Results: Four personas emerged and were characterized as the (1) Informed Altruist, (2) Real Talker, (3) Information Gatherer, and (4) Supporter. Characteristics differed across personas and provided insights into targeted narrative strategies. Described attributes included demographics, psychographics, communication style, vaccine goals and aspirations, vaccine challenges and frustrations, and vaccine hesitancy.

Discussion: This work demonstrates how multiple data sources can be used to create personas to deliver social media messages that can address the diverse preferences and needs of parents for HPV vaccine information. With increasing usage of social media for health information among parents, it is important for researchers to consider marketing and design thinking to create health communication messages that resonate with audiences.

Keywords: personas, HPV vaccination, vaccine hesitancy, Twitter, narrative communication, health communication

INTRODUCTION

From the early use of parables and fables, communicators across history have used stories to share ideas with diverse audiences. Storytelling has been established as a way to engage audiences, present important ideas through relatable scenarios and characters, and create and make use of memorable and persuasive messages through story plots and outcomes (1). In health education, the use of stories continues to evolve but remains an important strategy in persuasive communication, especially for audiences of diverse backgrounds and literacy levels (2). Entertainment education, or EE, is a specific area of health communication that leverages songs, televised stories (telenovelas), social media (including games and blogs) and other mediated communication to combine theory-based behavior change with storytelling (3).

Storytelling has been used for health education in various environments including broadcast television (4, 5), digital spaces (6, 7), and in-person healthcare delivery (8). The storytelling approach has the potential to reach and resonate with different populations and communities with diverse backgrounds and lived experiences (9–12), and can be a useful strategy to communicate science to non-expert audiences (13). This may be particularly relevant to vaccine science and communication, as storytelling has the potential to address concerns that are rooted more in emotions than lack of evidence (14, 15). Specific to the human papillomavirus (HPV) vaccine, storytelling has fostered vaccine confidence when shared through multimedia (16) and interpersonal conversations (17). Indeed, a previous study found that peer-expert narrative intervention nearly doubled the HPV vaccination initiation rate compared to a non-narrative approach (18). Additionally, HPV vaccine narratives or stories, as compared to pure informational resources, have been shown to garner more engagement on social media (19). While the use of stories and sharing of experiences on social media may vary by user type (i.e., parents, teens, health providers) (20), various aspects of storytelling have become a commonly seen characteristic of social media posts.

The use of characters and scenarios in storytelling and persuasive communication can influence many elements which are known to be fundamental drivers of behavior and behavior change, including audience beliefs about norms (what people like me typically do or should do), values (what are the typical costs and benefits of a hypothetical action in my community), problem-solving strategies, and interpersonal interactions between partners, families and communities (21). Characters in health communication stories must be relatable enough to engage audience interest. At the same time they need to be credible in their appearance and life situation, attitudes and beliefs, and actions and consequences (22). They should also elicit an emotional connection for audience members, so that their experiences are felt in a meaningful way.

Personas can be used to inform character development, and can be powerful tools through which to communicate narratives and storytelling for health education, training, and research. Personas are hypothetical archetypal representations of actual target users with details such as demographic

information, behaviors, goals, professions, etc., which are intended to represent a user and can be used to communicate key motivations, concerns, and interests (23). Often used in human-centered design (HCD) approaches, a problem-focused framework that emerged from the fields of industrial design (24), personas are increasingly applied in health-related solutions (25–27). The HCD process typically involves interviews, observation, and immersion in a user's context to develop user personas and use scenarios (23). Health studies have explored topics such as the use of personas to improve communicable disease workflow in public health (28), the ways personas provide information in online communities (29), and how people create their own online personas (30). Yet, we found little evidence of research examining the development of personas to utilize for disseminating health information through social media.

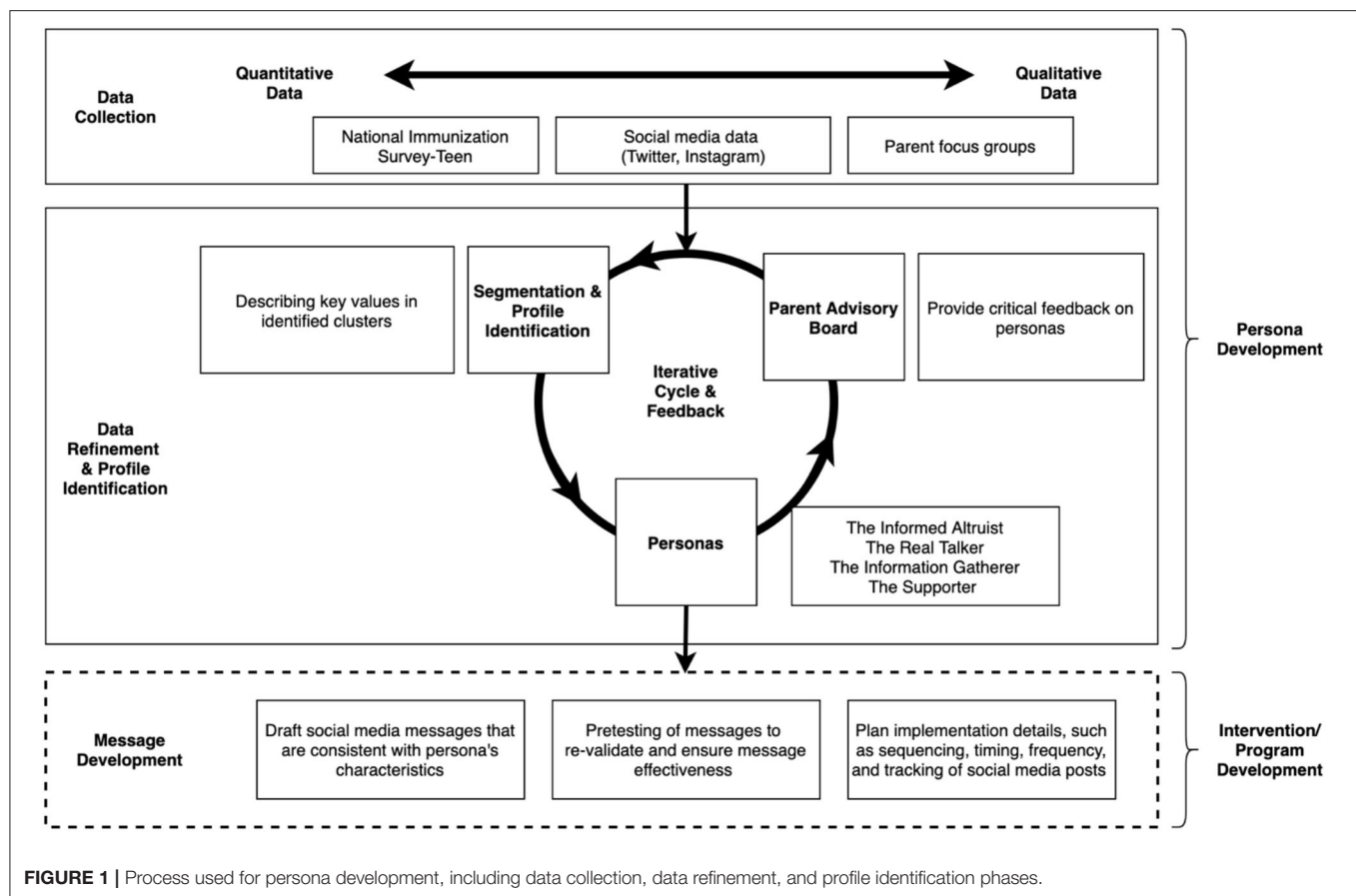
Bridging together the themes of digital health communication, storytelling, and design thinking, personas can provide a unique mechanism to create and communicate credible, accurate, and timely information in a meaningful and memorable way. Much health information is provided as information and facts designed to provide evidence to someone making health-related decisions, but as health interventions continue to emerge on social media and other online platforms, researchers and practitioners may seek to develop personas to deliver messages and materials. However, little has been documented on describing this approach for health messages on social media and how it can be informed by formative research and evaluation. To address this gap in knowledge, we provide a case-based and evidence-informed example of this approach, describing how personas can be developed to use on social media for targeting parents' decisions to vaccinate their children against the human papillomavirus (HPV). Specifically, the purpose of this project was to develop personas, the characters and their backgrounds, that can be used to communicate about the HPV vaccine and foster confidence among parents on Twitter.

METHODS

We utilized mixed methods to develop personas that represented both a breadth and depth of HPV vaccine understanding and experiences among parents and our approach was informed by a number of studies (31–33) that had used human-centered design. To interpret data and refine persona development, we created and worked with a parent advisory board (PAB). For persona presentation, we created persona profiles that highlight demographics, psychographics (34) (i.e., psychological traits, such as personality, values, desires, and lifestyle), communication style, vaccine goals and aspirations, and vaccine challenges and frustrations. **Figure 1** displays the process used for persona development. In brief, we conceptualized our process in three stages, (1) Data Collection, (2) Data Refinement and Profile Identification, and (3) Message Development. The current manuscript focuses on the first two stages.

Data Collection

To collect qualitative data, in May 2020 we conducted virtual focus groups ($n = 6$) with parents ($n = 48$) from across the U.S.



to gain a deeper understanding of what they considered and how they came to the decision to get their child vaccinated against HPV (35). We focused on their experiences and conversations (or lack thereof) with other parents about the HPV vaccine, and if hearing from other parents about their experiences was important to them when deciding to vaccinate. Parents were recruited from a national panel managed by Ipsos, a market research firm. To be eligible to participate in focus groups, parents had child(ren) ages 9–14, used Twitter at least once a week, did not hold anti-vaccine views, and spoke English. Participants were considered holding anti-vaccine views if they scored <2 average (on a Likert scale 1–4) where 1 is “strongly disagree” and 4 is “strongly agree,” on three HPV attitude questions—“How effective do you think the HPV vaccine is in preventing cancers caused by HPV?,” “How much do you agree or disagree that the HPV vaccine is an important part of your child’s health?,” and “How much do you agree or disagree that the HPV vaccine is safe?.” Using a text-based focus group discussion format, we discussed their experiences getting information about the HPV vaccine and using Twitter to learn about health topics more generally. Four members of the research team used NVivo 12 to conduct qualitative analysis for the focus groups and structured findings by themes including content, delivery, and source of information. We utilized both a deductive approach with a priori codes based on the focus group guide as well

as an inductive approach that allowed additional themes to emerge that were relevant to our research questions. Cohen’s kappa was calculated for each coder pair, and then averaged. An average inter-rater reliability of 0.65 was achieved overall and any subsequent differences were reviewed and reconciled in line with the codebook. A full description of procedures and findings from the focus group study are published providing further detail (35).

For quantitative data, we examined the 2018 National Immunization Survey (NIS)-Teen (36) to identify parental vaccine concerns at a population-level (37). Parents who answered “not too likely,” “not likely at all,” or “not sure/do not know” to “How likely is it the teen will receive HPV vaccination in the next 12 months?” were considered to be HPV vaccine hesitant. The NIS-Teen provides data on common concerns described by parents when considering the HPV vaccine for their adolescent by asking “What is the MAIN reason [teen name] will not receive any HPV shots in the next 12 months?” and response options included vaccine effectiveness concerns, vaccine safety concerns, lack of physician recommendation, adolescent not sexually active, among others. Chi-squared tests were used to compare differences in gender of parent, as well as levels of hesitancy to vaccinate adolescent and reasons for delay. Analyses were conducted in SAS 9.4 (Cary, NC) using survey weighting methods described in NIS-Teen data user guide (36).

Finally, we utilized both quantitative and qualitative observational data from social media, specifically Twitter (38) and Instagram (39), to characterize social media-level communication patterns. The study team used an application programming interface (API) to collect public posts from these platforms that included relevant hashtags such as #hpvvaccine. We content analyzed social media posts and also examined post metadata, including likes and shares. Bivariate analyses allowed us to examine whether the content of the post was associated with engagement (e.g., comparing the average number of likes for information-focused vs. narrative-focused posts). In addition, through a network analysis of anti-HPV vaccine Instagram posts, we characterized how misinformation specific to the HPV vaccine was described and communicated (19).

Persona Development

To begin integrating data and developing our personas, we categorized the combined data (focus groups, NIS-Teen, and social media) by vaccine attitudes (i.e., supportive, hesitant), vaccine influences (i.e., individual, societal), and vaccine-specific issues (i.e., awareness, safety). We identified emerging patterns in characteristics and used these to develop our initial four clusters of potential personas. Of note, we focused on supportive and hesitant vaccine beliefs for our persona development, and excluded anti-vaccine beliefs, as our goal was to create personas to deliver information to parents who are considering or are unsure of the HPV vaccine for their child. From this point, we introduced psychographics (i.e., attitudes, aspirations, motivations) to our data-derived clusters, and merged and shifted characteristics from different personas based on iterative evaluation of the combined datasets and evolving themes to arrive at our first iteration of the four personas.

Data/Persona Refinement

We assembled a diverse parent advisory board (PAB) by recruiting on Twitter, ultimately choosing six parents (five female, one male) who identified as African-American, South Asian-American, and Caucasian, from across six states in the U.S., including urban and suburban, with children ages 11–12. Vaccinating their adolescent against HPV was not required, such that some parents on the PAB had gotten their children the HPV vaccine, while others were still deciding; however, none of the parents had decided against vaccinating their adolescent. The PAB provided expert insights and feedback on persona characteristics, lifestyle, vaccine motivations, vaccine issues, communication, contextual influences, and individual influences. Over a 6-month period, we held monthly meetings with the PAB to discuss and refine the personas.

Before each meeting ($n = 6$), we asked that all PAB members complete a workbook with persona development materials and targeted questions to gather extensive feedback. The questions aimed to capture thoughts about persona descriptions while connecting their lived experiences to the personas. We have provided two sample workbooks as **Supplementary Materials**. Once the workbooks were completed, the study team compiled summary documents and conducted a thematic analysis of all

responses, identifying recurring themes within each section of each workbook.

We used the widely accepted 3C model of vaccine hesitancy (40) to identify distinct vaccine beliefs for each of the personas related to confidence, complacency, and convenience. We ranked each persona on a Likert scale (low, somewhat, moderate, and high) on the three metrics. For confidence and convenience, a high score correlated with positive associations with the HPV vaccine, while a low score correlated with more negative associations with the HPV vaccine. Confidence refers to trust in the effectiveness and safety of vaccines, the system that delivers them—including the reliability of the health professional—and/or the motivations of policymakers who make determinations about vaccines. Convenience refers to the degree to which the comfort, time, place, and quality of a vaccine affects uptake of the vaccine. Complacency was reversed scored, meaning that a high score correlated with more negative associations and a low score correlated with more positive associations. Complacency refers to a low perceived risk of vaccine-preventable diseases and therefore it is assumed vaccines are not needed.

Persona Profile Identification

The final four personas were described to highlight their unique characteristics, including demographics, goals and aspirations, challenges and frustrations, communication needs, as well as confidence, convenience, and complacency of the 3C model. Background information included demographics such as gender, age, marital status, education level, and child(ren) status, as well as lifestyle information such as occupation, extracurriculars, and personality characteristics. Goals and aspirations correlated to each persona's attitudes and beliefs in regards to promoting health behaviors related to HPV vaccine uptake. Challenges and frustrations correlated to the obstacles each persona faced in terms of processing health information, engaging with others, and impediments to action regarding the HPV vaccine. Communication needs described the communication style, preferences, and social media activity/engagement utilized by the personas to connect with others in their social networks both on and offline.

RESULTS

Table 1 provides a joint display that describes how findings from each data source (i.e., focus groups, NIS-Teen, social media, and PAB) were integrated and used to inform the development of each persona. This method of organization was used to demonstrate how deliberate we were in using the data to inform the development of specific personas. Cross-cutting themes drawn from the key findings across different data sources emerged to ground our persona development. Furthermore, integrating findings from across multiple data sources both complemented and expanded the understanding of each persona, particularly as it related to HPV vaccine beliefs, motivations, and behaviors.

In *focus groups*, parents stated that they wanted to hear about experiences from other parents but did not know how to

TABLE 1 | Data type and content used to inform development of each persona.

Persona	Data source			
	Social media	NIS-Teen*	Focus groups	Advisory board
Informed Altruist	Informational resources an important foundation and most prevalent.	Likely to say “yes” to the vaccine. Few safety or effectiveness concerns	Parents want evidence to help them support their decision to vaccinate.	Has a powerful job and is non-confrontational when it comes to vaccine conversations
Real Talker	Myth busting and addressing conspiracy theories and lies.	Confident speaking to parents who are “not likely at all” to vaccinate adolescent and have high safety concerns	In regards to vaccine experiences, parents thought positive experiences should be highlighted and made more memorable.	Young parent who draws from personal experiences
Information Gatherer	Misinformation is prevalent and at times difficult to decipher—addressing distortive tactics.	Need strong provider recommendation and credible, accurate information	Parents want to hear from other parent experiences but also wanted to have data to support these narratives and stories.	Wants to make best choice for family. Afraid of making the wrong decision
Supporter	Personal stories received the most engagement.	More likely to be a father-figure who may not have high HPV vaccine awareness or knowledge	Talking to other parents about the HPV vaccine or vaccines in general is a difficult. Many parents are unsure how/where these interactions take place.	Seen as a mentor and active listener

*NIS-Teen, National Immunization Survey—Teen.

start this conversation. Parents also indicated that while positive experiences with the HPV vaccine were far more common, the negative experiences were often more memorable. Additionally, parents thought that hearing about other parent experiences would be an important complement to data and resources. That is, experiences alone would not be sufficient to help strengthen their confidence, but were a necessary complement to the science and evidence supporting the HPV vaccine.

NIS-Teen data revealed that among parents whose adolescents had not started or started but not completed the HPV vaccination in 2018, 30% were not likely at all, 15% were not too likely, and 9% were unsure about vaccinating their adolescents in the next 12 months. Compared to “not too likely” parents, “not likely at all” parents had greater concerns for HPV vaccine safety (14 vs. 25%), fewer received a physician recommendation (17 vs. 8%), and fewer lacked knowledge about the vaccine (11 vs. 3%) (all $p < 0.0001$). Mothers, compared to fathers, were more likely to have concerns about safety and side effects (21 vs. 11%). However, fathers were more likely to report not knowing about HPV vaccine (10 vs. 7%) and fewer received a physician recommendation (17 vs. 12%) (all $p < 0.0001$). These data indicated that current HPV vaccine attitudes and knowledge vary depending on specific subgroups and tailored communication should be considered.

Social media data demonstrated that positive sentiment about the HPV vaccine was more prevalent than negative, and most often communication through informational posts. Specific to Twitter data ($n = 193,379$ tweets), the majority of content was positive and content shared by parents was more often personal experiences compared with information or resources. On Instagram ($n = 508$ posts), while more posts communicated positive sentiment about the HPV vaccine, posts with negative sentiment were more often about personal stories and experiences, and also received more engagement (i.e., more likes). Social media data also revealed that misinformation

takes many forms, but at the same time demonstrates patterns and consistent elements. For instance, conspiracy theories and recently uncovered “unknown facts” about the HPV vaccine clustered together, most often with the sentiment of purporting to reveal a lie (19). Vaccine injury stories were told through a distortive lens often implying correlation or comparison between two unrelated pieces of information or evidence.

Parents on the advisory board provided critical data points to inform the development of personas. The two sample workbooks provided as **Supplementary Materials** were used to gather individual data from PAB members, and we followed this with a group discussion on the workbook topics. Personas evolved based on this feedback, as seen when comparing the persona names across the two workbooks—for example, the Researcher became the Information Gatherer.

The PAB described how they personally relate to each persona, which added a final layer of realism to the persona descriptions. The PAB either saw themselves or others they knew in the personas.

- “Many elements of this description remind me of myself or some in my closest circle.”
- “As I was reading I could name specific people in my life who fit the characteristics of each character.”

They proposed demographics, communication styles, strengths, and challenges for each of the personas based on lived experiences.

- “As a woman, I think I do think of this person [Informed Altruist] as a college educated woman who may or may not have left the work force and now has the time and means to partake in volunteer positions. I think this person might also work for a non-profit.”
- “They [the Real Talker] are very articulate at getting their point across and with ease. They can be very demanding at times.”

The PAB suggested that it would be important to highlight specific fears around vaccines (e.g., making the wrong decision or not feeling confident in a choice).

- “She [information gatherer] is well-intentioned and warm-hearted, but flighty. She would rather not make a decision if she thinks she may make a wrong decision.”
- “I wonder if instead of the [information gatherer] being scared to make the wrong choice it is more wanted to make the best choice for their family.”

The advisory board also discussed how they personally communicate with other parents around vaccines, and how we could incorporate those specific details into the personas (i.e., confrontational vs. non-confrontational on social media, being an active listener).

- “I would never want to suggest to another parent that he or she is not protecting their child if they do their research and then make a choice not to vaccinate.”
- “I think many of us in this category are averse to conflict, which also compounds the stress of being challenged if our facts aren’t airtight.”

Personas

Four fictional personas emerged that represent different parent types when it comes to the HPV vaccine and decision making. Displayed by their profiles in **Figure 2**, the four personas were the (1) Informed Altruist, (2) Real Talker, (3) Information Gatherer, and (4) Supporter.

The Informed Altruist

The Informed Altruist is a college-educated parent who promotes the collective good of HPV vaccination and has pro-social motivations in all aspects of life. This persona is married, mother to multiple children, and approximately 40 years in age. The informed altruist is a hard-working, managerial-level individual who is kept busy by their work in a health-related field. They prefer an upbeat, fast paced environment. While work is demanding, this persona finds that their spare time is spent getting involved in community groups through their children. If asked to describe their general attitudes and outlook, the informed altruist would say they are compassionate, dedicated, knowledgeable, idealistic, respectful, decisive, and confident. They strive to set positive examples for others, and that is no different when it comes to helping educate parents on the importance of the HPV vaccine, something they care deeply about. Because work and life are time-consuming, this persona greatly values convenience and easy access to credible, reliable information, especially when it comes to health and related topics such as vaccination. Access to reliable information is made easy through their profession and close relationships with others in the field. This makes the informed altruist very knowledgeable about vaccines and confident when it comes to sharing this knowledge with others. Their primary goal regarding the HPV vaccine is to encourage vaccine uptake to benefit the greater good. They enjoy sharing what they know about the HPV vaccine in group settings and take a non-confrontational approach

when it comes to discussing differences of opinion regarding the HPV vaccine. The informed altruist also uses their social media platform to educate others but will not directly engage with comments or direct messages. They are most frustrated by individuals who make selfish health decisions and lack understanding of the impact of such decisions. And while this persona is knowledgeable, understanding, and always advocating for the HPV vaccine, they sometimes struggle to voice their own questions and concerns because others look to them as a parent expert and the go-to source. The informed altruist ranked “high” in both confidence and convenience and ranked “low” in complacency.

The Real Talker

The Real Talker is a curt but personable parent who is driven to inform, educate, and myth-bust when it comes to relaying information about the HPV vaccine to friends and family. This persona is a community college-educated, single mother, in their 30’s, who is the primary breadwinner for their family and works in the service industry. They enjoy spending their free time creating memories with friends and family. Despite their primary focus caring for their child(ren), they spend any remaining free time volunteering and getting involved with grassroots activities happening in their community. If asked to describe their general attitudes and outlook, the real talker would say they are protective, hardworking, assertive, blunt, intense, personable, and confident. They are particularly passionate about keeping their family and friends safe and healthy, especially when it comes to preventive health behaviors. They enjoy sharing their informed opinion with others and actively create moments to talk about the health topics they care deeply about—such as the HPV vaccine. Their primary goal regarding the HPV vaccine is to be a strong advocate for vaccination and actively myth-bust and dispel misinformation that they come across in their personal lives and online. They are comfortable having difficult discussions both in group settings and in more intimate one-on-one settings. Because they are blunt and “to the point” they may come off as overly opinionated and, in some cases, railroad conversations that become heated. The real talker is heavily frustrated by online anti-vaccine campaigns and struggle to sympathize and communicate with those who hold anti-vaccine beliefs. Science and fact checking are highly valued and the key evidence this person uses when discussing the HPV vaccine with friends and family. The real talker ranked “high” in confidence, “moderate” in convenience and ranked “low” in complacency.

The Information Gatherer

The Information Gatherer is an open-minded, yet cautious parent who relies on their online communities and network to learn about the HPV vaccine and help inform their decision making. This persona is a stay at home parent in their late 30’s with some college education who has found creative ways to build income through the creation of online content and a social media presence. They enjoy gathering information and opinions online related to various health-focused topics, like the HPV vaccine, and like taking their time when it comes to making health decisions. Because they are the first of their

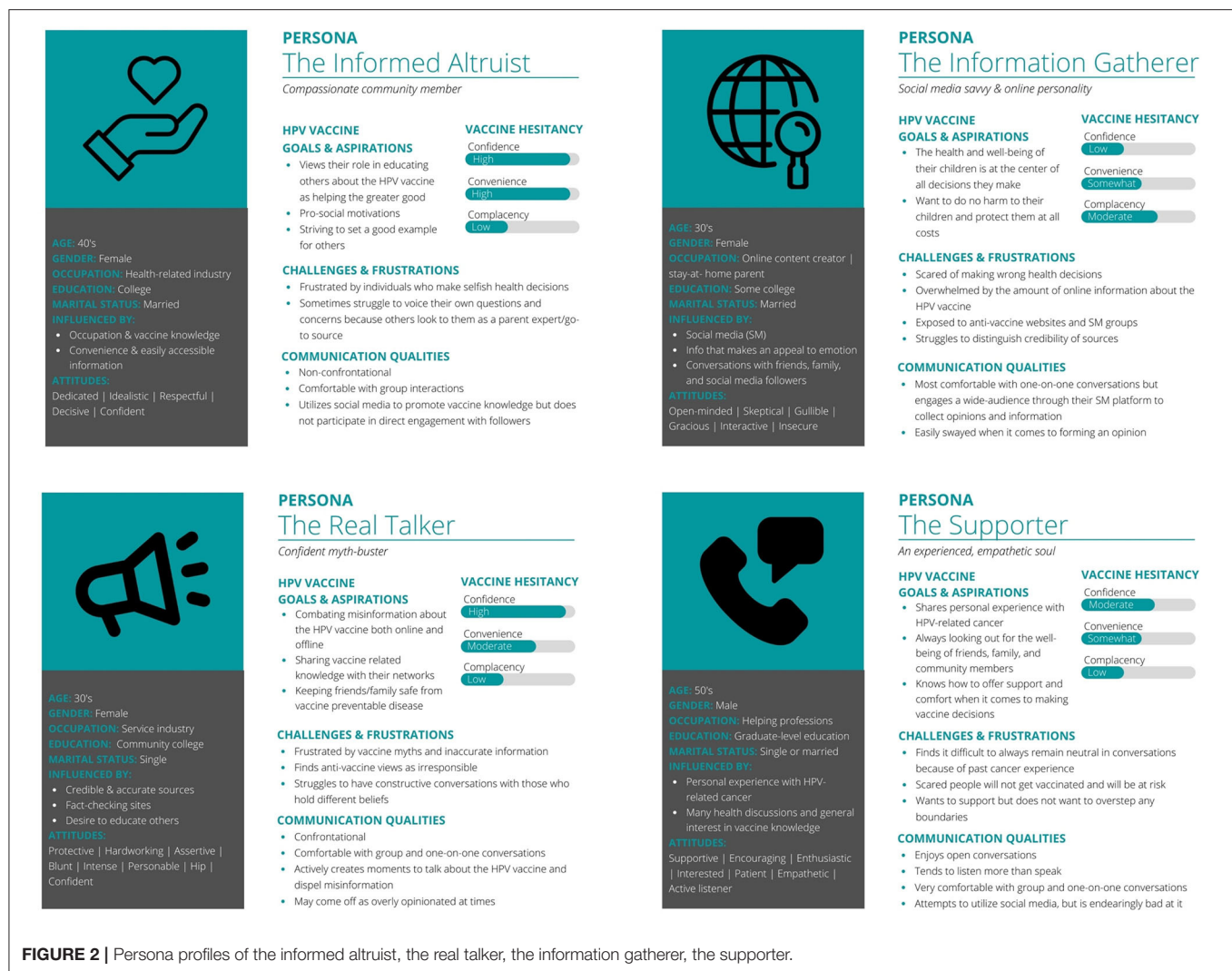


FIGURE 2 | Persona profiles of the informed altruist, the real talker, the information gatherer, the supporter.

friend group to have children, they are also the first to research recommended vaccinations for children. Through their online community, the information gatherer purposely explores and browses social media outlets that offer varying and opposing opinions to learn about differing perspectives and why parents make certain health decisions. If asked to describe their general attitudes and outlook, the information gatherer would say they are open-minded, gracious, interactive, skeptical, insecure, and flighty. When it comes to determining whether or not the HPV vaccine is necessary for their child, they struggle to sift through the overwhelming amount of information and have a very difficult time identifying what sources to trust. Because of this, they are easily swayed by emotional appeals by anti-vaccine social media campaigns and frequently fall prey to misinformation. This makes it challenging for the information gatherer to provide answers to the questions raised by their child about why they need the vaccine. This persona is also challenged by the overwhelming and conflicting extremes of online health information and will turn to their trusted health care provider for guidance. Ultimately, their primary goal is to make the best

decision to protect their child and do no harm to them. The information gatherer ranked “low” in confidence, “somewhat” in convenience and “moderate” in complacency.

The Supporter

The Supporter is a kind, encouraging, and empathetic parent and grandparent who is known within the community to be the “go-to” person for support as they are well-attuned to the interests and well-being of others. This persona is an older individual in their 50–60’s and father to adult children who have multiple of their own. Having had first-hand experience with an HPV-related cancer makes this persona lead with emotion in conversations about vaccine preventable diseases. However, with graduate-level education and having spent the majority of their life in a helping profession, this persona is able to remove the personal element and support others in making their vaccine decisions. If asked to describe their general attitudes and outlook, the supporter would say they are caring, enthusiastic, interested, patient, empathetic, and an active listener. This persona knows how to support others in making vaccine decisions however possible, which is their

primary goal. They find joy in having open conversations with family, friends, and community members but tend to listen more than they speak. They are very comfortable having one-on-one conversations about the HPV vaccine and vaccinations in general, though they prefer to have those conversations off-line. The supporter is not very active on social media, but they try to be, and are endearingly bad at it. Overall, this persona finds it hard to remain fully neutral in HPV-vaccine conversations due to past personal experience and hopes to inspire others to get vaccinated so that they are protected and don't have to go through what they did. Their experience with HPV-related cancer makes them a very knowledgeable source and an advocate for trusting the guidance of primary care physicians who want the best for their patients, young and old. The supporter ranked "moderate" in confidence, "somewhat" in convenience and "low" in complacency.

DISCUSSION

Our findings described the development of four personas that can be used to communicate with parents about the HPV vaccine on social media: the Informed Altruist, the Real Talker, the Information Gatherer, and the Supporter. Developing personas takes data-driven decisions and formative work to identify core values and characteristics that are salient to both the target audience (i.e., parents) and content area (i.e., HPV vaccine). Based on data from a variety of sources, including focus groups, national surveys, and social media, we identified and presented unique beliefs, attitudes, motivations, lifestyles, and communication styles related to the HPV vaccine, synthesized through four personas. While personas have been used in social marketing and health research (32, 41, 42), we found little evidence of persona development for social media interventions.

Personas have been used in a variety of contexts outside of health communication. This approach, describing not only beliefs related to the HPV vaccine but also broader lifestyle behaviors and motivations, highlights the importance of drawing from the fields of marketing and consumer insights (43), where personas have long been used to identify the ideal client or customer (44). Our findings further demonstrate an application of lifestyle marketing on health promotion and communication, by focusing on what people like to do, what they are motivated by, and how they like to spend their free time (45).

Pro-vaccine messaging can be enhanced by using personas to help craft messages and identify narratives for different segments of the population. The personas that we have developed are designed to appeal to parents and are based on data and observations from focus groups, a national survey, social media, and parent input. While this study did not describe message or narrative development, this is the next natural step in the process, using personas to guide and inform ethical message creation (see **Figure 1**). Each persona will be the foundation for a character, or person, that discusses the HPV vaccine based on the persona experiences and life motivations. Messages will be designed as if they were there being told from each of the characters, making the messages more relatable. The characters will interact with

one another and be used to create a story; however, this is not required—personas can also be used to create messages that are standalone that are meant to target people who think or act in a similar way.

The use of social media personas that can provide health information while engaging the target audience is an important tool that can be utilized in public health. By documenting and describing our inputs, process, and outputs of persona development, our process and findings can be applied to other topics in health education and social media research and practice. This strategy can be used not only for health promotion and communication on social media, but also to address the growing and damaging presence of online health misinformation. Many fake social media accounts exist that are designed to accomplish a range of goals, including the spread of health misinformation (46). These accounts can be very successful and often, social media users are unable to identify such accounts (47). The COVID-19 infodemic has shown the need for a research-informed, ethically-based approach to counter inaccurate and biased health information. A model to guide the development of pro-public health personas can offer a way to influence social media users to engage in health promoting behaviors. It is also important to consider how personas can be used to deliver messages that are both culturally competent and health literate to further ensure acceptance and understanding of the information being provided.

Engaging narratives surrounding the personas must also be created to capture the attention of social media users. People are faced with hundreds or even thousands of competing messages every time they engage with their social media feed. The power of narrative in HPV vaccine work has been identified through various studies, including narratives shared through multimedia (16) and interpersonal conversations (17). Extending this work to social media is an important next step and personas are a tool to assist this expansion of the field. In addition, emotional appeal can be heightened through personas and has the potential to address vaccine hesitancy in an important novel way (14). Indeed, research has shown that messages that are emotionally arousing are more likely to be recalled (48), strengthen persuasion (49), and encourage discussion of messages (50). Using images that match the narrative message can also be important for ensuring the message is understood and accepted by the audience (51). Narratives can also help provide social scripts to influence health-related attitudes and behaviors (52).

Our methods are at the intersection of two complex topics: the development of personas to deliver important health information, and vaccination which is known to invoke strong positive and negative sentiment in both traditional and social media. Delving into these multi-faceted topics requires advanced data tools to fully investigate and understand the subject. Mixed methods research, or the integration of both quantitative and qualitative data to answer a single research question (53), is increasingly being seen as a methodology suited for tackling complex public health problems. In our study, we used quantitative data from the National Immunization Survey—Teen to inform us of the primary reasons that parents cited for not vaccinating their adolescent. We collected qualitative data from

focus groups and a parent advisory board to better understand those reasons, gather further insight, and explore solutions, all to inform the development of the personas. Additionally, social media data showed us the vaccine messages that parents are exposed to, so that the personas could be responsive to this environment. This robust methodology will ensure that the personas resonate with the parents in our study, as their foundation is quantitative and qualitative data from parents.

Finally, the goal of our project was to develop personas (and as a next step, messages) for parents on Twitter. As such, we focused recruitment of our parent advisory board to parents who were Twitter users and were very familiar with the culture and features of the platform. Future work will want to consider how working with end users from different online platforms may be useful and beneficial to inform project activities on various social media. While these personas are developed specifically for an intervention on Twitter, this approach and actual personas could be (and should be) adapted or applied to various digital environments and social media platforms. Additional personas may also be added for specific parents populations. Furthermore, this approach can be applied to emerging health needs. We have outlined our approach and detailed the ways various data sources have informed the persona development to provide one potential roadmap and methods that can be applied to other health topics with different audiences.

There are a few limitations worth noting. Due to the iterative process of development, not all personas have been ascribed certain demographic characteristics (e.g., race/ethnicity, gender identity/expression, sexual orientation, etc.). This may confer a strength as it will allow for a fluid evolution of the personas to their narrative state in a next phase of message development. Also, personas were developed to communicate information to parents who are still deciding or hesitant about the HPV vaccine and not parents who are completely against the vaccine. In addition, while the personas may capture large segments of the parent population, there are undoubtedly features and characteristics that are not reflected in the four typologies and regular verification can contribute to their expansion and refinement, particularly when applied to different health topics and audiences. Further, though advisory board membership exhibits considerable diversity in race/ethnicity and geography, it may not fully reflect all factors that contribute to parental decisions related to HPV vaccine uptake.

CONCLUSIONS

While other disciplines have used personas for design and marketing, they have been an underutilized tool in health promotion and communication on social media. The ability to capture and communicate both a breadth of experiences and depth of understandings gives this strategy a real potential for impact at both the macro- and micro-levels of influence.

Furthermore, combining the use of personas with narratives and storytelling can provide a meaningful and memorable way to organize and communicate health information at the population-level while at the same time relating to individual experiences.

DATA AVAILABILITY STATEMENT

National Immunization Survey - Teen data is publicly available through U.S. Centers for Disease Control and Prevention at <https://www.cdc.gov/vaccines/imz-managers/nis/datasets-teen.html>. Other study-related data are available via corresponding author given appropriate ethical approvals are obtained.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Drexel University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

PM, AK, JM, and AL contributed to the conception and design of the study. PM, SC, MRos, ET, and AL contributed to the recruitment of focus groups and parent advisory board. PM, SC, MRoc, ET, AK, JM, and AL performed primary analyses for NIS-teen, social media data, focus group, and parent advisory board workbooks. PM, SC, MRos, RM, and MRoc contributed to the development of personas. All authors contributed to the reporting of the work described in the article and have approved the final version of this manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fdgh.2021.682639/full#supplementary-material>

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Successful Multi-Level HPV Vaccination Intervention at a Rural Healthcare Center in the Era of COVID-19

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Objectives: To develop and test a human papillomavirus (HPV) vaccination intervention that includes healthcare team training activities and patient reminders to reduce missed opportunities and improves the rate of appointment scheduling for HPV vaccination in a rural medical clinic in the United States.

Methods: The multi-level and multi-component intervention included healthcare team training activities and the distribution of patient education materials along with technology-based patient HPV vaccination reminders for parents/caregivers and young adult patients. Missed vaccination opportunities were assessed pre- and post-intervention ($n = 402$ and $n = 99$, respectively) by retrospective chart review and compared using Pearson χ^2 . The patient parent/caregiver and young adult patient population ($n = 80$) was surveyed following the reminder messages and penalized logistic regression quantified unadjusted odds of scheduling a visit.

Results: Missed opportunities for HPV vaccination declined significantly from the pre-intervention to the post-intervention period (21.6 vs. 8.1%, respectively, $p = 0.002$). Participants who recalled receipt of a vaccination reminder had 7.0 (95% CI 2.4–22.8) times higher unadjusted odds of scheduling a visit compared with those who did not recall receiving a reminder. The unadjusted odds of confirming that they had scheduled or were intending to schedule a follow-up appointment to receive the HPV vaccine was 4.9 (95% CI 1.51–20.59) times greater among those who had not received the vaccine for themselves or for their child.

Conclusions: Results from this intervention are promising and suggest that vaccination interventions consisting of provider and support staff education and parent/caregiver and patient education materials, and reminders can reduce missed opportunities for vaccinations in rural settings.

Keywords: HPV vaccination, rural, healthcare team training, text reminders, intervention-behavioral, visit reminder, patient education, missed opportunities

BACKGROUND

Improving human papillomavirus (HPV) vaccine uptake could prevent tens of thousands of cancer cases each year. HPV is a sexually transmitted infection that causes cervical, anal, penile, vaginal, vulvar, and oropharyngeal cancers, and genital warts. While HPV vaccination can prevent most HPV-related cancers, more than 20,000 women and 14,000 men are diagnosed with HPV-associated cancers each year in the United States (1). This is troubling given that HPV vaccination rates remain substantially lower than national targets (80% by 2030 for adolescents aged 13–15) (2). Indeed, only about 54% of adolescents have met this target in more than 13 years after the vaccine was recommended for girls and 8 years after the recommendation for boys (3). Improving uptake of the HPV vaccine is a public health imperative.

Higher HPV vaccine uptake in rural communities could improve health outcomes for this unique population. The United States non-metropolitan residents have higher cervical cancer incidence, late-stage diagnoses, and death rates than metropolitan residents (4). Data from the 2019 National Immunization Survey-Teen show startlingly low HPV vaccine initiation and series completion rates for adolescents in rural regions. Rates of initiation or series completion are up to 10% points lower than for urban regions (5, 6). Vaccine registry data reveals that teens living in rural areas were 1.8 times more likely than urban residents to have a missed opportunity for HPV vaccination (when one receives another immunization and not the HPV vaccine) (7). *Developing and deploying effective strategies for improving rural HPV vaccine coverage is critical.*

Rural barriers to HPV vaccination are multi-factorial. A robust body of literature explicates barriers in receiving preventive health services, such as vaccination for HPV (8–11) and underscoring distinct challenges faced by rural residents (12, 13). At the patient level, individuals often lack awareness of the importance of vaccination, experience fear or fatalism, or are dissuaded by prevailing anti-vaccination norms (10, 14–17). Rural residents may experience limited healthcare access: studies show that rural adolescents are less likely than urban counterparts to attend a well-child visit and to receive a provider recommendation for HPV vaccination (6). In addition, providers and clinics are often limited by a lack of systematic methods for identifying patients eligible for vaccination; inadequate reimbursement and time for counseling about vaccination; and follow-up systems that do not track intervals for repeated doses (18). Rural clinics also face shortages of medical providers, especially pediatricians, well-versed in delivering adolescent vaccines (11, 19, 20).

Complicating the situation further, in March 2020, the WHO classified COVID-19 (i.e., coronavirus) as a global pandemic leading to an unprecedented strain on the U.S. healthcare system (21); nevertheless, it presents a teachable moment to communicate the importance of vaccination to counter anti-vaccination sentiment and improve rates of HPV vaccination. In the United States, the vast majority of non-essential medical care (e.g., well-child visits) did not occur during the peak of the COVID-19 pandemic (22, 23). In the early months

of the pandemic, up to 40% of appointments for children's immunizations and 80% of appointments for teen's HPV vaccinations have been missed (24). As well-child visits have been resuming, adolescents have been the least likely to catch-up on immunizations, compared to younger children and infants (25). Furthermore, publicly-insured adolescents have experienced larger declines in immunization since the start of the pandemic in March 2020 than privately insured adolescents (3, 26).

Multi-level interventions are needed to reduce HPV vaccination disparities. Solving complex public health issues requires consideration of factors at multiple levels, such as the individual (e.g., fear, fatalism, lack of awareness, and misperception of threat), clinician (e.g., missed opportunities), clinic (e.g., limited operating hours), community, and society (e.g., low awareness and prioritization of vaccine). Current studies find that multi-level interventions display a synergistic effect, with interventions targeting parents and providers achieving higher levels of HPV vaccine uptake than interventions targeting each group alone. However, many of these past studies have not been rigorously tested in rural populations.

This study developed and tested a multi-level and multi-component intervention in a rural Telluride, Colorado, United States. The intervention consisted of healthcare team training activities to strengthen and increase strong and consistent HPV vaccination recommendations and evidence-based patient-directed HPV vaccine education materials as well as technology-based parent/caregiver reminders to make vaccine appointments for their age-eligible children. This study sought to fill important gaps in the literature, including exploring the impact of combining technology-based interventions with human-delivered communication. Few previous studies have tested the combination of strong provider recommendations for the vaccine with automated reminders to patients.

METHODS

Study Location

Telluride Regional Medical Center (TMC) serves rural patients in the western United States. Telluride, Colorado is a rural community of <2,500 residents. In addition, Telluride is a mental health and primary care Health Professional Shortage Area (HPSA) and a Medically Underserved Area (MUA). Located in a box canyon of the Colorado Rocky Mountains in San Miguel County, Telluride is surrounded by mountains, receives over 167 inches of snowfall annually, and driving conditions are often treacherous. The nearest city to Telluride is Montrose (<20,000 people) and is approximately 1.5 h drive along over 65 miles of mountainous roads. TMC includes 5–8 primary care clinicians and approximately 7–10 other clinic staff members. They provide primary care services to all ages, from birth to death and are about 100 miles from the nearest hospital. The clinic uses eClinicalWorks® (eCW) for the electronic health record (EHR). They have prioritized increasing HPV vaccination rates in 2017 when they began collaborating with Dr. Kepka, an associate professor at the University of Utah, United States

and an investigator at Huntsman Cancer Institute, and the Intermountain West HPV Vaccination Coalition (led by Dr. Kepka) (27).

Healthcare Team Training—Telluride Medical Center Provider Facilitation and Education Campaign

Dr. Kepka assembled a University team to guide the development and implementation of the components of the multi-level HPV vaccination intervention. Team members included two clinical informatics experts, a graduate student in nursing, a program manager and data analyst, and Dr. Kepka (an HPV vaccination expert and health services researcher). The development of the parent/caregiver and young adult reminder intervention included three video calls between the University team and TMC providers and support staff at the end of 2020. Calls consisted of an environmental scan of existing HPV vaccination efforts, a discussion on possible approaches for improving HPV vaccination rates and delivery, and conversations around the facilitation of TMC provider and support staff vaccination efforts by the University team. The video calls also included a walkthrough of the EHR workflow and immunization preparation activities at TMC. The team determined prioritization of the target population, the development of a vaccination patient reminder campaign and messaging content, and campaign implementation within the EHR. The team also completed a walkthrough of running the campaign with TMC team members as completed *via* virtual meeting. A step-by-step documentation and guide for EHR implementation developed by the University team were provided offline to the providers and support staff at TMC.

Human papillomavirus vaccination training for the healthcare team included two 1-h early morning video calls that focused on training providers and support staff at TMC on evidence-based HPV vaccination systems, vaccine recommendations, and patient education materials relevant to their patient population. Healthcare teams were taught how to deliver a strong, brief, and consistent provider recommendation for the HPV vaccine to their patients (28). They were also taught to treat every patient visit like a vaccination visit regardless of whether the child or young adult were at TMC for vaccinations. Last, healthcare team members were given evidence-based patient center HPV vaccination education materials (28). These training activities were facilitated by Dr. Kepka and the graduate student in nursing and were conducted in early 2021. Breakfast was provided to the TMC team as a thank you gesture for attending the healthcare team training activities.

Before and after the two training activities, an online survey that included HPV and HPV vaccination knowledge questions and barriers to vaccination was completed online by providers and support staff at TMC using Research Electronic Data Capture (REDCap) tools hosted at the University of Utah (29, 30). The pre-test survey was administered 2-weeks prior to the first training and the post-test survey was delivered about 2-weeks after the last training. Healthcare team survey respondents received an HPV vaccination coffee mug or lunch bag, a chance

at a raffle prize after the first survey, and a \$50 gift card after the completion of the second survey and training activities. Survey results, such as HPV vaccination barriers identified by providers and support staff, were examined. The percentage of providers and support staff selecting a given barrier was calculated from the total number of provider and support staff survey respondents. The percentage change described differences between pre- and post-intervention. Frequencies for provider and support staff self-report of feasibility and usability were obtained and compared using Pearson's χ^2 .

Reminder Message Campaign

With the assistance of the University team, TMC providers and support staff developed a HPV vaccination reminder campaign for patients/caregivers with age-eligible children for the HPV vaccine (children ages 11–17) and young adults (ages 18–26) who are also age eligible for the HPV vaccine. The reminder message was branded as coming from TMC instead of sending reminders from their individual provider. HPV vaccination messages reminding patients or their parents/caregivers to schedule an appointment were sent from the Medical Center *via* patient preferred method (i.e., text or email) using patient outreach capabilities provided by the EHR system available at TMC (eClinicalWorks®).

Human papillomavirus vaccination reminder messages were designed using evidence-based recommendations highlighted by the American Cancer Society's HPV Vaccination Roundtable (28). First, the team pilot-tested a HPV vaccination reminder message directed at parents and caregivers of 11-year-olds to a small sample of parents/caregivers at TMC ($n = 44$) in August 2020. Then, the team improved the design of the reminder campaign and expanded the target group to parents and caregivers of children ages 11–17 who are age-eligible for the HPV vaccine and to young adults ages 18–26 who are also age-eligible for the vaccine. The final round of the HPV vaccination reminders was sent to the larger group of participants in October 2020.

An example reminder message that was sent *via* text or email to parents/caregivers at TMC during the reminder campaign is listed as:

You'd do anything to protect your child...

Now is the time to give [NAME] the gift of cancer prevention.

The HPV vaccine protects boys and girls against up to 6 types of cancer.

Our records indicate that [NAME] has turned 11 since the beginning of the COVID-19 pandemic. We recommend Tdap, HPV, and Meningitis routine vaccines at the 11-year-old visit. Don't delay, get your child scheduled today for a well-child visit by calling (###) ###-####.

We are taking special precautions to ensure all well-child visits are safe during these challenging times.

Chart Review

A cross-sectional retrospective chart review of HPV immunization of all vaccine-eligible patients (ages 11–26 years) visiting the clinic prior to intervention (September 01

to December 01, 2019, $n = 402$) and a shorter period of time following the intervention (January 15 to March 15, 2021, $n = 99$) was performed. Age at the time of the visit was collected as a continuous variable and included in analyses as whole years (with no rounding). All other collected variables were binarized into yes/no categories and Pearson's χ^2 with probabilities were calculated for pre- and post-intervention comparisons. To determine the robustness of χ^2 estimates, sensitivity analyses were performed to examine the effects of partially overlapping samples. A dataset of non-overlapping individuals between pre- and post-interventions was created, and p -values compared for pre-intervention, post-intervention, and post-intervention without overlaps. Age distributions were compared using 95% confidence intervals for the median with the null-hypothesis locational parameter equal to the pre-intervention median. Analyses were performed using SAS software (version 9.4, SAS Institute, Cary, NC).

Post-Intervention Parent/Caregiver and Young Adult Patient Survey

A short online survey was conducted among the TMC parent/caregiver and young adult patient population about 3 weeks following the vaccination reminder intervention. Participants received an email invitation to the survey with a URL link that was used to take the survey. The survey asked patients, parents, and/or caregivers if they had received a reminder; what mode (email, text, or telephone) of reminder they received; if they scheduled, or planned to schedule, an appointment; if they or their child had received the HPV vaccine; two open-ended qualitative response questions about scheduling the appointment and comments about the campaign; and demographic questions. Participants had the option to receive a \$10 gift card as a thank you gift for their time upon completion of the survey. The survey was designed and administered using the online SurveyMonkey application (SurveyMonkey, Inc., San Mateo, California, USA, www.surveymonkey.com).

Survey data were analyzed descriptively using frequencies, distributions by scheduling (or intent to schedule) an appointment, and Pearson's χ^2 with probabilities. Unadjusted odds ratios (cORs) were calculated for the odds of scheduling an appointment by age, gender, receiving a reminder, mode of reminder, and receipt of the vaccine for either self or child. Analyses were performed using SAS software (version 9.4, SAS Institute, Cary, NC).

The study was considered to be exempted by the University of Utah Institutional Review Board as a primary care quality improvement study.

RESULTS

Chart Review

Less than 27.3% of individuals in the post-intervention sample overlapped with the pre-intervention sample. Sensitivity analyses demonstrated robustness of χ^2 estimates for all factors, except for "other visit" (attenuated to no difference, $p = 0.891$) and being up to date on the HPV vaccine at the beginning of the visit (difference observed, $p = 0.017$), indicating the

use of the full post-intervention dataset to be appropriate (**Supplementary Table S1**). The age distributions varied between pre- and post-intervention (**Table 1**). The median age increased from 17 to 18 years ($p = 0.05$), and normality assumptions appeared to be reasonable in both the pre- and post-intervention populations ($X = 17.47$, $M = 17$, $s = 4.72$, skew = 0.50, and kurtosis = -0.96 ; $X = 18.99$, $M = 18$, $s = 4.61$, skew = 0.09, and kurtosis = -1.37 , respectively). Higher proportions of younger (ages 10–14) patients were seen prior to the intervention (34.3 vs. 21.2%), and higher proportions of older (ages 19–28) patients were seen after the intervention (49.5 vs. 33.6%). Having any HPV vaccine records on file at the time of visit differed from pre- to post-intervention (22.4 and 43.4%, respectively, $p < 0.0001$). Those without a vaccine record on file and were also not categorized as up-to-date, had an "unknown" HPV vaccination status (pre-intervention $n = 90$, 38.1% of those not up-to-date; post-intervention $n = 43$, 68.3% of those not up-to-date). Neither the number of wellness visits, patients up-to-date on an HPV vaccination schedule, patients receiving an HPV vaccination during the visit, nor patients declining a vaccination at the time of visit varied between pre- and post-intervention. A lower proportion of patients following the intervention were due for the HPV vaccination initial dose and/or booster compared with those due prior to the intervention (20.2% vs. 35.6%, $p = 0.0035$). Missed opportunities for HPV vaccination declined significantly from the pre-intervention to the post-intervention (**Table 1**) (21.6 vs. 8.1%, respectively, $p = 0.002$).

Survey Following Reminder Message Campaign

Parents/caregivers of HPV vaccine eligible patients and young adult patients at TMC who responded to the survey were primarily female ($n = 71$, 91%) and equally distributed between those 18–45 years and those over 45 years old. A little more than one-third received or remembered receiving a vaccination reminder ($n = 28$, 35.4%). Of those reporting the mode of reminder, most of them reported receiving an email message vs. a text message ($n = 22$, 68.8% vs. $n = 10$, 31.3%). Just under one-third of the parents/caregivers reported getting their child the HPV vaccination ($n = 21$, 27.3%) and slightly over one-third reported getting the HPV vaccine for themselves ($n = 27$, 34.2%).

Those who scheduled or intended to schedule an appointment differed by age ($p = 0.0086$), receipt of a reminder from TMC ($p = 0.0002$), and by vaccination status for their child ($p = 0.0074$) or themselves ($p = 0.0116$) (**Table 2**). Parents/caregivers who were over 45 years old had 3.46 times the unadjusted odds (95% CI 1.36–9.27) of scheduling or intending to schedule a follow-up visit as compared with those patients or parents/caregivers 18–45 years old. Those receiving the TMC reminder had 6.96 times greater odds (95% CI 2.44–22.79) of scheduling a visit as compared with those who did not recall receiving a TMC vaccination reminder. The crude odds of HPV vaccine recipients scheduling, or stating that they had scheduled, a follow-up appointment was 70% less than those who had not received the HPV vaccine (cOR = 0.30, 95% CI 0.11–0.77) (**Table 2**). However, the unadjusted odds of parents and/or caregivers of

TABLE 1 | Cross sectional review of human papillomavirus (HPV) vaccination at Telluride Medical Center (TMC) pre- and post- intervention, 2019–2021^a.

	Pre-intervention (<i>n</i> = 402)		Post-intervention (<i>n</i> = 99)		χ^2 <i>p</i> -value ^b
	N	(%)	N	(%)	
Age at time of visit^c					**0.05
10–14	138	(34.3)	21	(21.2)	
15–18	129	(32.1)	29	(29.3)	
19–28	135	(33.6)	49	(49.5)	
Wellness visit: Annual physical or well child check					0.1656
No	296	(73.6)	66	(66.7)	
Yes	106	(26.4)	33	(33.3)	
Other visit: non-wellness visit (acute care or other)					*0.1222
No	103	(25.6)	33	(33.3)	
Yes	299	(74.4)	66	(66.7)	
UTD on HPV: Up to date on HPV at beginning of visit					0.3704
No	236	(58.7)	63	(63.6)	
Yes	166	(41.3)	36	(36.4)	
Due for HPV: at time of visit					***0.0035
No	259	(64.4)	79	(79.8)	
Yes	143	(35.6)	20	(20.2)	
Received HPV: at visit in question					0.8533
No	363	(90.3)	90	(90.9)	
Yes	39	(9.7)	9	(9.1)	
Missed opportunity: patient was due for vaccine but did not receive it at visit					***0.0020
No	315	(78.4)	91	(91.9)	
Yes	87	(21.6)	8	(8.1)	
Due now: based on current date, patient is due for booster or initial vaccine					*** <0.0001
No	282	(70.2)	91	(91.9)	
Yes	120	(29.9)	8	(8.1)	
Declines: patient or parent declined at time of visit					0.6281
No	381	(94.8)	95	(96.0)	
Yes	21	(5.2)	4	(4.0)	
No records: patient does not have any vaccine records on file^d					*** <0.0001
No	312	(77.6)	56	(56.6)	
Yes	90	(22.4)	43	(43.4)	

^aCross-sectional retrospective chart review performed for patients (ages 10–28 years) visiting the clinic between September 01 and December 01, 2019 (pre-intervention) or between January 15 and March 15, 2021 (post-intervention). TMC is a rural (CMS RHC, FORHP, FAR level = 4, RUCA = 10.0, RUCC = 9, UIC = 12, MUA, and HPSP for primary care and mental health) Medical Center located in Colorado.

^b*P*-values shown. Pearson's χ^2 with probability calculated for categorical variables. No overlap in 95% CIs, with normal distribution assumption, of median age pre- and post-intervention was witnessed and was confirmed in sensitivity analysis. (Pre-intervention: kurtosis = −0.96, skewness = 0.50; post-intervention kurtosis = −1.37, skewness = 0.09). *Significant at $\alpha \leq 0.1$, **significant at $\alpha \leq 0.05$, ***significant at $\alpha \leq 0.01$.

^cAge collected as a continuous variable (pre-intervention $X = 17.47$, $M = 17$, $s = 4.72$; post-intervention $X = 18.99$, $M = 18$, $s = 4.61$).

^dThose without a vaccine record on file and not up-to-date, have an “unknown” HPV vaccination status (pre-intervention $n=90$, 38.1% of those not up-to-date; post-intervention $n=43$, 68.3% of those not up-to-date).

children who had received the HPV vaccine stating that they had scheduled, or were intending to scheduled, a follow-up appointment was 4.93 times (95% CI 1.51–20.59) that of those whose children had not received the vaccine. Only gender and the mode of reminder (email compared to text message) did not vary by scheduling (and intent to schedule) a follow-up appointment ($p = 0.4153$; and $p = 0.2733$, respectively), although, due to cell sizes $n < 5$ for both covariates, estimates were considered as unreliable.

Healthcare Team Member Survey Following Facilitation and Education Campaign

The number of providers and support staff completing the pre-intervention and post-intervention surveys did not change ($n = 17$). Survey responses were not paired from pre- to post-intervention and results represent changes at the clinic level. Most respondents agreed or strongly agreed to utilize education and resources in the future ($n = 17$, 100%, data not shown),

TABLE 2 | Human papillomavirus (HPV) vaccination survey following reminder intervention, Telluride Medical Center (TMC) 2020^a.

Individual Level Variables	Scheduled an appointment for your child or self, following the message ^b						Crude odds of scheduling/intent ^c	
	Total (n = 80)		No and not intending (n = 33) ^b		Yes or intend to schedule (n = 41) ^b			
	N	(%)	n	(%)	n	(%)		
Age							***0.0086	
18-45	39	(48.8)	23	(69.7)	16	(39.0)	ref	
Over 45	41	(51.3)	10	(30.3)	25	(61.0)	3.46	(1.36–9.27)
Gender^d							0.4153	
Female	71	(91.0)	29	(93.6)	36	(87.8)	ref	
Male	7	(9.0)	2	(6.5)	5	(12.2)	1.78	(0.4–10.47)
Received TMC Reminder?							***0.0002	
No	51	(64.6)	28	(84.9)	17	(42.5)	ref	
Yes	28	(35.4)	5	(15.2)	23	(57.5)	6.96	(2.44–22.79)
Mode of Reminder?^e							0.2733	
Email	22	(68.8)	6	(85.7)	16	(64.0)	ref	
Text message	10	(31.3)	1	(14.3)	9	(36.0)	2.50	(0.42–26.62)
Did your child receive the HPV vaccine?							***0.0074	
No or N/A	56	(72.7)	29	(90.6)	26	(63.4)	ref	
Yes	21	(27.3)	3	(9.4)	15	(36.6)	4.93	(1.51–20.59)
Did you receive the HPV vaccine?							***0.0116	
No or N/A	52	(65.8)	15	(46.9)	31	(75.6)	ref	
Yes	27	(34.2)	17	(53.1)	10	(24.4)	0.30	(0.11–0.77)

^aOnline survey of parental and/or caregiver HPV vaccination and vaccination intention following a vaccination reminder intervention at a rural (CMS RHC, FORHP, FAR level = 4, RUCA = 10.0, RUCC = 9, UIC = 12, MUA, and HPSA for primary care and mental health) Medical Center in Colorado.

^bParticipants were asked if they had scheduled an appointment for their child or self, following the appointment reminder and response options included: Yes, a well-child check (n = 9, 12.2%); Yes, a lab visit for vaccines only (n = 6, 8.1%); No, but I intend to (n = 26, 35.1%); or No, and I don't plan to (n = 33, 44.6%). These responses were binarized for analysis into: No, and not intending (n = 33, 44.6%); or Yes (well-child, or lab visits) or intending to schedule (n = 41, 55.4%).

^cPearson χ^2 with probability calculated. *Significant at $\alpha \leq 0.1$, **significant at $\alpha \leq 0.05$, ***significant at $\alpha \leq 0.01$. Items in bold for crude odds of scheduling, or intending to schedule, an appointment following the reminder intervention indicate statistical significance (i.e., do not include the null observation) at a 95% level.

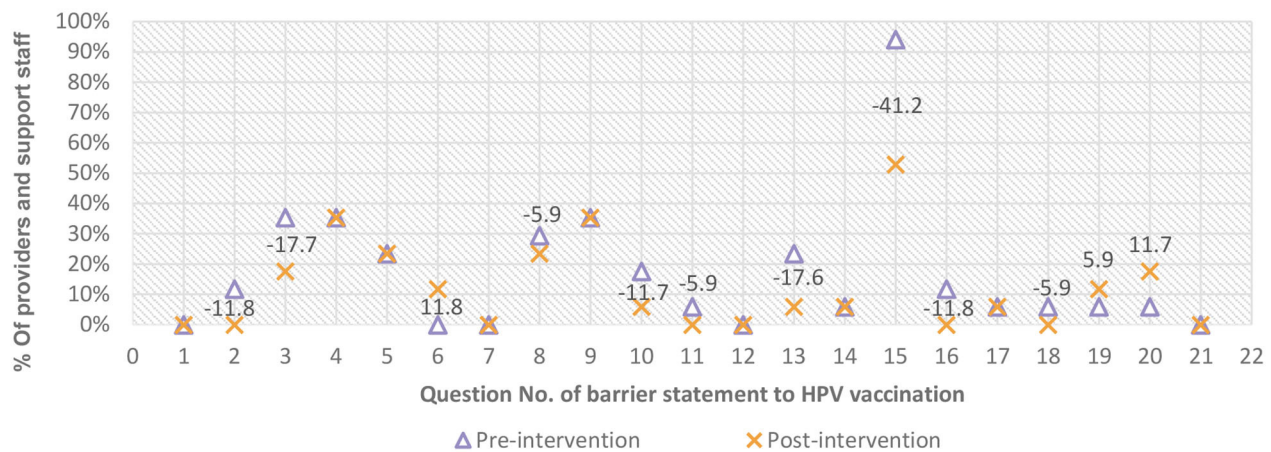
^dGender categories included female, male, transgender, or other. There were n = 2 respondents that either did not respond to the question, or selected transgender, or selected other, and were not included in analyses by gender.

^eMode of reminder, n = 48 respondents chose answer option of “none of the above,” n = 3 indicated receiving a phone call, and n = 7 indicated getting a text message reminder. “None of above” (responses only) were excluded from analysis.

and that the education and materials provided were helpful in treating every visit like a vaccination visit (n = 14, 82.4%, data not shown). The number of providers and support staff identifying a lack of educational materials as a barrier to vaccination decreased more than 17% points following the intervention, as did lack of time to discuss vaccination (**Figure 1**). The most frequently identified barrier to HPV vaccination selected by providers and support staff at TMC, in both the pre- and post-healthcare team training surveys was parental vaccination hesitancy or refusal, which declined 41.2% points, the greatest decrease (by percentage point) seen across vaccination barriers. Lack of standing orders (–11.8%), lack of time to administer the immunization (–11.7%), cost (vaccine is expensive) (–11.8%), lack of a provider reminder system for discussing vaccination (–5.9%), lack of HPV knowledge and training (–5.9%), and being unconvinced of the vaccine efficacy (–5.9%) all decreased by more than 5% points following the intervention. There were three (3) barriers that were selected more frequently by providers and support staff following the campaign and those included: lack of EHR use to track vaccination (11.8%), being unsure of

the need for vaccination (11.7%), and a personal fear of adverse and/or side effects (5.9%), which all increased by at least 5% points (**Figure 1**).

When examining what had been helpful in facilitating HPV vaccination by providers and support staff *via* free-text responses (data not shown), three general themes emerged as helpful: framing HPV vaccination as cancer prevention, education and materials provided, and education and discussion on HPV and vaccinating both male and female patients prior to the 15th birthday of the patient. An example of a statement of framing HPV vaccination as cancer prevention was “We have really taken on the approach as presenting this vaccine as part of cancer prevention, which parents are much more likely to receive well”. A characterization of the helpfulness of the education and discussion of HPV and vaccination was “We also have been able to provide valuable statistics on the prevalence of HPV once a patient becomes sexually active, and by stressing that we vaccinate early when children can mount a strong response long before they are exposed has helped parents understand why we vaccinate early against HPV”. Feasibility measures



Legend of survey questions and statements of barriers to vaccination

Q)	Barrier statement	%Δ ^b	Q)	Barrier statement	%Δ ^b
1)	HPV vaccine lacking in stock	-- ^c	12)	Lack of Clear Recommendations in Guidelines	-- ^c
2)	Lack of standing orders for vaccination	11.8	13)	Lack of Educational Materials	17.6
3)	Lack of time to discuss vaccination	17.7	14)	Lack of Strong Provider Recommendation	0.0
4)	Lack of time to determine if vaccine needed	0.0	15)	Parental Hesitancy or Refusal	41.2
5)	Lack of previous patient vaccination records	0.0	16)	Vaccine is expensive	11.8
6)	Lack of EHR use to track vaccination	11.8	17)	Lack of HPV Workflow Algorithm Guide	0.0
7)	Ineffective or lack of CIIS Use	-- ^c	18)	Unconvinced about HPV Vaccine Efficacy	-5.9
8)	Lack of System for Provider Reminder to Discuss Vaccine	-5.9	19)	Personal Fear of Side/Adverse Effects	5.9
9)	Lack of Reminder for Returning to Clinic for Vaccine HPV Series Completion	0.0	20)	Unsure of Need for Vaccine	11.7
10)	Lack of Time for Vaccine Administration	11.7	21)	Anticipate No Clinical Barriers	-- ^c
11)	Lack of HPV Vaccine Knowledge and Training	-5.9			

^aProviders and support staff at a rural (CMS RHC, FORHP, FAR level=4, RUCA=10.0, RUCC=9, UIC=12, MUA, and HPSA for primary care and mental health) medical center in the U.S. who participated in an educational intervention and completed an online survey prior to the intervention (n=17) and following the intervention (n=17).

^bPercent of providers and support staff selecting the barrier, given by the survey statement and question number, of the total number of provider and support staff survey respondents. Percent point change (%Δ) from pre- to post-intervention with direction.

^cBarrier was not selected by any providers or support staff in both the pre- and post-intervention surveys.

FIGURE 1 | Pre- and post-intervention survey of encountered HPV vaccination barriers among providers and support staff^a with percent point change^b. Legend of survey questions and statements of barriers to vaccination.

and usability among providers and support staff at TMC were favorable overall in both the pre- and post-intervention surveys (Table 3), with most strongly agreeing that: "...the benefits of current practices in place for HPV vaccination at my facility outweigh the costs/risks" (70.6 and 52.9%, respectively), "...the practices in my clinical setting are valuable and address barriers to HPV vaccination" (47.1 and 64.7%, respectively), and "current strategies I use for HPV vaccination in my clinic are easy to understand" (58.8 and 72.7%, respectively). Although, none

of the feasibility and usability measures showed a significant difference (Table 3) following the facilitation and education campaign intervention ($p > 0.2$ for each).

DISCUSSION

Overall, the multi-level and multi-mode HPV vaccination intervention performed well in a rural setting, even during the COVID-19 pandemic. Our findings indicate that patients who

TABLE 3 | Survey of feasibility and usability of human papillomavirus (HPV) vaccination practices according to providers and support staff at a rural Medical Center following an educational campaign, 2020–2021.

	Pre-intervention		Post-intervention		χ^2 <i>p</i> -value ^a
	<i>n</i>	(%)	<i>n</i>	(%)	
Feasibility Measure					
<i>I believe the benefits of current practices in place for HPV vaccination at my facility outweigh the costs/risks</i>					0.2897
Strongly agree	12	(70.6)	9	(52.9)	
Agree; Neither agree nor disagree	5	(29.4)	8	(47.1)	
Usability Measures					
<i>I believe practices in my clinical setting are valuable and address barriers to HPV vaccination</i>					0.3001
Strongly agree	8	(47.1)	11	(64.7)	
Agree; Disagree	9	(52.9)	6	(35.3)	
<i>Current strategies I use for HPV vaccination in my clinic are easy to understand</i>					0.4533
Strongly agree	10	(58.8)	8	(72.7)	
Agree; Neither agree nor disagree; Strongly disagree	7	(41.2)	3	(27.3)	

^aPearson's χ^2 , P (df = 1) reported.

did not receive the HPV vaccine at the time of visit, although they were due for the vaccination (i.e., missed opportunities), declined significantly following the HPV vaccination intervention period. Parental vaccination hesitancy or refusal, the most commonly reported vaccination barrier by providers and support staff, also declined by 41.2% points.

While most barriers decreased in the frequency of selection by providers and support staff, there were a few vaccination barriers that were selected more frequently following the campaign. These included: lack of EHR use to track vaccination; personal fear of adverse and/or side effects; and being unsure of the need for vaccination. The lack of a system for provider reminders to discuss immunization decreased during a time of clinic overburden from COVID-19, while lack of an EHR to track vaccination and being unsure of the need for vaccination both increased following the education intervention. This likely characterizes sentiments expressed by providers and support staff in person during the educational campaign of a lack of a national immunization registry and a largely seasonal and/or transient patient-population that is often unsure of their own and/or child's HPV vaccination status. Future work for enhancing immunization uptake, particularly in rural settings, could include better integration of immunization registries at a national level with enhanced optimization of provider reminders which would improve provider and support staff confidence for the need of vaccination among transitory patient populations.

These early results are promising but without a control group, or comparison to another similar clinic during the same time period, we cannot characterize the effect or the degree of effect the intervention had vs. other external factors. Future analyses could include difference-in-difference calculations to extend these findings from association into causal. Small cell sizes, due largely to unequal pre-post intervention population sizes, were present. At this time, we are unable to accurately characterize the impact of the COVID-19 pandemic on HPV vaccination in this population. The COVID-19 pandemic paused regular in-person appointments for many and may also have resulted in fewer

people getting the HPV vaccine; counts may be underestimated as some people may get vaccinated once the pandemic is over; or counts may be accurate as some people may forego vaccination. This would be consistent with previous research indicating a preference for a single vaccine per visit, and many may prioritize the COVID-19 vaccine over the HPV vaccine.

The results of this study suggest that, among rural patients aged 18 and older, those receiving a clinic HPV vaccination reminder, regardless of the mode, are 6.96 times more likely to schedule or intend to schedule a follow-up visit for vaccination for either their child or themselves (cOR = 6.96, 95% CI 2.44–22.79). Small numbers ($n < 5$) in several of the cells in the contingency table of scheduling a follow-up visit contributed to imprecise (i.e., wide CIs) and unstable estimates of probability and odds for gender, mode of reminder, and a child's receipt of the HPV vaccine. It is unclear why so many people reported not receiving the reminder messages. This could be due to limited patient recall, or inaccurate records of patient contact information or contact preferences. Future studies could examine this issue in an attempt to increase acceptance, receipt, and/or memorability of messages.

The population of providers and support staff, while sizable for a single-clinic rural intervention, suffered from small cell sizes issues and some unstable estimates were present. Additionally, the responses were unpaired and we were unable to measure individual changes in responses or knowledge improvement from prior to and following the facilitation and education campaign. None of the comparisons of pre- to post-intervention survey responses from providers and support staff were statistically significant at $\alpha = 0.05$, however, many of the outcomes demonstrated improvement and have important clinical implications for HPV administration and championing vaccination for the future. Caution should be taken in generalizing our results to all rural areas and the unique regional, cultural, economic, and medical landscape should be considered before implementing any public health campaign among vulnerable populations. We are unsure how the pandemic will influence HPV vaccination over time.

Results from this multi-level and multi-model intervention are promising and suggest that vaccination interventions consisting of provider and support staff education and training activities, parent/caregiver and young adult reminders, and evidence-based patient education materials can reduce missed opportunities for HPV vaccination in a rural setting. Future research should assess the implementation of larger scale multi-level and multi-model HPV vaccination interventions in rural primary care settings across the United States to reduce inequities in HPV vaccination rates and the incidence and mortality of HPV-related cancers among these vulnerable patient populations.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Utah Institutional Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

DK designed the study, led the data collection and analysis activities, and interpreted the results. EM and AW designed

the HPV vaccine training and intervention activities. GF and BG are our clinical informatics experts and contributed to the design of the digital intervention. SA, HB, SM, and AP assisted with interpretation of findings. GC provided senior input on study design and interpretation of findings. DK, KC, and SA drafted the manuscript. All authors reviewed and provided edits to the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fdgth.2021.719138/full#supplementary-material>

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Vacteens.org: A Mobile Web app to Improve HPV Vaccine Uptake

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U.S. HPV vaccine uptake remains below the Healthy People 2030 goal of 80% series completion. Parental concerns and misinformation about the efficacy and safety of the Human Papillomavirus (HPV) vaccine remain, and may be addressed by digital interventions tailored to their concerns. Reported here are results from a small scale randomized trial testing a mobile web app for parents and their adolescent daughters (ages 11–14 years) encouraging HPV vaccination in New Mexico, an ethnically-diverse U.S. state.

Methods: A clinic-cluster randomized trial where pediatric clinics ($n = 9$) were recruited and randomized, and parent-adolescent pairs ($n = 82$) within clinics received either the Vacteens.org/Vacunadolescente.org mobile web app or Usual and Customary (UC) HPV Vaccination information. Parents completed online surveys at baseline and 3-months. Daughters' HPV vaccine data were collected from the New Mexico State Immunization Information System 1 year post baseline.

Results: Three month survey results found Vacteens.org/Vacunadolescente.org parents to have higher positive HPV vaccine beliefs, informed decision making, intent to vaccinate and vaccine confidence outcomes than UC parents. HPV vaccine data found higher first dose HPV vaccination (Pearson $\chi^2 = 6.13$, $p = 0.013$, Vacteens.org/Vacunadolescente.org group 59.4%, UC group 40.6%), and higher HPV vaccination series completion (Pearson $\chi^2 = 6.49$, $p = 0.011$, Vacteens.org/Vacunadolescente.org group 68.4%, UC group 31.6%).

Conclusions: The small trial results showed the Vacteens.org/Vacunadolescente.org web app prompted positive vaccine-related attitudes and beliefs, and more HPV vaccination initiation and series completion. Mobile web apps can make decision-making tools for HPV vaccination widely available on digital platforms, reducing vaccine hesitancy, and confusion and increase HPV vaccine uptake.

Keywords: HPV, vaccination uptake, digital intervention, adolescents, parents

INTRODUCTION

In the U.S. uptake of Human Papillomavirus (HPV) vaccine remains far below the Healthy People 2030 goal of 80% series completion (1). Nationally, 54.2% of adolescents aged 13–17 were up-to-date for the Human Papillomavirus (HPV) vaccine in 2019 [females 56.8%; males: 51.8% (2)]. In New Mexico, HPV vaccination completion for this adolescent age range also remains low (59.8%).

While a number of factors may account for this less than desirable vaccine uptake, parental concerns, and misinformation about the efficacy and safety of HPV vaccine remain barriers to reaching public health vaccination goals (1, 2). Vaccine initiation is affected by health beliefs (e.g., vaccine knowledge; importance of preventive vaccinations; side effects concerns), while vaccine completion [2 doses if started by age 14; 3 doses if after age 15 (3)] is affected both by logistical barriers (e.g., forgetting; scheduling difficulties; child care; travel time; physician hesitancy) and health beliefs (4–10). Health beliefs are amenable to health education interventions. Research indicates there is a great deal of (1) confusion and uncertainty about HPV vaccine and (2) concomitant misinformation about HPV vaccine, who it is meant for, and the conditions under which it is maximally effective.

Identifying effective strategies to improve HPV vaccination rates is a priority for the Centers for Disease Control and Prevention (CDC) (11) and the World Health Organization (WHO) (12). Physician and clinic-based interventions have shown some positive effect on vaccine uptake (13–15), however parental concerns and hesitancy remain barriers to HPV vaccine acceptance. Given that clinicians have limited time to interact with parents during primary care pediatric and adolescent visits, parental barriers to HPV vaccination may ideally be addressed by digital interventions (in this case, smartphone applications) that are tailored to their concerns, especially since virtually all U.S. adults under age 50 use the Internet (16). As of 2019, there were few differences in Internet use by gender, ethnicity, or urban/rural status, with use exceeding 85% in all groups. Nearly 1 in 5 adults under age 50 of both genders use their smartphone for online access, with Hispanics and rural adults showing the highest use of this cellular Internet access (16).

Reported here are findings from a randomized trial on a smartphone web app for parents and adolescent girls (ages 11–14) that was intended to encourage HPV vaccination in New Mexico, an ethnically-diverse U.S. state. The trial tested the following hypotheses:

H1: Parents assigned to the *Vacteen/Vacunadolescente* mobile web app will express more favorable HPV vaccine beliefs, informed decision making, intent to vaccinate for HPV, self-efficacy for HPV vaccination, and benefits and risks of HPV vaccination for their daughters than parents assigned to the Usual and Customary (UC) Information control group.

H2: More daughters of parents assigned to the *Vacteen/Vacunadolescente* mobile web app will initiate and complete the HPV vaccination series than daughters of parents assigned to the UC Information control group.

MATERIALS AND METHODS

Vacteens/Vacunadolescente Mobile Web app

The current project translated an earlier version of the website (the *GoHealthyGirls* website) to a mobile app platform, *Vacteens/Vacunadolescente.org*, and provided both English and Spanish versions. Mobile web apps are mobile device sensitive web sites designed to function like native operating system (Android or iOS) apps, but avoid the problems of operating system exclusivity. They maintain app functionality across mobile platforms, and are more easily updatable should that be required. The web app developed in this project was an informed decision-making website for parents and adolescent daughters (ages 11–14) that employed both Informed Decision Making [IDM, (17)] and Diffusion of Innovations Theory [DOI, (18)] principles in messaging. Informed Decision Making theoretical principles indicate focusing on beliefs and attitudes parents hold that constitute barriers to vaccination, often based on misinformation, is important for vaccination messaging. At the same time, DOI theory suggests that treating vaccination as an innovation is useful, and messaging on the simple, compatible with beliefs, and trialable characteristics of HPV vaccination will improve vaccine adoption. The website was programmed as a web app for mobile devices with open non-linear navigation. It had a video introduction by a well-known New Mexican pediatrics physician, a Vaccine FAQ section, and five modules: (1) *Get Answers!* about HPV and vaccines, risks and side effects of the vaccine, risks of HPV, benefits of HPV vaccination and organizations recommending HPV vaccination; This module addressed the concerns and misinformation parents have about the HPV vaccine. (2) *Let's Talk* on the communication process around vaccination, including a video simulation on how to talk with your daughter about HPV vaccination, guidelines for talking to family members and physician about HPV vaccination; This module provides communication examples to be modeled by parents discussing vaccination with their daughters, and suggestions for discussions with other family members and the health care provider. (3) *Vaccine How-To* with instructions for making an HPV vaccination appointment; This module contains location and appointment tools for getting vaccinated that parents and teens can use for vaccination action plans. (4) *Teen Tools* with interactive games for teens, i.e., HPV Challenge Quiz, and HPV Myth vs. Truth swiping game; This module contains interactive and engaging activities for both teens and parents, all focused on providing accurate and motivating information about the HPV vaccine. (5) *We're Ready* providing email and texting HPV vaccination reminder systems to promote completion of the vaccination series, accessible from any page in the web app. This module provides notification and reminder tools for the second and possible third dose of the HPV vaccine. While the predominant messaging in the web app was focused on parents, their daughters also had specific content for their use (*Teen Tools*). Overall, the web app content and language were designed to encourage both parent and adolescent use, both separately and together.

Development of the Vacteens/Vacunadolescente Web app

The *Vacteens/Vacunadolescente* web app was systematically developed through developmental research. The *GoHealthyGirls* project (funded by the National Institute of Allergy and Infectious Diseases—U19 AI084081) employed DOI and related IDM research to guide the iterative development of a website for parents of young female adolescent daughters (ages 11–14). It was systematically developed via parent and adolescent focus groups, navigability and usability tests (19), and a beta test with an ethnically-diverse sample of parents and daughters in New Mexico (20). Results indicated the website to be easy and enjoyable to use and had clear impact on theoretical antecedents to HPV vaccine uptake (e.g., attitudes, risk perceptions, consequences, self-efficacy, and intent to get daughter vaccinated).

Clinic-Cluster Randomized Trial

A clinic-cluster randomized trial was conducted in New Mexico. Pediatric clinics ($N = 9$) were recruited and randomized to receive either the *Vacteens/Vacunadolescente.org* web app ($n = 5$) or the Usual and Customary (UC) HPV vaccination information ($n = 4$) available from the Centers for Disease Control and Prevention (CDC) online. Clinics were randomized before recruitment of parents and daughters, but physicians and clinic staff were kept blind to treatment assignment. Parents were recruited from clinics by project staff via telephone contact. Inclusion criteria for the trial were to be parents of an 11–14 year old daughter who had not yet received HPV vaccination. Exclusion from the trial was to have had the parent's daughter already vaccinated for HPV. Participants were qualified and registered for the project on a project registration website and provided online informed consent, daughter assent, and HIPAA waiver to access daughter vaccination records from the New Mexico State Immunization Information System (NM-SIIS). All project procedures were reviewed and approved by the University of New Mexico Main Campus Institutional Review Board. Parents of daughters aged 11–14 and the daughters themselves were recruited from participating pediatric clinics ($N = 82$ parent-daughter pairs). Parents were assessed via online survey at baseline and 3-month post-baseline assessments. Once parents were qualified, consented and registered for the project, and had completed the baseline assessment (see Parent Surveys on Antecedents to Vaccination), based on their clinic randomization, they were provided a link to either the *Vacteens/Vacunadolescente.org* web app or the UC CDC web link. These links remained active for the year-long project for parents and their adolescents to browse. HPV Vaccine uptake data available from NM-SIIS for daughters of participating parents were collected at 1-year post-baseline.

Parent Surveys on Antecedents to Vaccination

Parents were assessed by online surveys via QuestionPro survey software at baseline and 3-month assessment points. The surveys measured participants' demographic characteristics (gender, age, race/ethnicity, language preference, educational level, and

sociodemographic status), and HPV related variables, including: HPV knowledge [Cronbach's $\alpha = 0.60$ (21)], HPV vaccine attitudes, e.g., "It is important to get vaccines because they prevent disease," [$\alpha = 0.89$ (22, 23)], perceived daughters' risk of HPV, e.g., "Infection with HPV can lead to serious illness," [$\alpha = 0.73$ (19, 23)], beliefs about HPV and HPV vaccination, e.g., "The HPV vaccine is effective at preventing cervical cancer," [$\alpha = 0.91$ (24)], intention to have daughter vaccinated (single item), "If you were asked to make a decision right now about getting your daughter her first HPV shot, what would you decide?," HPV informed decision making, e.g., "I know which options are available to me regarding the HPV vaccine [$\alpha = 0.98$ (25)].

Vaccination Records

Vaccination records were acquired by matching parent identification information to the NM-SIIS database. Record acquisition was performed by an honest broker, who was blind to clinic and parent randomization status. Participants' parents last name, adolescents last name, first name and birthdate were used as matching variables in vaccination record acquisition. First and second shot completion data were recorded from participant daughters' records.

Data Analysis

Statistical analyses were conducted with SPSS ver. 27. Both descriptive statistics and inferential tests for group differences were calculated. To evaluate differences in vaccine beliefs and attitudes, one-tailed t -tests were used. We chose to use one-tailed tests because our hypotheses were directional and a less conservative approach to analysis was believed to be appropriate for this relatively small sample evaluation [cf. Kirk (26)]. The effect of intervention group on HPV vaccine uptake was determined via non-parametric Chi-Square analyses, as recommended by Williams and Monge (27). Analyses were conducted on an unadjusted for clinic cluster effects basis after determining the Intraclass Correlation (ICC) within clinics for participant baseline HPV knowledge variables was near zero.

RESULTS

Participants

Parent participants ($N = 82$) were 92.5% female, 38.5% Hispanic, 6.2% American Indian/Native Alaskan, 1.2% Asian, and 37.8% Caucasian, with 12.3% unspecified and 3.7% missing information. The average age of parent participants was 38.96 years ($SD = 9.64$), and average age of daughter participants was 12.05 years ($SD = 1.08$). Educational attainment was 3.8% 11th grade or less, 33.8% high school diploma or G.E.D., 25.0% Associates degree, 18.8% Bachelor's degree, 8.8% Masters degree, 1.3% Doctorate degree, and 7.5% Other Professional degrees. Language preference for parent participants was 96.3% English, with 16.3% additionally speaking Spanish, and 6.3% additionally speaking a Tribal Language.

Hypothesis 1: Vaccine Antecedents

Three-month follow-up surveys were completed by 38% ($n = 31$) of the study sample. The remainder of the participants were not

available to be surveyed due to early termination of the trial by the funding agency. A review of all baseline participants found no statistically significant differences (Pearson's χ^2 -tests) in demographics between participants who did and did not respond to 3-month assessments. Analyses of the available 3-month assessment data for parents found several statistically-significant differences between the *Vacteens.org/Vacunadolescente* and UC Information participants. Planned *t*-tests ($p < 0.05$, one-tailed, $df = 31$) revealed significant between group differences in the predicted direction for HPV vaccine beliefs [$t_{(31)} = 3.87$, $p = 0.001$]; Informed Decision Making [$t_{(31)} = 4.29$, $p = 0.047$]; parents in the *Vacteens.org/Vacunadolescente* were also more likely to intend to vaccinate their daughters right away than later or not at all (Pearson $\chi^2 = 5.70$, $p = 0.05$. Cohen's $d = 0.94$, $OR = 6.23$). In addition, parents in the *Vacteens.org/Vacunadolescente* group were significantly more confident about their vaccination choices (Informed Decision Making; Pearson $\chi^2 = 4.28$, $p = 0.03$, $d = 0.80$, $OR = 4.92$), and a trend toward being more aware of the benefits and risks of vaccination (Pearson $\chi^2 = 2.97$, $p = 0.08$).

Hypothesis 2: Vaccination Outcomes

HPV vaccine uptake data from the NM-SIIS database was obtained for all daughters of parents enrolled in the trial ($n = 82$). A review of first shot date and date of entry into the study determined that some daughters ($n = 13$) had received their initial HPV vaccinations prior to study, and thus were not qualified to participate. Data for these cases were excluded from the analysis; exclusion occurred equally from the *Vacteens.org/Vacunadolescente* ($n = 7$) and UC Information ($n = 6$) groups, leaving a final $N = 69$ for analysis. Analyses of first dose data revealed a significant treatment group difference (Pearson $\chi^2 = 6.13$, $p = 0.013$, $d = 0.62$, $OR = 3.45$), such that rate of HPV vaccination initiation in the *Vacteens.org/Vacunadolescente* condition (59.4%) was 18.8% higher than the UC Information condition (40.6%). Further, HPV vaccination series completion in the *Vacteens.org/Vacunadolescente* group was statistically-significantly higher (Pearson $\chi^2 = 6.49$, $p = 0.011$, $d = 0.64$, $OR = 4.53$) (68.4%) compared to the UC group (31.6%), an absolute increase of 36.8%.

DISCUSSION

The results of this trial indicated that the *Vacteens.org/Vacunadolescente* mobile web app bolstered parents' positive HPV vaccine beliefs, Informed Decision Making, and intentions to vaccinate, and most importantly led to higher levels of vaccine initiation (i.e., first dose) and series completion (i.e., second dose). The small sample of parent-daughter pairs may limit confidence in the outcome, but the effect sizes and odds ratios are in the moderate range, suggesting a substantial effect of the *Vacteens.org/Vacunadolescente* web app that would potentially make large in-roads into vaccine uptake when distributed widely.

There are a number of implications that the study results suggest for deploying the *Vacteens.org/Vacunadolescente* mobile web app. First, it could be used in conjunction with a pediatric

clinic practice, where physicians recommend use of the mobile web app prior to well-child visits, sports physicals, or vaccination appointments. Parents who browse the app may make informed decisions about vaccination before the visit and be ready for vaccine initiation, saving valuable time in the doctor-patient interaction, time that is already at a premium. It also may make it more comfortable for providers to talk with parents about HPV vaccination, knowing that the topic was already presented and many of parents' concerns were covered in the mobile web app. Further, tools provided in the *Vacteens.org/Vacunadolescente* mobile web app, like the text and email follow-up reminders, could make vaccine dose completion more likely, as our data show. Thus, in combination with presumptive recommendations (13) by pediatricians for HPV vaccination and other clinic-based techniques, the use of *Vacteens.org/Vacunadolescente* might substantially improve vaccine uptake in this age range during clinical encounters.

A second possibility is that the *Vacteens.org/Vacunadolescente* mobile web app could be used by parents independent of medical clinics. Many vaccinations of all kinds now occur outside of pediatric or other medical practices in, for example, pharmacies oriented to vaccine provision. This lessens the reliance on pediatricians and other medical providers for advice and recommendation for the HPV vaccination, and for vaccine provision. Other entities involved in vaccination, such as state health departments, school health officials, and pharmacy chains, could promote the use of the *Vacteens.org/Vacunadolescente* mobile web app to increase HPV vaccination initiation and completion at whatever provider to which parents have access in communities. Further, parents of adolescents in this age range are often excessively busy, leading to a drop in the frequency of having their child seen by a pediatrician or medical professional, often limited to as little as once a year for a well-child checkup prior to the start of the school year. Again, these factors may make the use of *Vacteens.org/Vacunadolescente* mobile web app outside of the clinic viable as a way to support and promote vaccination independent of clinical practice.

The present investigation carries some limitations. The small sample size is a limitation, and further research will be needed to confirm the impact of the web app on vaccine uptake and related variables. The findings are also limited to young adolescent girls ages 11–14, even though HPV vaccination is recommended for boys. We are currently conducting a trial with a version of the web app tailored to parents of young male adolescents in the same 11–14 years of age. The loss of some parents due to already having had their daughter vaccinated, is of some concern; however, the results remained statistically significant with moderate effect size. It seems that some parents were simply not sure as to whether they had their daughter vaccinated for HPV. Paper-based methods for tracking vaccination, especially in adolescence, are now rarely used, and parents may lose track of vaccination instances. Currently, the New Mexico Department of Health provides an online portal where parents can search for their child's vaccination record (a number of states have begun to adopt this technology), but parents may be unaware of this resource. The loss of a

substantial amount of 3-month follow-up survey data due to trial termination by the funding agency is a limitation to the study. The loss of these data certainly limits conclusions available from the study survey analyses. In retrospect, the trial termination (due to insufficient progress in clinic recruitment) is regrettable given the promising data that the investigation was able to obtain. The location of the trial in New Mexico may limit its generalizability due to its ethnic mix, containing predominately Hispanic and Native American minority participants. Whether the mobile web app would be just as effective with African American parents or other minority group parents is unknown. A final limitation is the young age of the sample (11–14 years). HPV vaccination is recommended for individuals up to age 26 and we cannot be certain that the *Vacteens.org/Vacunadolescente* mobile web app would convince parents of older daughters (those ages 16+) to seek the HPV vaccine for them. The *Vacteens.org/Vacunadolescente* web app focused its messaging on this younger 11–14 years age range, and parents of older teens (females and males) may need somewhat different messaging that is sensitive to older teens having more agency in vaccination decisions.

The results of this investigation suggest that mobile web app technology, systematically developed for ease and convenience of use on mobile and other computing devices and guided by DOI and IDM theories of health behavior, that communicates about parents' concerns, lack of information, and misinformation parents hold regarding the HPV vaccination, can substantially improve HPV vaccine uptake. A recent review of social media and mobile technology interventions to improve HPV vaccine uptake (28) indicates that text message, e-mail, phone contact and social media groups can improve HPV vaccine uptake. This investigation adds mobile web applications to the list of digital techniques for vaccine uptake improvement. To prevent a variety of HPV-related cancers, the use of digital communication outside clinics for promoting HPV vaccination is well worth considering, especially as many parents' lives are replete with digital messaging and mobile devices.

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DATA AVAILABILITY STATEMENT

The raw de-identified data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of New Mexico Main Campus Institutional Review Board. Written informed consent to participate in this study was provided by adult participants, and adolescent assent was provided by adolescent participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

WW oversaw research project in all aspects, conducted data analysis, and major amount of manuscript writing. GZ was involved in message construction, measurement, and manuscript writing. AK was involved in message construction, clinic recruitment, and manuscript writing. DB was involved in message construction, web app development, testing, and manuscript writing. JR was message language translation and web app development. LC was involved in clinic recruitment, message construction, and vaccine data. VM was involved in message development and measure assessment. RS was involved in clinic recruitment. All authors contributed to the article and approved the submitted version.

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Conflict of Interest: WW, DB, JR, and VM were employed by company Klein Buendel Inc.

Outside of the present work GZ has served as an external advisory board member for Merck and Moderna and as a consultant to Merck. In addition, he has received investigator-initiated research funding from Merck administered through Indiana University.

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

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Human Papillomavirus Vaccination and Social Media: Results in a Trial With Mothers of Daughters Aged 14–17

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Introduction: Parents acquire information about human papillomavirus (HPV) vaccines online and encounter vaccine-critical content, especially on social media, which may depress vaccine uptake. Secondary analysis in a randomized trial of a Facebook-delivered adolescent health campaign targeting mothers with posts on HPV vaccination was undertaken with the aims of (a) determining whether the pre-post-change occurred in self-reports of the mothers on HPV vaccination of their adolescent daughters; (b) describing the comments and reactions to vaccine posts; (c) exploring the relationship of campaign engagement of the mothers assessed by their comments and reactions to posts to change in the self-reports of the mothers of HPV vaccination.

Materials and Methods: Mothers of daughters aged 14–17 were recruited from 34 states of the US ($n = 869$). A social media campaign was delivered in two Facebook private groups that differed in that 16% of posts in one were focused on indoor tanning (IT) and 16% in the other, on prescription drug misuse, assigned by randomization. In both groups, posts promoted HPV vaccination ($n = 38$ posts; no randomization) and vaccination for other disease (e.g., influenza, $n = 49$). HPV and other vaccination posts covered the need for a vaccine, the number of adolescents vaccinated, how vaccines are decreasing the infection rates, and stories of positive benefits of being vaccinated or harms from not vaccinating. Guided by social cognitive theory and diffusion of innovations theory, posts were intended to increase knowledge, perceived risk, response efficacy (i.e., a relative advantage over not vaccinated daughters), and norms for vaccination. Some vaccination posts linked to stories to capitalize on identification effects in narratives, as explained in transportation theory. All mothers received the posts on vaccination (i.e., there was no randomization). Mothers completed surveys at baseline and 12- and 18-month follow-up to assess HPV vaccine uptake by self-report measures. Reactions (such as sad, angry) and comments to each HPV-related post were counted and coded.

Results: Initiation of HPV vaccination (1 dose) was reported by 63.4% of mothers at baseline, 71.3% at 12-month posttest (pre/post $p < 0.001$), and 73.3% at 18-month

posttest (pre/post $p < 0.001$). Completion of HPV vaccination (two or three doses) was conveyed by 50.2% of mothers at baseline, 62.5% at 12-month posttest (pre/post $p < 0.001$), and 65.9% at 18-month posttest (pre/post $p < 0.001$). For posts on HPV vaccines, 8.1% of mothers reacted ($n = 162$ total), and 68.4% of posts received a reaction (63.2% like; 13.2% love, 7.9% sad). In addition, 7.6% of mothers commented ($n = 122$; 51 unfavorable, 68 favorable, 1 neutral), and 50.0% of these posts received a comment. There were no differences in pre–post change in vaccine status by the count of reactions or comments to HPV vaccine posts ($P_s > 0.05$). Baseline vaccination was associated with the valence of comments to HPV vaccine posts (7.2% of mothers whose daughters had completed the HPV series at baseline made a favorable comment but 7.6% of mothers whose daughters were unvaccinated made an unfavorable comment).

Conclusion: Effective strategies are needed in social media to promote HPV vaccines and counter misinformation about and resistance to them. Mothers whose daughters complete the HPV vaccine course might be recruited as influencers on HPV vaccines, as they may be predisposed to talk favorably about the vaccine. Comments from mothers who have not been vaccinated should be monitored to ensure that they do not spread vaccine-critical misinformation. Study limitations included lack of randomization and control group, relatively small number of messages on HPV vaccines, long measurement intervals, inability to measure views of vaccination posts, reduced generalizability related to ethnicity and social media use, and use of self-reported vaccine status.

Clinical Trial Registration: www.clinicaltrials.gov, identifier NCT02835807.

Keywords: human papillomavirus, vaccine, social media, mothers, adolescents

INTRODUCTION

Despite the recommendation of the Advisory Committee on Immunization Practices (ACIP), (1) only 54% of adolescents aged 13–17 were up-to-date for the human papillomavirus (HPV) vaccine in 2019 (women 57%; men: 52%) (2), far below the healthy people 2030 target of 80%. Vaccine initiation and completion are affected by health beliefs (e.g., vaccine knowledge; the importance of preventive vaccinations; side effects concerns) (3–6) which are amenable to change through health education interventions. Identifying effective strategies to improve HPV vaccination rates is a national and international priority (7, 8).

Parents frequently use the Internet as a reliable source of information on child health (9–11), and online interventions may reach large proportions of parents whose children are not up-to-date on the HPV vaccine. Parents acquire information about HPV vaccines online (12–15), but unfortunately, inaccurate, misleading, unsupported, and harmful information can be circulated online (16, 17), including about vaccines (12, 18–22). False claims are made that HPV vaccines increase teen sexual activity; a low prevalence of HPV-related diseases exists; other modes of prevention are available; HPV vaccines are unsafe due to insufficient testing; HPV vaccines have severe side effects or cause death; HPV vaccine regulations are a product of corruption or conspiracies; and HPV vaccines violate civil liberties (15, 22–27). HPV vaccination decisions of the parents are affected by this online content (12, 28–31) which can depress vaccine uptake

(12, 28–31). For instance, in one survey, parents who heard stories about only harms (e.g., mild side effects and death) were unlikely to vaccinate children for HPV even if they also heard stories about disease prevention (12).

Social media, in particular, spread information on HPV vaccines and transmit vaccine-critical content (12, 32–34). Growing research on social media, particularly related to vaccines, finds widespread misinformation and unsubstantiated claims about corruption, conspiracies, and distrust in vaccine regulations, especially of drug companies, government agencies, and physicians (35). Parents have reported receiving stories about the harms of HPV vaccines on social media and news media, while stories on the prevention of HPV disease occurred in conversations (12). In one study, mothers who first learned about HPV vaccines through social media tended not to vaccinate daughters, while those first hearing about it from their general practitioner vaccinated them (36). There have been calls for efforts to improve accurate HPV content on social media and correct misinformation (37–41) to improve clinical encounters on HPV vaccines (32).

Much of the past research on HPV vaccine content in social media has been descriptive and correlational (21, 26, 42), with few studies examining the impact of HPV vaccine messages prospectively (43, 44). The authors recently completed a randomized trial on a 12-month social media adolescent health campaign delivered to mothers of daughters aged 14–17, which contained posts promoting HPV vaccination. A unique feature

of social media is the presence of user-generated content (e.g., comments and reactions), and an analysis of the first 10 posts on HPV vaccination in the campaign (45) revealed that about 10% of mothers reacted/commented on HPV vaccine posts. Mothers posting supportive comments were more likely to have vaccinated daughters at baseline, as had those remaining silent, while mothers posting critical comments were less likely to have vaccinated daughters. In this study, we present analyses of pre-post change in reports of the mothers on vaccination of their adolescent daughters after the entire year-long social media campaign, a description of comments and reactions to all vaccine posts, and the relationship of campaign engagement of the mothers to comments and reactions.

MATERIALS AND METHODS

Trial Design

Mothers with teenage daughters were enrolled in a randomized controlled trial with the primary purpose of evaluating the effect of social media posts on their permissiveness toward indoor tanning (IT) by daughters. After a baseline survey, mothers were randomly assigned to one of two Facebook private groups. Randomization was accomplished by the project biostatistician, using permuted-block randomization (block size = 2). All mothers received a Facebook feed of posts on adolescent health topics, mother–daughter communication and current events, which differed on whether the feed included posts on IT (intervention) or prescription drug misuse (control). Both feeds contained posts on HPV vaccination and vaccination for other diseases (e.g., influenza) as there was no randomization on the presence of the HPV vaccination messages. A community manager added mothers to the groups, scheduled posts, and monitored and responded to comments during the 12-month campaign, after which mothers completed posttest surveys at 12- and 18-months post-randomization. To retain participants, any mothers who left the private groups were contacted and asked to re-join and mothers were alerted to upcoming posttests and compensated (\$40 for baseline, \$20 for 12-month posttest, and \$40 for 18-month posttest). Daughters were invited to complete the baseline survey and both posttests (compensation = \$20, \$15, and \$25, respectively) but were not enrolled in the social media feed. Study staff other than the community manager and project coordinator were blinded. The Western Institutional Review Board (IRB) and the IRBs at East Tennessee State University and the University of Connecticut approved study protocols.

Participants

Between May 2017 and June 2018, mothers were enrolled who met inclusion criteria: (1) having a daughter aged 14–17; (2) living in one of 34 U.S. states without a complete ban on IT by minors; (3) reading English; (4) having a Facebook account and logging in at least once per week; and (5) willing to “friend” the community manager of the project to join a private Facebook group. Mothers were excluded if they were unable to read English or did not consent and “friend” the community manager. Initially, mothers were recruited in Tennessee through community-based methods (e.g., working

with Coordinated School Health coordinators, presentations at community events, and outcalls from a survey center). When these methods did not yield a sufficient number of mothers, Qualtrics was contracted and recruited mothers from its survey panel in 33 other states. All mothers were blind to treatment because they received a social media feed whose purpose was described as providing information on adolescent health and mother–daughter communication. Statistical power calculations provided a target sample size of 860 that would achieve 80% power for small to moderate effects. Mothers provided email addresses for daughters and parental consent, and daughters were invited to complete assessments, providing informed assent. To avoid a major recruitment barrier, the participation of the daughter was not required. When mothers had more than one daughter, the one with the nearest birthday was selected.

Intervention

The research team developed a social media intervention, named *Health Chat*, using principles of social cognitive theory (SCT) (46), transportation theory (TT) (47), and diffusion of innovations theory (DIT) (48). The campaign also covered skills for communicating with teens (i.e., active listening, self-disclosure, empathy, and conflict management). Posts sought to create transportation into and identification with stories by linking to narratives from mothers and daughters about health risks, not giving permission for risky behaviors, and avoiding engaging in risky behaviors oneself (47, 49). Posts referenced current events and public figures to heighten the engagement of the mothers and encouraged mothers to react to (e.g., like) and comment on posts to evoke social comparison processes that can build norms (50, 51). Posts included social norms-based appeals, appearance-based messaging, and health-risk messaging.

Messages were created by investigators and reviewed by the entire team for acceptability and readability. Initial messages were pretested in a pilot feed with mothers ($n = 90$) not in the trial and changes were made to enhance aesthetics, message clarity, and engagement based on the results. Messages addressing current events were created during the intervention. Approximately 84% of posts addressed adolescent health topics and mother–daughter communication. Topics included vaccinations (e.g., influenza and human papillomavirus), mental health (e.g., stress and bullying), substance use (e.g., alcohol, cannabis, and tobacco), healthy lifestyles (e.g., physical activity and nutrition), media literacy, and general parenting (e.g., college preparation). They were selected based on formative research with mothers, engagement of the mothers during pilot testing, or emerging issues in comments of the mothers during the campaign. About 16% of posts focused on preventing IT (intervention group) or prescription drug misuse (control group). The two private Facebook groups received the same feed of posts except for the manipulated posts on IT or prescription drug misuse.

Several techniques were used in an attempt to increase engagement by mothers with the social media feed. Almost all posts included an image or infographic, along with the text. Some included links to outside sources. Many posts included a question or conversation starter, such as “Do you know if your

daughters is up-to-date on her vaccines?” to invite mothers to react to and comment on posts. Finally, posts on topics of high human interest but not tied to any of the specific health topics were included periodically in the feed, such as soliciting favorite recipes or book recommendations.

A group of posts promoted vaccination for HPV ($n = 38$ posts) and general vaccine information, including influenza vaccination ($n = 49$ posts). Regarding HPV, posts covered the need for the vaccine (perceived risk), percent of adolescents vaccinated, the proportion of parents choosing to vaccinate children against HPV (descriptive norms), how HPV vaccines are decreasing infection rates (response efficacy), and stories of women who died from cervical cancer (perceived severity) or parents who decided to vaccinate their children (identification). Posts on vaccination for other diseases addressed misinformation surrounding vaccines, the need for annual influenza shots (risk), vaccine safety and efficacy (response efficacy), adolescent vaccine schedules (how-to knowledge), and reducing barriers to vaccination. Posts were in didactic (e.g., providing facts about rates of HPV) and narrative (e.g., sharing a story about someone who died from cervical cancer) format. Narratives were intended to influence through a process of identification with the characters in the stories. The primary focus on communicating with mothers was appropriate as they drive decisions about HPV vaccines (52–54) although HPV vaccination may be one of the first opportunities to engage adolescent daughters in healthcare decision-making (55). The posts on HPV and other vaccinations were not randomly assigned; the feeds in both Facebook groups included these posts.

The social media campaign was run in two private Facebook groups. In these groups, posts, comments, reactions, and membership were only viewable to participants and they could not share group content with Facebook users outside the group. This prevented contamination. Messages were posted two times a day to each group over 12 months (~710 total posts). This rate was designed to be sufficient to influence but avoid message fatigue. A community manager scheduled posts, monitored reactions/comments, and replied to misinformation. In addition, mothers received a bi-weekly email newsletter highlighting the most popular recent posts.

Measures

Primary Outcomes

The primary outcome measures in the baseline and 12- and 18-month posttest surveys in this analysis were self-reports of HPV vaccination by mothers. Mothers were asked if the daughter had been vaccinated for HPV and if so, how many shots had she received. Initiation of vaccination was defined as receipt of one-shot of HPV vaccine and completion was defined as two or three shots (two shots are recommended for girls under age 15 while three shots are recommended for girls aged 15–17). Daughters were asked these same questions for themselves.

Demographics

Demographic characteristics were collected, namely, mother and daughter age and skin phenotype (e.g., eye color and hair color)

(56). Mothers also reported on personal and family history of skin cancer and political ideology.

Engagement

The engagement of the mothers with the HPV vaccination posts was measured by counting the number of reactions (i.e., like, love, and sad buttons) and comments to each post. Comments and reactions to posts on HPV and other vaccines were extracted by a trained research assistant at the end of the social media campaign, using Grytics software. The content of reactions was recorded (i.e., like, angry, love, haha, wow). Further, the content in the comments was coded by trained research staff. The comments were coded as favorable (i.e., positive discussion of HPV vaccine or statement daughter was vaccinated), unfavorable (i.e., critical of HPV vaccine or statement of hesitancy or refusal to vaccinate daughter), or neutral (i.e., part of general group dialogue but not related to HPV vaccination specifically). Each comment was coded by one research assistant and 60% were coded by a second coder to check inter-rater reliability (Krippendorff's $\alpha = 0.76$). Emergent themes were then identified based on content codes.

Statistical Analysis

Descriptive statistics were computed using SAS, Version 9.3. *F*-tests were utilized to determine if increases in HPV vaccination rates were statistically significant. Correlation coefficients were computed to compare mother and daughter reports. Multinomial logistic regression was fit to identify predictors of vaccine uptake from pre- to post-intervention. Alpha criterion level of 0.05 was set for all tests.

RESULTS

Profile of Sample

Demographic characteristics of the 869 mothers and 469 daughters enrolled in the study have been reported elsewhere (57). Briefly, mothers had a mean age of 43.1 years ($SD = 6.6$) and were 82.4% non-Hispanic white, 57.8% had a college education, and 51.1% had household incomes over \$80,000. They were diverse on political ideology, with 24.5% conservative and 23.8% liberal, with the remaining half (51.7%), middle of the road. The daughters had a mean age of 15.3 years, 74.7% were non-Hispanic whites, and 24.8% had a high-risk skin type.

HPV Vaccination Rates

At baseline, 63.4% of mothers reported that their daughters had received at least one dose of the HPV vaccine, with 50.2% saying they had received two or three doses (i.e., possibly completed series, depending on the age of the daughter). At the 12-month posttest, 71.3% of mothers reported that daughters had received at least one dose of the HPV vaccine (pre/post comparison $F = 14.05$, $p < 0.001$) and 62.5% reported that daughters had received two or three vaccine doses (pre/post comparison $F = 21.31$, $p < 0.001$). Looking just at mothers whose daughters had not completed the HPV vaccine series at baseline ($n = 293$, 227 with no shots and 66 with one shot), 18.5% of daughters with no shots at baseline and 53.0% of those who had received one

shot at baseline had completed the series at the 12-month follow-up ($\chi^2 = 31.46$, $p < 0.001$). At the 18-month posttest, 73.3% of mothers reported that daughters had received at least one dose of the HPV vaccine (pre/post comparison $F = 20.15$, $p < 0.001$), and 65.9% reported that daughters had received two or three vaccine doses (pre/post comparison $F = 38.05$, $p < 0.001$). Again, subsetting mothers whose daughters had not completed the HPV vaccine series at pretest ($n = 328$, 248 with no shots and 80 with one-shot), 22.2% of daughters with no shots at baseline, and 70.0% of those who had received one shot at baseline had completed the series at the 18-month follow-up ($\chi^2 = 61.79$, $p < 0.001$). Reports of the mothers of HPV vaccine uptake were corroborated by daughters (82.1–88.4% correspondence, $r = 0.65$ – 0.76 , $p < 0.001$).

Content and Valence of Reactions and Comments to HPV Posts

For social media posts on HPV vaccines ($n = 38$), 8.1% of mothers reacted to a post ($n = 162$ reactions total), and 68.4% of all HPV vaccine posts received a reaction (63.2% like; 13.2% love, 7.9% sad). In addition, 7.6% of mothers commented on an HPV vaccine post ($n = 123$ comments total; 54 unfavorable, 68 favorable, 1 neutral), and 50.0% of all HPV vaccine posts received a comment. Similarly, for posts on other vaccines, 5.4% of mothers reacted to a post ($n = 97$ reactions total) and 71.4% of the posts on other vaccines received a reaction (59.2% like; 0.0% love; 12.2% sad). In addition, 4.6% of mothers commented on posts on other vaccines ($n = 67$ comments total; 14 unfavorable, 48 favorable, 5 neutral), and 42.9% of these posts on other vaccines received a comment. Looking at all posts in the feed, 55.8% of mothers reacted to a post and 68.2% of posts received a reaction. In addition, 58.5% of mothers commented on a post and 53.8% of posts received a comment.

Content analysis of all vaccination comments was done to explore themes for both favorable and unfavorable comments (Table 1). Favorable themes included the daughters were vaccinated, boys, as well as girls, should be vaccinated, benefits of vaccines outweigh the risks, vaccines reduced rates of disease, and physician supported vaccination. Unfavorable themes included daughter received certain vaccines but not others; lack of efficacy, safety concerns, or fear of unknown long-term side effects; negative stories or vague unfavorable “issues” regarding vaccination; mistrust in sources promoting vaccines; and lack of physician support for vaccination. In addition, 4.9% of comments on HPV posts mentioned sexual activity related to decision-making about getting daughters vaccinated.

Engagement With HPV Posts

We explored the relationship between the engagement of the mothers with HPV and other vaccine posts and the status of the vaccine of their daughters. Specifically, we explored whether reactions and comments were associated with pre/post-change in vaccine status. We fit three multinomial logistic regressions, subsetting to include only mothers who reported that their daughters had not completed the HPV vaccine series at baseline. Counts of reactions and comments to HPV vaccine posts (zero vs.

TABLE 1 | Themes in the comments to posts on human papillomavirus (HPV) and other vaccinations.

Themes	HPV vaccine posts		Other vaccine posts	
	<i>N</i>	%	<i>N</i>	%
Favorable comments				
The daughter was vaccinated	42	34.1	33	49.3
Boys as well as girls should be vaccinated	12	9.8	0	0.0
Benefits of vaccines outweigh the risks	7	5.7	5	7.5
Vaccines reduce the rate of disease	5	4.1	3	4.5
Physician supports vaccination	2	1.6	1	1.5
Unfavorable comments				
Daughter received certain vaccines but not other, or their children received different vaccines from one another	18	14.6	3	4.5
Lack of efficacy, safety concerns, or fear of unknown long-term side effects	14	11.4	9	13.4
Negative stories or vague unfavorable issues regarding vaccination	11	8.9	1	1.5
Mistrust in organizations promoting vaccines	3	2.4	6	9.0
Lack of physician support for vaccination	8	6.5	0	0.0

2/3 doses: estimate = -0.24 , $t = 0.59$, $p = 0.56$; 1 vs. 2/3 doses: estimate = -0.26 , $t = -0.37$, $p = 0.71$) and other vaccine posts (estimate = -117 , $t = -1.08$, $p = 0.28$; estimate = 0.04 , $t = 0.08$, $p = 0.93$) did not differ by vaccine status at 18-month posttest.

Instead, baseline vaccine status was associated with the valence of comments to HPV vaccine posts (Table 2). More vaccine-favorable comments to HPV vaccine posts were made by mothers whose daughters had completed the HPV series at baseline. A few mothers whose daughters were unvaccinated also made favorable comments but mothers whose daughters had initiated but not completed the series made very few favorable comments. By contrast, vaccine-unfavorable comments were made primarily by mothers whose daughters were not vaccinated at baseline. Mothers whose daughters had completed the HPV series at baseline or had initiated but not completed the series made almost no unfavorable comments to the HPV vaccination posts. Although mothers made fewer comments to posts on other vaccines, this same pattern emerged among mothers based on the status of the baseline vaccination of the daughters.

DISCUSSION

Human papillomavirus vaccine uptake for daughters increased during the 12-month period of the social media campaign. The largest increase appeared in the completion of the series, with

TABLE 2 | Valence of comments to HPV and other vaccination posts by HPV vaccine status of daughter at baseline.

Valence of comment	Baseline HPV vaccination status		
	Not vaccinated	1 dose	2/3 doses*
N	317	104	405
HPV vaccination posts			
Favorable	3.5%	1.0%	7.2%
Unfavorable	7.6%	0.0%	1.2%
Other vaccination posts			
Favorable	3.2%	1.0%	3.7%
Unfavorable	2.5%	0.0%	0.5%

*Assumed to have completed HPV vaccination series.

smaller changes in the initiation of the series. It is not clear in the pre-post comparison whether these changes were due to the social media campaign, especially since engagement with posts was not related to the pre-post increase in HPV vaccine uptake. Unfortunately, Facebook stopped reporting whether participants viewed posts during the study, so we were limited to counting comments and reactions as indicators of engagement. However, mothers could have viewed posts without commenting on or reacting to them. Other research has shown that users following social media pages who view but do not comment may still be engaged with the content but may be concerned about privacy or have stronger information needs than social interaction needs (58–61). These users can be affected by the posts and pass the information along to others (61, 62). Thus, the number of comments and reactions may have under-estimated actual engagement with the posts in this study.

The effect of the campaign on the completion of the HPV vaccine series may have been slightly greater than on initiation of it for daughters. These mothers may be more inclined to vaccinate daughters than those who had not initiated the series in general, although some remained incomplete at the posttests. The campaign may have nudged some mothers who had started the HPV vaccine series for their daughters prior to the study to take steps to complete the series during the campaign or in the 6 months after it ended, as 70% of mothers whose daughters had received only one shot at baseline reported they had completed the series by the 18-month posttest. A much smaller proportion (18% at 12 months and 22% at 18 months) of those who had not yet vaccinated their daughters at the beginning of the trial had completed the HPV vaccine series at either posttest than those whose daughters who had already had one dose at baseline (53% and 70%).

A sizable group of mothers (27%) had daughters who remained unvaccinated throughout the trial and this group was more likely to post unfavorable comments, suggesting that some of these mothers with unvaccinated daughters were actively resistant to HPV posts. Vaccine-critical comments might be used to identify mothers who are resistant to HPV vaccines and tailor posts to respond to reasons for vaccine hesitancy expressed in their comments. By contrast, mothers who had initiated but

not completed HPV vaccination did not comment much either favorably or unfavorably on posts about it. This latter group may have been uncertain about whether to complete it or had barriers to completion, but they were also not strongly resistant to the vaccine. The social media campaign may have nudged some of them to get the HPV vaccine series completed.

Less than 10% of mothers engaged with the posts on HPV vaccination (i.e., reacted or commented) but the number of posts that received a reaction or comment was similar in rate to all posts in the feed. The most common comment in response to HPV vaccine posts was a mother sharing that she had her daughter vaccinated. For this reason, mothers who complete the HPV vaccine series for their daughters might be recruited as influencers on HPV vaccines in future vaccine-promotion programs, as some appear predisposed to talk favorably about the vaccine. However, they may need to be instructed on how to make comments that are likely to influence other mothers because many just simply commented that they had vaccinated their daughters without providing other information that might be influential such as noting the benefits of disease prevention or that physicians recommended it. This same tendency, seen in an early analysis of comments to initial posts (45), continued throughout the social media campaign. Simple statements may help increase perceived descriptive norms for HPV vaccination, which might influence some mothers to vaccinate their daughters (63, 64). But, for many hesitant or resistant mothers, simply providing more information or fact-checking misinformation may not be sufficient. Additional strategies, such as counter-narratives, peer correction, factual elaboration, coherence/credibility appeals, and developing media and e-Health literacy skills (45, 65–71), may be needed to dispel the concerns about lack of efficacy, safety and harmful side-effects, and mistrust of organizations and agencies promoting HPV vaccines. These same vaccine-critical comments about safety and efficacy have been documented in other studies of social media content on HPV vaccines (72–79) and seem to have resonated with some mothers. Sharing stories about why mothers vaccinated daughters for HPV may help correct misinformation and overcome mistrust as stories can influence through identifying with characters, shifting social norms, and reducing counter-arguments by being transported into the stories (49, 80–82). Some mothers shared stories in unfavorable comments in this study and others (22, 23), and they may have had a strong negative impact. Comments and reactions from mothers who have not vaccinated daughters for HPV should also be monitored for misinformation on vaccines, which should be addressed quickly to help forestall it from going viral (65).

The comments that physicians did not support HPV vaccination need to be countered as medical professionals can be important, credible, and influential sources of information on HPV vaccination (14, 83–85). Mistrust in organizations and agencies promoting the HPV vaccine has been observed in other analyses (72, 74, 76, 86) and may be instrumental for hesitant or resistant mothers. Derogating the source is one way to reduce the perceived risk for not vaccinating their daughters when they have

decided not to use it and rely instead on less effective prevention methods (87, 88).

Limitations

The study had several limitations. The lack of randomization and absence of a control group undermined conclusions about whether the social media campaign produced the observed change in HPV vaccination rates at posttest. The number of messages specifically on HPV vaccination was small (about 5% of all posts) but they were supplemented by nearly 50 posts on other vaccinations (e.g., influenza) which should have improved vaccination intentions in general. The measurement times at 12- and 18-months post-randomization were long and risk history effects, where secular events (changes in personal health history; visits to physician offices, and other media coverage on HPV, vaccines, or health topics) could have occurred after the HPV vaccination messages that influenced decisions of the parents to vaccinate daughters. Once again, the lack of randomization meant the design could not control for this threat to internal validity. The inability to collect data on views from the Facebook feed meant we could not determine whether mothers saw the HPV and other vaccination posts. The decision by Facebook to eliminate reports on views of posts in the private groups was out of our control and occurred after the study was launched. We contacted Facebook and requested access to the views data but they were unable to provide it. Instead, we decided to use counts of reactions and comments to the vaccination posts, which were still reported by Facebook, as indicators of viewership, but as noted above these likely underestimated actual engagement with the vaccination posts. It is worth noting that the lack of an objective measure of exposure to campaign messages by individual respondents often is limited in community-based evaluations of public health campaigns that rely on other media such as television, radio, print, and billboards. While the sample was large and included mothers from 34 states of the US, it may have limited generalizability because mothers were predominately non-Hispanic white and had regular social media use, the Qualtrics survey panel tends toward participants with higher socioeconomic status, mothers who chose to participate were interested in their health of the daughters, mothers lived in states that may be less socially progressive as they did not have bans on indoor tanning by minors, and daughters were older than the first age at which HPV vaccination is recommended. Self-reports of vaccine status of the mothers also may be biased but these measures have shown good specificity and sensitivity in past surveys (89–91) and produced estimates similar to government immunization records (92). Further, they were corroborated by reports of the daughters. The limitations were offset somewhat by strengths in the study: mothers were enrolled and pretested prior to the social media campaign and a pre-post change was observed, rather than inferring pre-existing vaccination beliefs and actions of the mothers.

Conclusion

Human papillomavirus vaccination rates in the United States continue to lag national health goals. Social media is a

major source of health information and supportive and critical information on HPV vaccination. Effective strategies are needed in social media to promote HPV vaccines and counter misinformation about them to move mothers who are resisting vaccination. Interspersing vaccine messages in a feed for parents may be effective, as it can expose them to a large number of messages. Even if social media messaging does not change the minds of highly resistant mothers who contribute unfavorable comments, carefully crafted messages may convince mothers who are uninformed, uncertain, or not currently taking action to vaccinate their daughters to ignore or resist the false claims and misinformation about the HPV vaccine and complete the series for their daughters.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Western Institutional Review Board and the IRBs at East Tennessee State University and University of Connecticut. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

DB: conceptualization, methodology, verification, investigation, writing—original draft, visualization, supervision, project administration, and funding acquisition. SP: conceptualization, methodology, verification, investigation, resources, writing—review and editing, supervision, project administration, and funding acquisition. KH: conceptualization, methodology, formal analysis, writing—review and editing, and funding acquisition. JBe: verification, validation, investigation, resources, data curation, writing—review and editing, and supervision. BW: conceptualization, methodology, investigation, writing—review and editing, resources, and funding acquisition. JBi: verification, validation, investigation, resources, data curation, writing—review and editing, and supervision. KB: conceptualization, methodology, investigation, writing—review and editing, supervision, project administration, and funding acquisition. JH: conceptualization, methodology, investigation, writing—review and editing, and funding acquisition. KA: verification, validation, investigation, data curation, and writing—review and editing. All authors contributed to the article and approved the submitted version.

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Adaptation and Dissemination of a National Cancer Institute HPV Vaccine Evidence-Based Cancer Control Program to the Social Media Messaging Environment

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Social media offers a unique opportunity to widely disseminate HPV vaccine messaging to reach youth and parents, given the information channel has become mainstream with 330 million monthly users in the United States and 4.2 billion users worldwide. Yet, a gap remains on how to adapt evidence-based vaccine interventions for the *in vivo* competitive social media messaging environment and what strategies to employ to make vaccine messages go viral. Push-pull and RE-AIM dissemination frameworks guided our adaptation of a National Cancer Institute video-based HPV vaccine cancer control program, the HPV Vaccine Decision Narratives, for the social media environment. We also aimed to understand how dissemination might differ across three platforms, namely Instagram, TikTok, and Twitter, to increase reach and engagement. Centering theory and a question-answer framework guided the adaptation process of segmenting vaccine decision story videos into shorter coherent segments for social media. Twelve strategies were implemented over 4 months to build a following and disseminate the intervention. The evaluation showed that all platforms increased following, but Instagram and TikTok outperformed Twitter on impressions, followers, engagement, and reach metrics. Although TikTok increased reach the most (unique accounts that viewed content), Instagram increased followers, engagement, and impressions the most. For Instagram, the top performer, six of 12 strategies contributed to increasing reach, including the use of videos, more than 11 hashtags, COVID-19 hashtags, mentions, and follow-for-follow strategies. This observational social media study identified dissemination strategies that significantly increased the reach of vaccine messages in a real-world competitive social media messaging environment. Engagement presented greater challenges. Results inform the planning and adaptation considerations necessary for transforming public health HPV vaccine interventions for social media environments, with unique considerations depending on the platform.

Keywords: HPV, HPV vaccine, social media, implementation adaptation, engagement, vaccine interventions

INTRODUCTION

Social media has become a mainstream health information channel with 330 million monthly users in the United States (1). Consequently, it has rapidly become a crucial public health communication tool for information dissemination and consumption (2). Social media channels offer a key opportunity for implementing and sharing accurate, timely, and culturally resonant public health messages, including vaccine messaging. However, a significant gap remains in how to effectively adapt evidence-based interventions (EBI), especially for the social media environment. We define adaptation as a systematically planned and proactive process of intervention modification to suit the specific characteristics and needs of a new context and enhance intervention acceptability (3). Dissemination of public health messages in social media environments requires a paradigm shift in dissemination approaches that departs from one-directional hypodermic needle dissemination (4) to a dialog-based, push-pull dissemination approach (5). We address a gap in the dissemination of EBI. Our 4-month observational social media study describes the intervention adaptation processes necessary for disseminating narrative human papillomavirus (HPV) vaccine intervention across three platforms in the real-time social media messaging environment (6).

The rise of social media during the digital age has fundamentally changed how individuals seek and receive health information (7). In the United States, 84% of 18- to 29-year-olds report using social media, with 71% reporting daily Instagram use and 65% reporting daily TikTok use (7). Other popular social media platforms among young adults include Reddit, Twitter, and YouTube (7). Each platform has different ways of sharing information, but all are predominantly peer-driven and user amplified (8). The use of social media for seeking health information, including vaccine information, was amplified during the COVID-19 pandemic (2). Given the number of social media users worldwide, these platforms offer a dynamic communication channel for disseminating preventive health messages and expanding reach to historically underserved populations (9). Disseminating accurate, yet culturally resonant vaccine information is critical in light of the polarized social media environment, particularly around vaccination (10–12).

Identifying effective social media strategies to increase HPV vaccination rates is a priority for the Centers for Disease Control and Prevention (CDC), World Health Organization, American Cancer Society, National HPV Vaccination Roundtable, and all National Cancer Center (NCI)-designated cancer centers in the United States (13–16). National roundtable experts prioritize the adaptation and dissemination of social media strategies to increase awareness and reach among unvaccinated youth, young adults, and parents (17). Yet, limited guidance exists on how to implement and adapt evidence-based HPV vaccine interventions on social media (18, 19). Drawing on an implementation and dissemination scientific framework, the push-pull capacity model (5, 20), and RE-AIM (19, 21), our observational study aimed to understand how the social affordances of social media can be harnessed to effectively disseminate an evidence-based HPV vaccine intervention.

The push-pull capacity dissemination framework (5, 20, 22) applied to the social media messaging environment includes a “push” intervention component to broadcast vaccine messages to media users and a “pull” component to engage users with intervention content, invite comments, encourage interaction, and share content with peers. Pushing our HPV vaccine content on social media is expected to evoke curiosity and interest in HPV vaccination, and generate more impressions on our posted content, while the pull component, which is whether and how various adaptation strategies may engage users, remained an impetus for the study.

The RE-AIM implementation framework (19, 21) that also guided our study proposes that the success of adapting an intervention is best evaluated by five dimensions: reach, effectiveness, adoption, implementation, and maintenance. In our study, we sought to evaluate the first of the five dimensions, to examine the reach of broadcasting the HPV vaccine narratives across three platforms: Instagram, TikTok, and Twitter.

Social Media Platforms Used by Youth and Young Adults

Instagram, founded in 2010 and one of the most popular social media platforms, caters to 500 million daily active users and 1 billion monthly active users worldwide (1). Among all users, 7.5% are 13–17, 29.9% are 18–24, and 32.1% are 25–34 years old (1). Thus, nearly one-third of active users are in the target age group (13–24 years old) for HPV vaccine promotion messages. Moreover, Instagram information sharing largely centers on videos, photos, and stories (23), which matches the format of our HPV vaccine videos and narratives.

TikTok, founded in 2017 and a video-centric global social media platform used by youth, has more than 1 billion monthly active global users and an estimated 80 million monthly users in the United States. The platform allows users to create and share short videos and has become the most downloaded non-gaming app globally (24). The user interface design facilitates easy-to-use editing and soundtrack functionality. TikTok's feed is unique compared to other platforms; users can interact with the “just for you” page and #Discover (by hashtag or audio file), which the TikTok algorithm populates with videos that have a high likelihood of user engagement. Engagement differs from YouTube where video length has no limit and users have more autonomy in choosing the next video to watch. Nearly half (47.4%) of the billion monthly users are 9–26 years old (25). TikTok's platform features 15-s video streams—with a recent update to post videos up to 3 minutes (26)—which are typically entertainment-based. The platform is distinct from Instagram in the sense that it does not allow the posting of photographs or infographics. TikTok is increasingly considered for disseminating health information, especially during the pandemic (27). HPV vaccination is recommended for preteens aged 9–11, and catch-up vaccination is recommended for young adults up to age 26 (28). The focus of this cancer control program is HPV vaccination and since TikTok has a large portion of users in our target population, we chose to include this platform.

Twitter, founded in 2006 and is text-based, is public and has 206 million daily active users, 38.5% of which are in the target age group for our HPV vaccine promotional messages (29). Unless privacy is specifically chosen by the user, Twitter posts, profiles, and materials are all automatically public, and hence, the data is publicly available (30). Although Twitter has the capability of posting photos and videos, the platform is predominantly text-based, fostering text interactions among users and conversation threads (31).

We chose these three social media platforms for their unique properties and potential to propagate health information to reach youth and young adults. We chose Instagram and TikTok due to the number of Millennial and Gen Z users on these platforms (1). Millennial users are defined as individuals born between 1981 and 1994 (32), while Gen Z users are born between 1995 and 2015. Additionally, due to the algorithm and functionality of Instagram and TikTok, there is more potential for users of these platforms to watch HPV videos, especially if any of them went “viral” (33). This is because “reels” posted from a public account can be viewed by anyone and not just network users on the reels tab on Instagram. Similarly, for TikTok, anyone can view a public video posted by a public account on their “for you” page (34). Using multiple strategies, we were interested to learn which strategies would propagate our vaccine messages the most and how performance differed by platform.

HPV Vaccination as a Highly Effective Cancer Prevention Measure

The HPV vaccination, federally licensed in 2006, is highly effective at preventing high-grade and persistent cervical intraepithelial neoplasia in women and is more than 92% effective at preventing HPV-associated cancers, including cervical, anal, and oropharyngeal cancers, with the latter in both men and women (35, 36). An estimated 14 million Americans are infected with new HPV cases annually as the most common sexually transmitted infection in the United States. More than half of these infections occur in people younger than 24 (37, 38). HPV is associated with 2 million HPV-attributable abnormal Pap smears, 1.4 million low-grade cervical dysplasias, and 300,000 high-grade cervical dysplasias annually (16). Yet, despite the robust safety profile of HPV vaccination that has reduced HPV morbidity by 64% among vaccinated 14- to 19-year-olds (39, 40), low vaccination rates (55%) persist particularly among young adults aged 18–26 and have dropped drastically during the pandemic. The CDC’s Advisory Committee on Immunization Practices and all US cancer centers recommend urgent catch-up vaccination (16).

Adapting an NCI Evidence-Based HPV Vaccine Cancer Control Program

To disseminate the evidence-based NCI cancer control HPV vaccine program (EBCCP) HPV Stories (41), the video-based intervention was adapted for the social media environment to reach youth, young adults, and parents of adolescents. The program consists of five parent videos and 13 young adult videos. The 1- to 2-minutes videos each present vaccine decision

narratives told by youth through informal conversation. Videos were filmed from the perspective of a voyeur witnessing a private dialog between two individuals (mother-daughter, peers, or romantic partners) in informal settings (e.g., in the kitchen, in a parked car, on a park bench, on the sofa while gaming, on the front steps of a brownstone, at a pool, and at a salon). Some videos also reflect conversations between doctors and families in a clinical setting in an exam room.

We describe the adaptation process of implementing a 4-month observational study by posting 13 HPV vaccine decision story videos on an HPV vaccine account. A second aim of the study was to evaluate how three distinct social media platforms perform regarding exposure to HPV vaccine messages. This study contributes to the vaccine communication, intervention, and implementation of science literature by describing the necessary translation steps for adapting HPV vaccine EBIs to the social media environment and gaining a better understanding of how different platforms may propagate vaccine messages.

METHODS

The EBCCP intervention was adapted and disseminated on social media over 4 months between February 14 and June 26, 2021, using three platforms: Instagram, TikTok, and Twitter. Our choice of platforms was informed by their use by the target audience of youth and young adults (1, 7) for whom HPV vaccination is recommended. Additionally, our choice of TikTok and Instagram platforms was based on these platforms disseminating primarily visual and video-based messages; hence, they align with the video format of the EBCCP.

Video Dialogue Adaptation Process

Adaptation of the video-based EBCCP consisted of first annotating the 1- to 2-minutes video scripts according to centering theory (42), and discourse coherence theory (43); shortening the videos into 15- to 30-second segments; and adding question captions at the end of video segments to arouse curiosity and entice users to watch the next video segment. The EBCCP HPV videos consisted of dialog, typically between two young adults, but some videos also reflected dialog between a parent and young adult or a doctor and young adult. The original 1–2-minutes video dialogue, which needed to be shortened to 15–30-s videos for social media, was segmented by considering the lexical cohesion properties, topic shifts, and dialog acts used in the video scripts. Dialog cohesion is a discourse property that explains why words “stick together” in discourse (43). Also, the content of multiparty dialogs is not the only consideration, but also the form of dialog and inherent signals of topic shift (44, 45). In addition to segmenting the videos by considering the dialog between participants in the conversation, we were also interested in informing our engagement strategy by generating (a) hot keys (questions) associated with each segment and (b) have answers in the subsequent segment and, thus, imply one of the most impactful dialogs, the question and answer (46). In this way, discourse coherence and centering theory guided the video segmenting adaptation process.

Handling of User Interaction

Although we expected comments, few authentic and organic comments were posted that went beyond emoji posts. Spam and misinformation comments were deleted. Authentic comments included positive emojis and favorable comments like “isn’t science great” or “Coloradoteensforvaccines great vid!” On one occasion, two women commented that they contracted HPV despite being vaccinated. Responses to these comments opened with an empathic statement acknowledging the disappointment of receiving an HPV diagnosis. Empathic statements were followed by clarifying the CDC recommendations, which emphasize the importance of on-time vaccination by age 15 for the most optimal protection.

NCI EBCCP HPV Vaccine Decision Narratives

Thirteen NCI EBCCP HPV vaccine video stories were adapted and implemented (video content details and links to view videos available in the **Supplementary Material**). The 13 videos included: (a) young adult peer HPV vaccine dialogue (e.g., college women having a boba drink after lecture and discussing why one of the women missed class to visit her “gyno” and received the recommendation to vaccinate against HPV); dialogue among two men playing basketball and discussing a visit to the doctor for genital warts; hair salon peer dialogue discussing the experience of a colposcopy procedure after a HPV diagnosis; small-town peer dialogue about getting the HPV vaccine shot as part of being a summer coach and the vaccine preventing throat cancer; Vietnamese-American peer dialogue about vaccinating both men and women to protect the health of romantic partners; peer LGBTQ+ conversation at pool about vaccinating as better protection than thinking HPV will clear up on its own); (b) doctor–young adult HPV vaccine dialogue (e.g., a young adult woman being hesitant to vaccinate because her mother would disapprove; LGBTQ+ dialogue with doctor that HPV vaccination is recommended for all regardless of sexual orientation; beginning to date someone romantically and vaccinating to protect sexual reproductive health regardless of a partner’s sexual health history); (c) parent–young adult HPV vaccine dialogue (e.g., mother–daughter conversation about the mother’s sister being diagnosed with late-stage cervical cancer; mother–daughter (preteen) HPV vaccine dialogue about the benefit and safety of vaccinating); and (d) a monolog about not knowing much about HPV but realizing how common it is and the benefits of vaccinating.

Intervention Adaptation Strategies for the Social Media Message Environment

Twelve strategies were used to adapt the NCI EBCCP HPV vaccine intervention to the social media setting. The selection of adaptation strategies was informed by the vaccine social media literature (47–50), implementation and dissemination of science frameworks, such as RE-AIM (19, 21) and push-pull (5, 20), and empirically grounded experience by two co-authors who are social media micro-influencers. The 12 strategies are listed in **Table 1**. Next, we elaborate on each strategy.

TABLE 1 | Social media engagement strategies employed across 4 months.

Intervention adaptation and engagement strategies

1. Use of strategic handle name (i.e., @realhotgirlshot) adapted from influencer Megan the Stallion (@realhotgirlsh*t) who has 26.4 million followers
2. Segmenting and shortening the evidence-based cancer control program (EBCCP) HPV vaccine videos into 30 second segments with captions and questions
3. Strategic use of platform features: reels, video length, stories, highlights, geotagging, polls
4. Use of hashtags and captions to widen reach i.e., number of followers (e.g., including links, facts, or questions in captions)
5. Use of a Linktree inserted into each account profile bio to encourage cross-platform engagement
6. Posting content frequently and regularly i.e., 3x weekly
7. Tag and follow influencers (e.g. @CDCgov)
8. Follow for Follow strategy with those that follow similar accounts
9. Engaging with similar accounts (e.g., @DenverTeensforVaccines)
10. Visual Aesthetics (e.g. use of Canva templates to deliver engaging and vibrant content)
11. Hot Keys & Segmentation of EBCCP videos
12. Use of timely COVID-19 vaccination as discussion point to engage users

Strategic Handle Name

We chose to name the accounts on Instagram, Twitter, and TikTok with the handle @realhotgirlshot. This handle references pop culture trends and is an adaptation of the Houston, Texas-based celebrity female hip-hop and rap artist Megan Thee Stallion, who has coined the term “real hot girl sh*t” in lyrics from one of her trending songs and who won three Grammy awards in 2021 for the best rap song, best new artist, and best rap performance (51). Her phrase “real hot girl sh*t” gained popularity in 2019, when audio from the song trended on TikTok (52). With more than 1.2 million videos using that audio on TikTok, we theorized that using this handle name and audio would bolster our vaccine promotion recognition and potential to go viral. Also known as a spoofing strategy, this approach was applied to capitalize on the name or audio recognition (53), which, in this case, reflects American youth culture. The approach to using our handle name aimed to contribute to increasing the following and sharing of the account and its postings. With our target audience being primarily youth aged 11–26 who are eligible for the HPV vaccine, along with parents, we used this handle to be relatable and “catchy” to our target audience.

Segmenting and Shortening NCI EBCCP HPV Vaccine Videos

We used videos, which had previously and significantly increased HPV vaccination in randomized controlled trials, to disseminate and broadcast culturally tailored HPV vaccine information. The videos were segmented by logical sequences and shortened to fit the requirements of each platform. We drew on the social affordance literature to understand how the informal social media dissemination environment and social affordances of the

different platforms may enhance the diffusion of the evidence-based vaccine video segments and how these social affordances may amplify the communication process (54). For instance, TikTok only allows posting videos of up to 3 minutes long (26), whereas Instagram allows both photos and videos to be posted, along with stories, reels, and IGTV (23). Reels on Instagram can be a maximum of 30 seconds, whereas IGTV videos can be 15 minutes when uploaded from a mobile device and up to 60 minutes when uploaded from the web or a computer (55). For Twitter, videos, pictures, and links can all be shared, but any text-based content can include no more than 280 characters per tweet. The maximum length for videos on Twitter is 2 minutes and 20 seconds (56). Given this information, each HPV video was shortened to 1 minutes in the adaptation process and posted on all platforms.

Social Media Platform Features

Additional strategies, such as posting content on reels on Instagram or “for you” pages on TikTok and inserting mentions, were used to increase engagement depending on the video length and platform. We drew on the social affordance literature (54) to understand how aspects of these platform affordances may increase exposure to our vaccine messages among social media networks and exposure among anyone on social media (outside of networks). For Instagram, if videos were no longer than 30 s, they were posted to reels. This strategy was used to increase views because all public reels posted by a public account can be viewed in the reels tab on Instagram (55). This increases the potential of the video being viewed and can increase reach. Influencers use reels as an engagement strategy. Reels have played a key role in increasing organic reach for these users (57). The more views on a reel’s video, the more potential for increased engagement and followers (57).

For TikTok, a similar strategy was used. Although TikTok does not have a reel’s function, shorter videos are known to do better on the app and gain more popularity (58). Thus, videos were edited and segmented to be shorter without sacrificing the educational content. Additionally, TikTok’s “for you” page functions similarly to the reels tab on Instagram. As Instagram allows any user to view a reel video posted by a public account, including users they do not follow, TikTok has a similar function. The “for you” page on TikTok allows users to engage with content from accounts they may not already follow and can help increase organic reach (34). For Twitter, videos can be up to 2 minutes and 20 seconds in length, links can be shared, and photos can be posted in a tweet. A user can include one to four photos in a tweet (59). Because Twitter does not have a “for you” page or reels tab, videos and photos were shared as tweets on this platform.

Other platform features were strategically used to increase engagement, including geotagging, stories, polls, and highlights. Geotagging was used to tag the broad location of the post. For this study, Orange County, California was mainly tagged, because much of our research team is from the University of California, Irvine and we wanted to reach local followers. Geotagging encourages engagement from followers in the tagged area (60). Moreover, potential followers can access the post if they click on or search that geotag (60). All content shared on Instagram as a

post or reel was also shared on Instagram stories. This strategy was used to alert new and potential followers of our latest posts and encourage engagement. Geotagging and polls were used on stories to encourage engagement. Polls asking about intent to vaccinate were utilized. When engaging with similar accounts and micro-influencers, we also shared some of their content with our stories. If stories were relevant and created engagement, we saved them as highlights on our Instagram profile. Because we had a public profile, highlights could be seen by any user, regardless of whether they followed us (61). This allowed for further engagement with the story content because stories can only be viewed for 24 h, but highlights can be viewed as long as they are public (61). These strategies were used on Instagram because TikTok and Twitter do not have these functions.

Use of Hashtags, Captions, and Links to Widen the Reach

Captions and hashtags on each platform functioned differently and were adapted to fit the requirements of each platform. Captions on TikTok can be up to 100 characters and up to 33 hashtags, whereas captions on Instagram can be up to 2,200 characters and up to 30 hashtags (62). Tweets can be up to 280 characters with an unlimited number of hashtags (63). Using this information, captions on TikTok were shortened to include the minimum relevant information, such as “CDC states that the HPV vaccine is highly effective in preventing the targeted HPV types!”. Drawing on cognitive load theory (64–66), for Instagram as with the other platforms, captions were organized in an “eye-catching” way to not overwhelm the reader. We did so by spacing out sentences, including only relevant information and facts, using emojis, using a conversational style, asking questions, and including important links on both the captions and profile.

Hashtags were used on all platforms, with the maximum number of hashtags being used on Instagram due to the high character count for the caption. This hashtag strategy was not used for TikTok, because many influencers suggest that using too many hashtags on TikTok can backfire and attenuate the chances of increasing views (67): only one to four hashtags for TikTok videos were used. Because Twitter has also a smaller character limit for tweets, hashtags were used sparingly on this platform. Relevant hashtags that were currently trending and had a high follower and usage count were used across platforms. For example, trending COVID-19 and vaccine hashtags #COVID, #Pandemic, #ThisIsOurShot, and #IgotTheShot were included to increase engagement.

Driving Content Across Platforms

Another strategy used to increase engagement and reach included creating a Linktree account to drive content across platforms (68). Linktree is a social media reference landing page where a dedicated URL is provided to organize and reference all URL links in one space. Because many young adults use multiple social media platforms (69), Linktree showed promise to gain wider reach through cross-platform communication (70). Linktree uses links to each active account promoting HPV vaccination that is shared directly on the profiles of each account (71). Such a cross-platform communication strategy was theorized to encourage

TABLE 2 | Example content calendar of weekly social media themes and postings April 2021.

Theme	Content post title	Caption
Week 2		
About HPV vaccination (April 5)	Rural small town young women video (Segment 1)	<p>Happy Monday!</p> <p>Did you know that HPV infections and cervical pre-cancers (abnormal cells on the cervix that can lead to cancer) have dropped significantly since the vaccine has been in use?!</p> <p>According to the CDC, among young adult women, infections with HPV types that cause most HPV cancers and genital warts have dropped 71 percent!!</p> <p>Talk to your doctor about how you can protect yourself from HPV-related cancers today.</p> <p>#HPV #HPVawareness #AskAboutHPV #CaHPVVaxWeek #CaliforniaHPVFree #HPVvaccine #ThisIsOurShot #COVID19 #Pandemic #HPVandCancer #HPVPrevention #PreventHPV #IgotTheShot #EducateToEradicate #HPVAlliance #Vaccine #Covid19 #CuckFancer #CervicalCancer #Vaccinate #VaccinatetoEradicate #Finals #Student #College #PublicHealth #Health #Nutrition #Selfcare #ZoomUniversity #Zoom</p>
World health day #LetsTalk (April 7)	World health day #LetsTalk (Filler Post)	<p>Happy World Health Day!</p> <p>As we celebrate today, we encourage you to remember that vaccines represent one of the most important global health achievements.</p> <p>According to the WHO, immunizations save approximately 2.5 million lives every year!!</p> <p>Take charge of your health. Talk to your doctor today about what vaccines you may need. Stay safe!</p> <p>#WorldHealthDay #HealthDay #Immunization #VaccineAwareness #Vaccination #HPV #HPVawareness #AskAboutHPV #HPVvaccine #ThisIsOurShot #COVID19 #Pandemic #HPVandCancer #HPVPrevention #PreventHPV #IgotTheShot #EducateToEradicate #HPVAlliance #Vaccine #CuckFancer #CervicalCancer #Vaccinate #VaccinatetoEradicate #Health #Nutrition #Wellness #Selfcare #Zoom #Quarantine</p>
About HPV vaccination (April 9)	Rural small town young women video (Segment 2)	<p>Happy Friday!</p> <p>Did you know that previous studies indicate the protection provided by HPV vaccine is long lasting?!</p> <p>According to the CDC, studies have followed people who received HPV vaccine for about 10 years, and protection has remained high in those individuals.</p> <p>There has been no evidence of the protection decreasing over time either!</p> <p>Talk to your doctor about how you can protect yourself from HPV-related cancers today.</p> <p>#HPV #HPVawareness #AskAboutHPV #CaHPVVaxWeek #CaliforniaHPVFree #HPVvaccine #ThisIsOurShot #COVID19 #Pandemic #HPVandCancer #HPVPrevention #PreventHPV #IgotTheShot #EducateToEradicate #HPVAlliance #Vaccine #Covid19 #CuckFancer #CervicalCancer #Vaccinate #VaccinatetoEradicate #Finals #Student #College #PublicHealth #Health #Nutrition #Selfcare #ZoomUniversity #Zoom</p>

cross-platform engagement from both current and potential followers who may have engaged with our content.

Frequent Content Posting

To increase engagement and retention of followers, the content was posted weekly over 4 months, highlighting not only vaccine messages but other public health wellness and lifestyle events (about three times weekly) as well. Instagram's and Twitter's ability to post both videos and photos made it easier to create and share content. Strategies to post consistently and organize content were used. Content calendars, social media holidays and observances, and social media planning apps were utilized for this study. Social media vaccine intervention literature has also shown that posting on general prevention and lifestyle interest topics, and not only vaccine promotion, will facilitate retaining interest and engagement with an account (47, 48, 72). Planning apps, such as Planoly, were used to organize content and captions before posting (73). Content calendars were created to organize days for posting along with themes, holidays, and observances for each month. In addition, the content was created using free online graphic design apps, such as Canva, for "filler" posts to celebrate relevant holidays and observances. Filler posts function to help content creators post content more efficiently and consistently and to keep interested (74) (see **Table 2** for sample weekly posts).

Organic content (content published that is not advertised or paid) from the EBCCP was disseminated regularly. The vaccine

content was culturally grounded and originally drawn from interviews. The end of videos contained cues-to-act tag lines to prompt action, i.e., schedule vaccination or talk to a health care provider about vaccination and ask questions.

Tag and Follow Influencers

Other strategies used to increase engagement across platforms included tagging and following influencers, "follow for follow," and engaging with similar accounts and influencers. Following influencers in the public health field, such as @CDCgov or celebrity rapper Megan Thee Stallion (@theestallion), according to social affordance theory, is likely to prove helpful in building a following, network, and reach. Following and tagging accounts that are popular in a niche (e.g., @CDCgov for public health) or social media influencers, and celebrities like Megan Thee Stallion can increase the likelihood that people who do not already follow you will see your content. This strategy was used on Instagram. Tagging accounts on an Instagram post ensures content will be shown on the "tagged" tab of that account's profile (if the user allows tags to be public). This increases the potential of the post reaching the target audience.

Follow-for-Follow Strategy as Instagram's Unique Strategy

The follow-for-follow and following similar accounts strategies were used on all platforms. This strategy included following

every account that followed us to build engagement, trust, and retention of followers. Initially, as a new account, we needed to build a following from scratch. To do so, we chose to follow individuals who followed similar accounts. If individuals were interested in similar topics, they were more likely to engage with and follow our account.

Engage With Similar Accounts

Following similar accounts and influencers regarding vaccines, COVID-19, health, and HPV and tagging those accounts helped increase potential content views and engagement by building partnerships through a follow-for-follow strategy. By following similar accounts (e.g., @DenverTeensForVaccines) and engaging

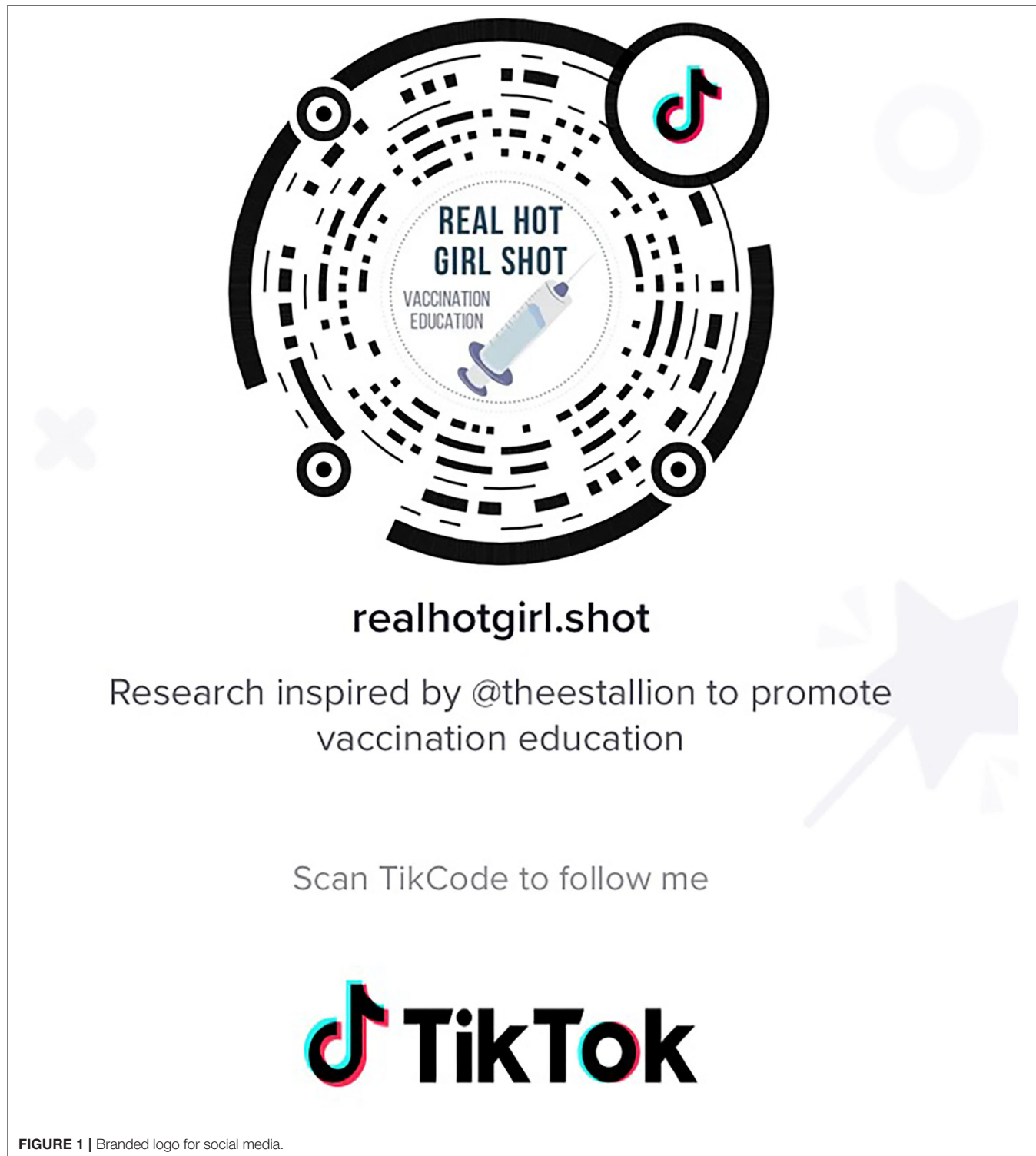


FIGURE 1 | Branded logo for social media.

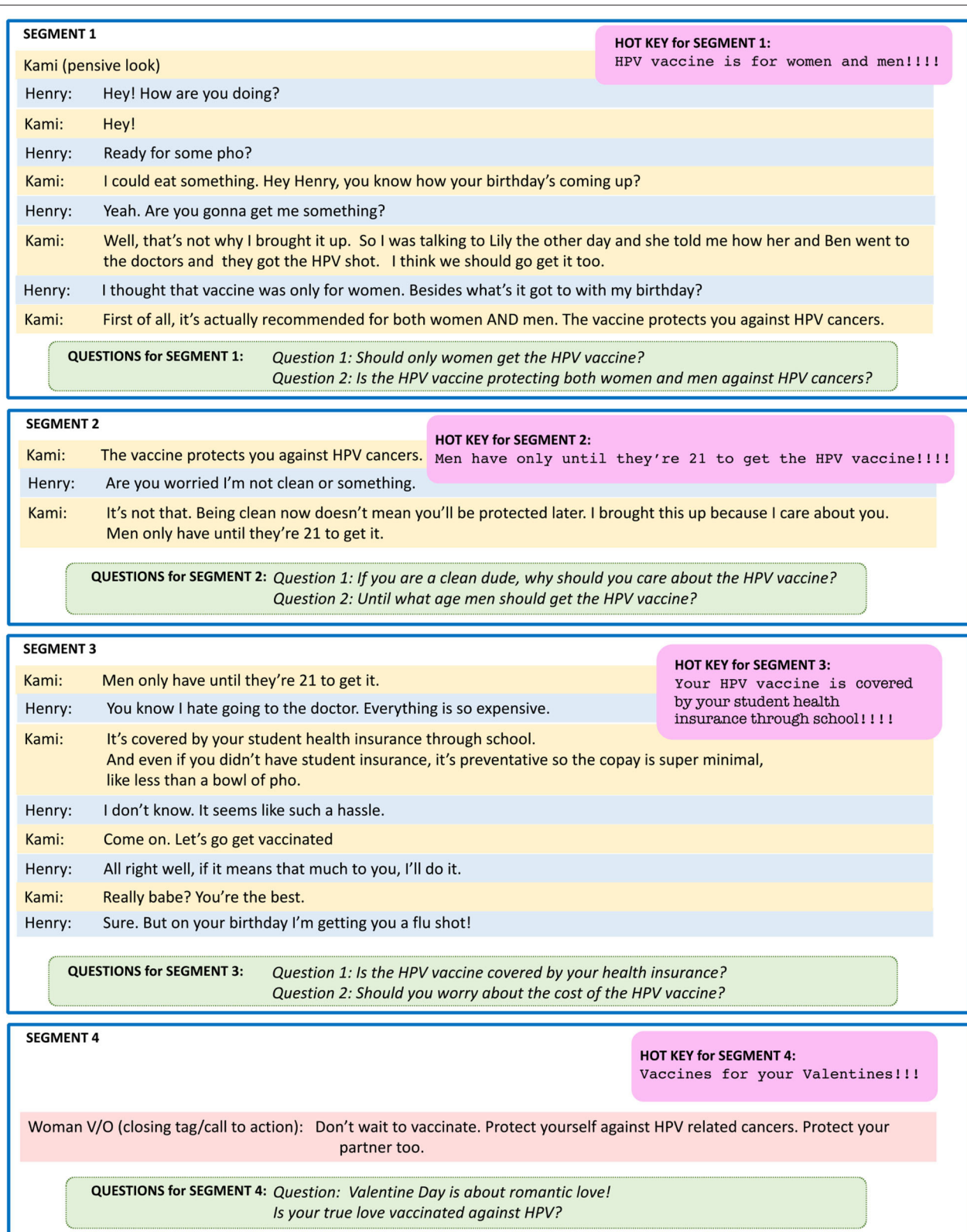


FIGURE 2 | Example of the segmentation of an EBCCP HPV video, showcasing the hot keys and questions associated with each segment.

with their content, mutual trust was formed to help build engagement. These similar accounts essentially engaged with our content if we did the same. Overall, the following accounts that had similar content regarding providing information on vaccine hesitancy or HPV were useful for increasing reach. The more likely other accounts engage with your content, the more likely your content reaches your audience.

Visual Aesthetics and Branded Logo

Visual aesthetics are important in creating a “branded” account that users will trust and want to follow. We created a QR code logo (see **Figure 1**) that was shared as the profile picture on all platforms to create a uniform brand identity. The username @realhotgirlshot was used as “Real Hot Girl Shot” with the title “Vaccination Education.” The business account was categorized as an educational platform on Instagram and TikTok. Using Canva, covers for the highlights were created using similar branding and fonts to the logo we created. Canva was also utilized to create filler posts and other aesthetic content. Its wide range of free templates made creating vibrant and engaging content much easier.

Hot Keys and Segmentation of the EBCCP HPV Vaccine Videos

Centering theory (42) assumes that each discourse segment evokes some entities, ideas, or other abstractions, referred to as centers. The theory provides a mechanism for scoring these centers, such that the highest scoring center becomes the “preferred center.” Each discourse segment has a different preferred center. We hypothesized that the preferred center of each segment of an EBCCP HPV video can be used to generate a hot key for each segment. As shown in the example illustrated in **Figure 2**, the first segment concerned three centers in this example of HPV vaccine video set in Little Saigon, a Vietnamese District in Southern California: C_1 = the gift for Henry’s birthday, C_2 = the HPV vaccine, and C_3 = a bowl of pho. As implied by the character Kami but not directly expressed, she intended to offer C_2 as C_1 , hence C_2 becomes the preferred center for Segment 1 of the EBCCP HPV video, illustrated in **Figure 2**. In addition, the utterances of Segment 1 offered an important theme of C_2 ; that it is recommended for both women and men. This theme of C_2 informed the hot key that we created for Segment 1. This explains why the two questions generated for Segment 1 (using them as captions) referred to the beneficiaries of the HPV vaccine. Both were yes-no questions, but they also raised awareness of the confidence in the vaccine, manifested by Kami and vaccine literacy, which Henry lacked because he was unaware that vaccinating was also recommended for men.

Note that Video Segment 2 started with the same last utterance Kami had in Segment 1. In this way, the two-party dialog remained coherent. Moreover, center C_2 looked forward to Segment 2, where a new center was introduced: C_4 = Henry being “clean” (in relation to sexual health). However, a causal coherence relation was established between C_2 and C_4 , ensuring that C_2 (the HPV vaccine) remained the preferred center even in Segment 2, but with a different theme, namely, one that

temporally constrained it, requiring vaccination for men to occur before they turn 21.

As in Segment 1, the hot key for Segment 2 was informed by the new theme of temporally constraining the HPV vaccine and, thus, addressing the factor of vaccine complacency. However, this time, the questions that were generated were no longer yes-no questions. In fact, Question 1 addressed the causal explanation between C_2 and C_4 , engaging participants to elaborate on their understanding of HPV vaccine complacency and manifest their vaccine literacy. Question 2 pinpointed the temporal constraint introduced as a new theme for the center of C_2 : the HPV vaccine.

Segment 3 considered the affordability of the HPV vaccine, yet another theme informed the hot key. It also introduced two new centers: C_5 = vaccination cost and C_6 = health insurance. Interestingly, when C_5 was introduced in Henry’s utterance, it showed how this explains his hesitancy. Viewers of this EBCCP HPV video segment might identify with Henry. Therefore, it is important that when C_6 was introduced immediately after Kami, it offered a solution to Henry’s hesitancy. When Henry continued being on the fence about vaccination, he referred to C_2 . Through the pronoun “it,” the segment maintained that this center was the focus of attention. When Kami referred in the next utterance to vaccination, by giving a cue to action, C_2 became the preferred center, yet in relation to C_6 , which informed the hot key of segment 3. Question 1 associated with this segment was a yes-no question, reinforcing the relation between C_2 and C_6 , addressing vaccine affordability. Question 2 further connected vaccine affordability to vaccine complacency by using the relation between C_2 and C_5 .

Segment 4 consisted of a single utterance, provided by another voice, building confidence in the HPV vaccine and its effectiveness in protecting against HPV cancer. This time, the hot key was generated differently. Because C_1 (the gift for Henry’s birthday) was the first center introduced in the dialog, referred to again in Segment 3 when Henry proposed a flu shot as a gift for Kami, we chose the hot key to be a gift for a special occasion. Because we were launching this segment before Valentine’s Day, we selected it as the special occasion. This idea was reiterated in the question associated with this segment: “Valentine’s Day is about romantic love! Did your partner get their HPV vaccine yet?”

Use of COVID-19 Vaccination as a Conversational Entry Point

In addition to the strategies discussed, vaccination for COVID-19 was used as a conversational entry point to guide our audience toward HPV vaccination messages. For instance, dialog on all platforms, including captions, story posts, and tweets were framed around discussions regarding COVID-19 vaccination. Posts focused on the pandemic anniversary in March 2021 emphasized the importance of getting vaccinated, following CDC guidelines, and tackling misinformation. Debunking COVID-19 myths were shared. The topic of COVID-19 vaccination was used as a conversational segue to talk about HPV vaccination. For example, a 71% decrease in health care visits for vaccination including HPV occurred during the COVID-19 pandemic (75). Content that was posted regarding low vaccination during

the pandemic emphasized the importance of prioritizing HPV and COVID-19 vaccination. Pandemic hashtags were used on all posts to emphasize this point, including #IGotTheShot, #ThisIsOurShot, #COVID19, and #Pandemic.

Data Analysis for Evaluation of Intervention Dissemination

Data for the evaluation of the observational study were retrieved from each respective platform's application programming interface and in the case of Instagram and TikTok, from business accounts with these two platforms. The business accounts made aggregate-level data accessible on engagement, the number of followers, reach, and impression metrics. Longitudinal data on the same individual users was not available. The descriptive and inferential statistics were performed to examine whether there were significant differences in the strategies used. Frequencies on mean accounts reached, and independent sample *t*-tests were performed accounting for unequal variances (Welch's *t*-test).

RESULTS

Platform Performance

Instagram outperformed TikTok and Twitter during the 4-month observational study period in Spring 2021 by receiving the greatest number of impressions, followers, and engagement, whereas TikTok reached the greatest number of unique accounts who viewed the handles' HPV vaccine messages (see Table 3).

Evidence for Intervention Adaptation and Dissemination Strategies That Increase HPV Vaccine Message Exposure

For Instagram, the top performer on engagement, impressions, and followers, evidence supporting the use of 6 of the 12 dissemination strategies was found for increasing the number of

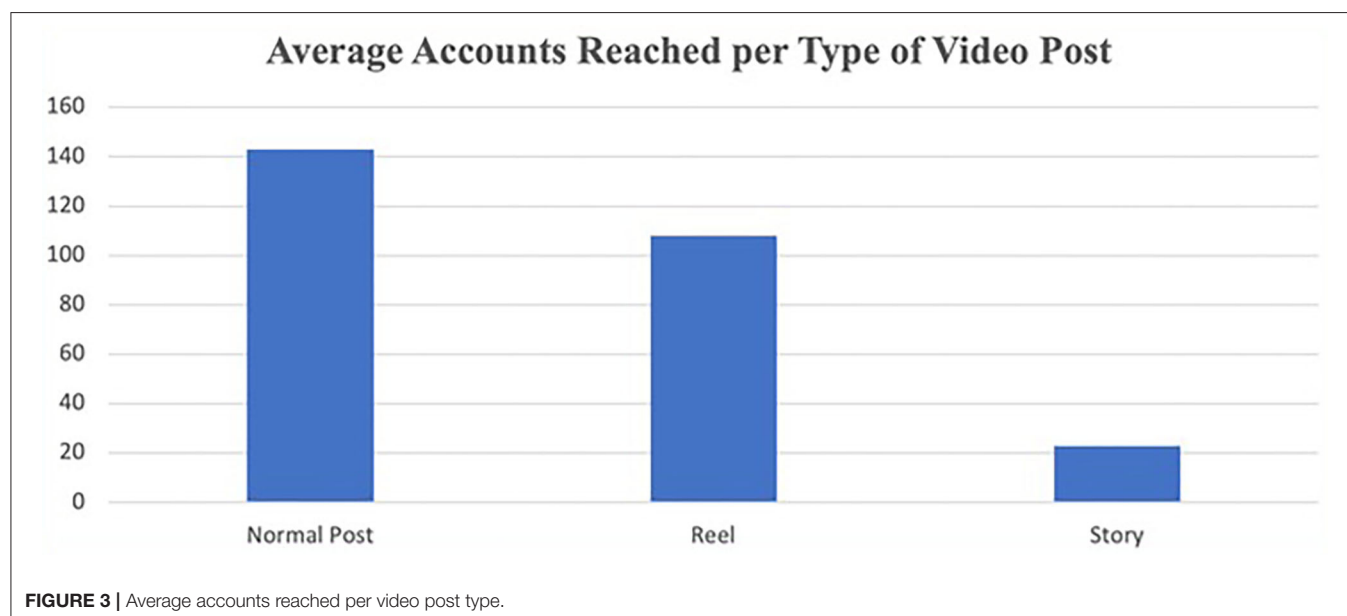
accounts reached. In reference to Table 1 listing of dissemination strategies, we found evidence for #3 strategic use of platform features, #4 use of hashtags, #6 posting content frequently, #7 tag and follow influencers, #11 hot key segmentation of EBCCP videos, and #12 use of timely COVID-19 vaccination as a discussion point to engage users. We elaborate on the evidence for these strategies next.

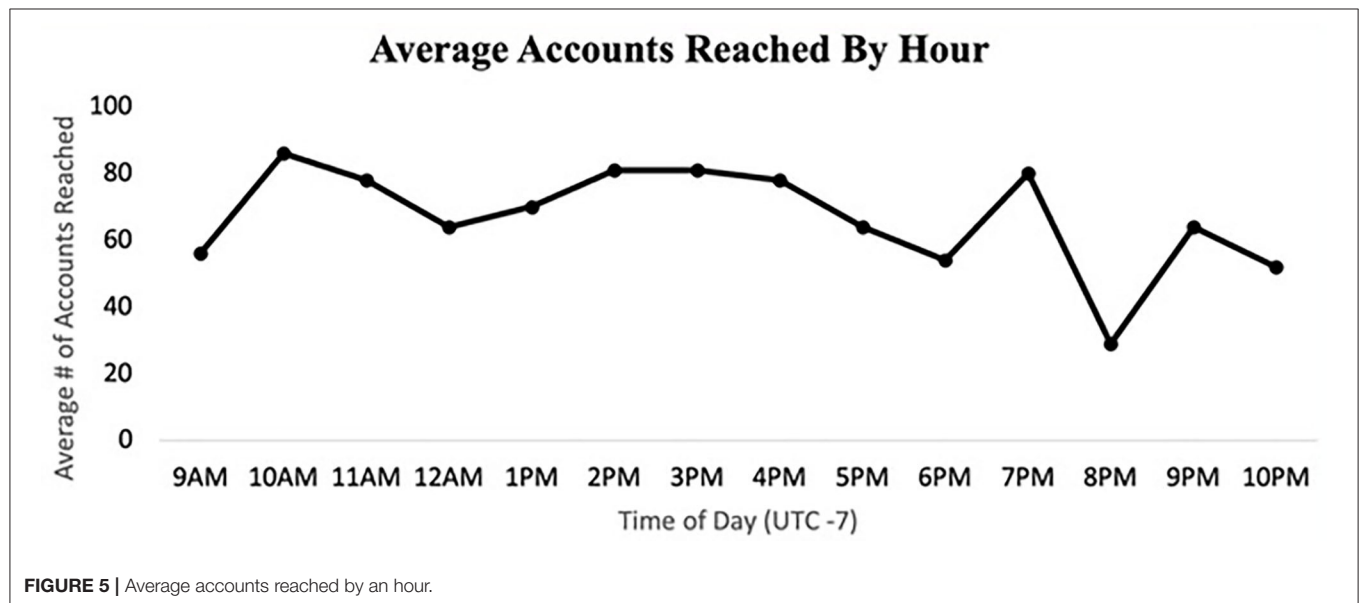
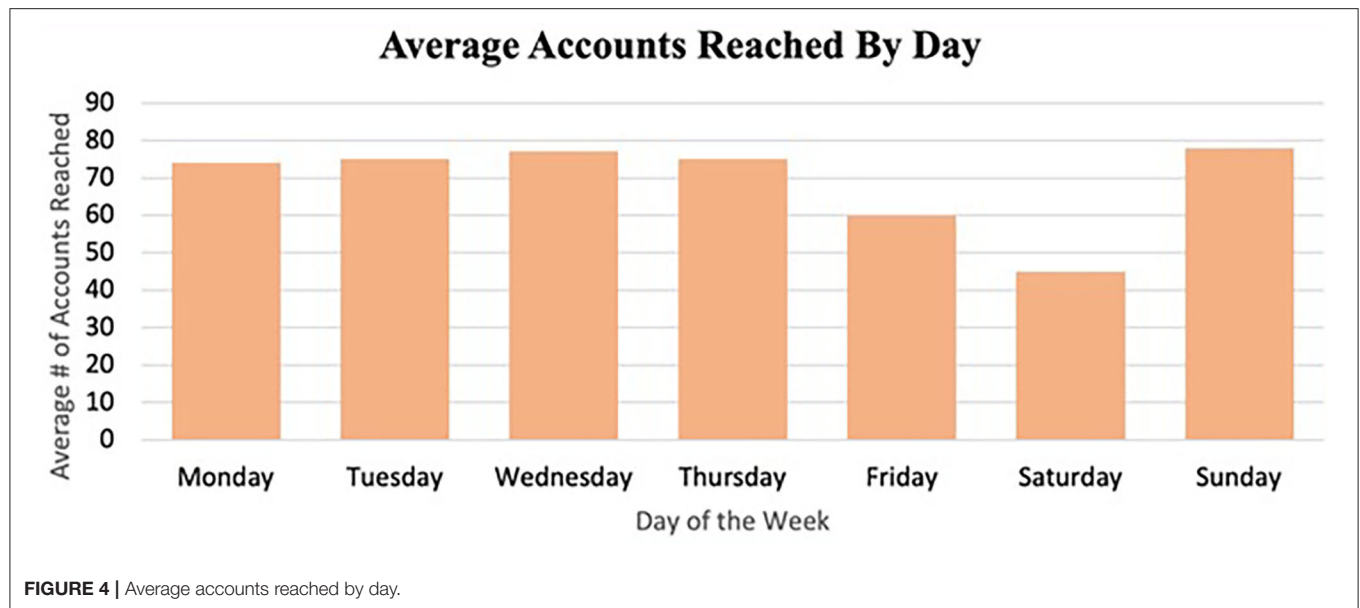
Strategic Use of Platform Features

Examining platform features on Instagram showed that although posting videos as reels (where anyone can view the video, not only followers of the account) or stories increased reach, normal posts reached a significantly greater number of accounts on average (143 ± 40 normal accounts reached) compared to posting content on reels (108 ± 54 accounts reached), or as a story (23 ± 9 accounts reached) (see Figure 3). The relationship was significant when comparing normal with story posts ($t = 20$, $df = 47$, $p < 0.001$), but was not significant when comparing normal posts with reels or story posts ($t = 1.7$, $df = 4$, $p = 0.157$). Normal posts reached 6,583 accounts, whereas story posts reached 1,729, and reel posts reached 541 accounts.

TABLE 3 | Social media platform performance.

	Impressions (# of times content was seen, viewed, or played on the app)	Reach (# of unique accounts that have seen our content)	Followers	Engagement (likes, shares, retweets)
Tik Tok	8,327	8,614	184	441
Instagram	9,986	7,998	389	621
Twitter	5,659		17	163





Use of Hashtags

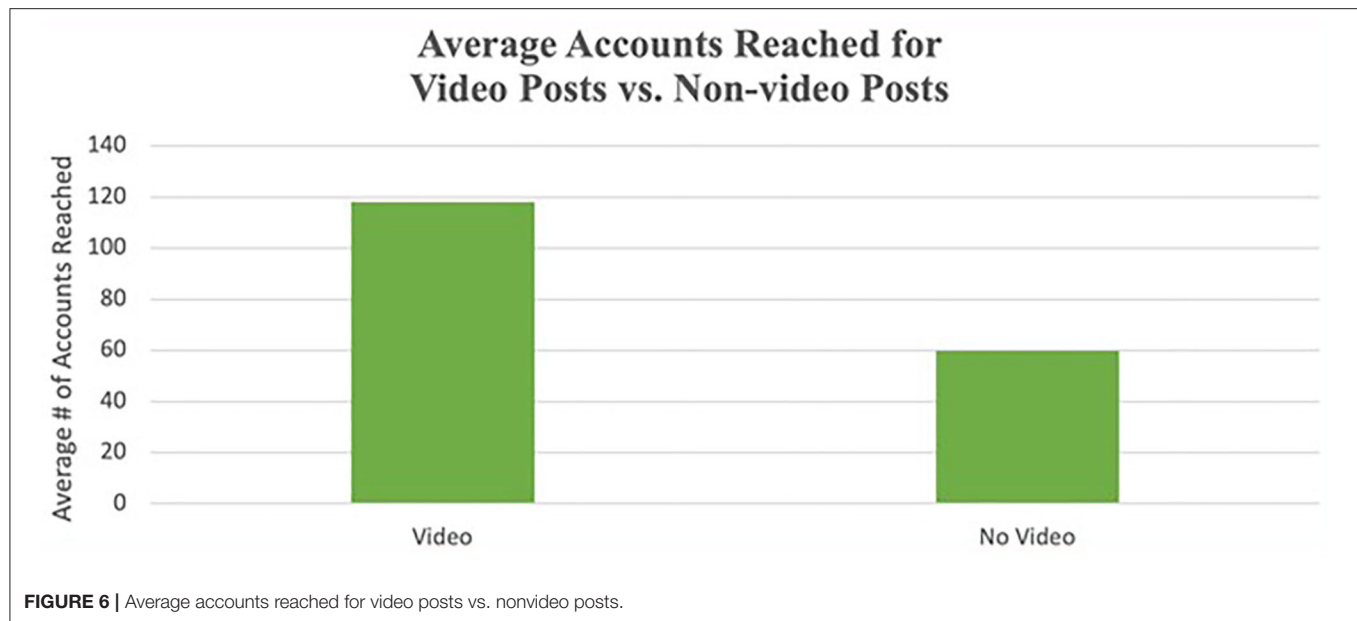
The use of hashtags significantly contributed to the dissemination of HPV vaccine messages. We found that for Instagram, posts using more than 11 vaccine-related hashtags (11.7) reached a greater number of accounts on average (140 ± 42) compared to posts using fewer than 11 hashtags (23 ± 9). The hashtag strategy was significant for increasing the average number of accounts reached ($t = 19.6$, $df = 53$, $p < 0.001$). The most accounts reached occurred in the fourth month of the observational study on a post about international women's day, reaching 255 accounts indicating an upward trend as the vaccine educational account gradually began building a following.

Posting Content Frequently

Posting content frequently, another dissemination strategy, is a necessary strategy in the competitive social media message environment. Additionally, the timing of posting matters on both days of the week and time of day. Posting content Sundays through Thursdays reached a greater number of average accounts. As for the time of day, posting mornings around 10 a.m., afternoons between 2 and 4 p.m., and evenings around 7 p.m. reached a greater number of accounts (see **Figures 4, 5**).

Tag and Follower Influencers

For tag-and-follow influencer strategies, posts that included mentions of other accounts reached a significantly greater



number of accounts on average (142 ± 26 accounts) compared with posts that did not include mentions (69 ± 64 accounts; $t = 5.3$, $df = 40$, $p < 0.001$). Engaging with similar accounts resulted in a modest 309 accounts following our “realhotgirlshot” account. Following individuals who followed HPV vaccination accounts (145) resulted in the greatest increase in followers. This was the most successful strategy in securing an audience in a short amount of time and was the source of the greatest proportion of followers. Followers included accounts representing educational groups, community organizations, nonprofits, podcasts, and informational accounts.

Hot Key Segmentation of EBCCP Videos

Support for the dissemination of the segmented (shortened yet sequentially delivered) HPV vaccine story videos reached significantly more accounts (118 ± 42 accounts) compared to posts with no video (60 ± 63 accounts; $t = 5.26$, $df = 40$, $p < 0.001$; see **Figure 6**). Posting videos on the Instagram reels option and the in-feed grid led to higher views or plays compared to posting videos to reels only or in-feed grid only (see **Supplementary Material** that shows views by video segment). The breakdown of HPV video segments comparing Instagram and TikTok showed that the video segments consistently received more views on the TikTok platform compared with Instagram (see **Supplementary Material**, for details on views per video segment). Two videos, the boba HPV vaccine discussion and the clinic Latina stories, received considerably more views (2,627 views for boba and 1,169 views for clinic Latina) on TikTok than on Instagram (see **Supplementary Material**).

COVID-19 Vaccination as Discussion Engagement

Using COVID-19 posts and hashtags to draw attention to the vaccine account significantly increased the accounts reached (149 ± 1) compared to vaccine posts that did not mention COVID-19 (68 ± 64 ; $t = 14$, $df = 125$, $p < 0.001$). Additionally, use

of COVID-19 hashtags resulted in reaching significantly more accounts (140 ± 42) compared with non-COVID-19 posts (23 ± 9 ; $t = 19.6$, $df = 53$, $p < 0.001$).

DISCUSSION

This observational study generated some of the first evidence to our knowledge, on which intervention dissemination strategies can increase user engagement and reach for educational HPV vaccine messages in a real-time, *in vivo*, competitive social media message environment. Although more difficult to measure, learning how promotional and narrative or dialogue-based vaccine messages perform in the competitive social media message environment lends greater external validity (21) and advances science about which strategies increase reach and engagement under conditions of message competition. This study generated evidence for how select social media platforms function to propagate vaccine messages. Six of 12 dissemination strategies were found to increase reach, engagement, impressions, and followers on Instagram, a platform well-suited to deliver vaccine video stories given its emphasis on visual delivery and primary use by young adults and parents—the target audience for HPV vaccine messages. Findings demonstrate that the inclusion of narrative EBCCP HPV vaccine videos contributed to significantly increasing the average number of accounts reached. Centering theory informed the strategy to coherently segment the original HPV vaccine videos into shorter videos that could be delivered sequentially.

Lessons Learned

Evidence for Strategies That Increase Reach and Followers

The study generated evidence for strategies that increased the number of followers, impressions, and engagement on

Instagram, whereas TikTok's video-exclusive platform increased reach (views among unique accounts) to a greater extent across all video segments during the 4 months. For Instagram, several strategies broadened the reach and increased accessibility of the HPV vaccine messages: segmenting videos and emphasizing specific vaccine messaging with captions or questions, using more hashtags including COVID-19 hashtags, posting normal posts frequently during certain times of the day and on certain days of the week, and using tag-and-follow influencer strategies (e.g., mentioning and following individuals and groups that follow HPV vaccine accounts, including educational groups, community organizations, nonprofits, podcasts, and informational accounts). This observational study, therefore, generated evidence for how the social affordances of these three platforms may increase access and reach of HPV vaccine messaging (54, 76).

Engagement Presents Greater Challenges on Visual and Hedonistic Platforms

Engagement, by contrast, occurred during the 4-month observational study, but it was muted in its expression by users on all three platforms. The two visually dominant platforms, TikTok and Instagram, have a greater click culture by reacting with emojis, but less so by reacting with extensive linguistic expressions (70). According to the push-pull communication framework, HPV vaccine messaging was predominantly broadcast, with little organic pull dialogue occurring on these platforms. Organic, user-generated pull communication explained by social affordance theory was not observed. Whether this is because of the topic or other explanations is unknown. Our study's low engagement stands in contrast to a 10-week statewide (South Carolina) social media HPV vaccine campaign on Twitter and Facebook that experienced pro- and anti-vaccine comments to a greater extent (48). However, it is noteworthy that both this campaign and a yearlong Danish social media campaign used paid content to push out content (47). Future research will need to explore what strategies can increase engagement. Network influencers and entertainment memes may be additional key strategies for deepening interest for greater engagement (5, 77, 78). Results brought attention to how dissemination strategies play out differently depending on the platform and the likely need for monetary incentives to respond with questions if unvaccinated. The high-quality HPV vaccine videos were intended to evoke interest and curiosity. For four months, the Instagram posts generated nearly a million impressions (the number of times vaccine messages were seen), reached nearly 8,000 unique accounts, and built a modest following of 389 accounts.

Tag-and-Follow Influencer Strategies and Engaging With Similar Accounts

Although we did not reach mega-influencer Megan Thee Stallion for endorsement of our vaccine account, following local micro-influencers in Orange County, California and public health and tagging HPV vaccine accounts boosted our following and reach. Social media influencers are known to improve marketing for many brands (79, 80). Influencers may be micro- (1,000–10,000

followers), macro- (10,000–1 million followers), or mega- or celebrity influencers (more than 1 million followers) (81), have differential influence, and may only endorse vaccine messages if they receive monetary compensation. With an account focused on vaccination, education, and public health, working with influencers who are social activists and care about similar topics may offer one strategy to increase following and engagement with the account.

Cross-Platform Behavior Is a Modest Strategy to Increase the Reach

Cross-platform user engagement was a strategy we expected to increase our following. Although having a Linktree in the bios did drive modest cross-platform activity (124 views), TikTok has a built-in option to cross-link with Instagram, while Twitter has hyperlink options to drive cross-platform messages. TikTok and Instagram do not permit hyperlinks. Overall, the Linktree cross-platform engagement strategy did not significantly increase following or reach but could still be considered to encourage cross-platform traffic.

Planning and Time for Building a Following and Influence

Real-time, *in vivo* social media interventions (i.e., in the dynamic message environment as opposed to implementing an intervention in a controlled social media environment) are both tricky and interesting, and many lessons were learned from the 4-month observational study. Planning for the time it takes to develop a following, networks, influencers, posting strategies, and content must all be considered in the planning of social media interventions, especially given the new communication paradigm of messages propagating primarily through peer networks (8, 10, 81). Just as it takes time to build real-world communities, the same is true for online ones (48, 82). Developing a following can take many months with routine posting and can present challenges, particularly for an account with no name recognition, influencers promoting the account, or viral content. This has also been the case with the few HPV vaccine observational social media studies (47, 48). The adaptation strategies we implemented offer an approach to begin establishing a community, but the time and effort it takes to become an influencer can present challenges. Engaging with similar accounts, establishing relationships with other users, following similar accounts, and creating content seem necessary ingredients. Because social media apps do not rest and new content is continually pushed out by other accounts, posting content continuously and engaging with others online is necessary to establish a strong following and network. Therefore, researchers conducting similar research should keep in mind that it can take several team members to manage a single account and several months to establish even a modest following. Having adequate time, planning, and resources to manage the account and engage with others is paramount for social media.

Posting on Specific Days and Times

Posting on specific days and times that followers are on the app is an important strategy that we could not take advantage of fully. As it takes time and effort to manage the accounts and

posting on specific days and times can be difficult. The days and times when many followers are on the app are viewable in the analytics for TikTok and Instagram. However, these days and times vary between platforms, and researchers were not always available to post during that time. Online applications exist that can automatically post preplanned content and captions on Instagram for both in-feed posts and stories (83).

Repostable Content

Creating “repostable” content is also an important strategy. Content that is reposted means it is shared more often and more likely to be seen and, thus, more likely to go viral. The type of content posted, how relatable it is, and how relevant it is to pop culture is something to consider because contents, such as memes and reels, are known to garner the most exposure on Instagram and Twitter (77, 84). In the future, we aim to create more relatable yet educational content that is likely to be shared and reposted by other users on these platforms. This will likely increase engagement and reach (47, 48, 85).

Sustained Engagement and Implications for Adapting Public Health Interventions

Another unknown is the different rates of growth and engagement on each platform. In this case, Instagram had the highest rate of growth and the most followers and engagement through likes, comments, and shares. TikTok, on the other hand, received more views consistently across video segments and the most views for a single video, the Boba talk, and clinic Latina. By contrast, the intervention implemented on Twitter observed limited growth and the research team struggled to increase followers and engagement on this platform but was also less experienced with this platform. A social media background with technical knowledge of marketing strategies for propagating messages and effectively growing accounts is essential. Critical for sustained engagement seems to be the inclusion and posting of trends and topics other than vaccination to maintain interest. This was found to be the case in another social media study (72), where keeping the audience’s interest by taking an integrative holistic approach worked to sustain engagement.

The COVID-19 vaccine posts and hashtags helped broaden the reach of our audience and make our content easier to find for those who did not follow our account but may be interested in keeping up with public health. For instance, users that followed COVID-19 or pandemic hashtags may have easier access to our content. In all, this strategy was used to capitalize on discussions regarding health and wellness, vaccinations, public health, and COVID-19. Framing discussions around topics that are already being discussed both online and offline was a simple way to pull our audience in and garner attention and engagement.

Limitations

The research team faced challenges in the design, implementation, and evaluation of the study. In particular, growth and going viral on Instagram, Twitter, and TikTok can be time-consuming and requires unique strategies that dynamically respond to upcoming current events. It was difficult to solicit engagement through likes, comments, and shares from our target

audience, especially because of the public nature of the accounts and low handle recognition. In addition, with only aggregate data available, it was not possible to measure whether individual users watched consecutive video segments.

The dosage of intervention exposure could not be measured directly, nor could we assess whether the same individuals followed the sequential posting of segmented videos. Future research will feature a randomized trial design and examine dose-response effects. Platform choice may need to be guided by those that provide metrics with a more granular analysis of individual users. Because of the public nature of the accounts, it was impossible to measure how much exposure each user had to the educational content on Instagram, Twitter, and TikTok.

CONCLUSION

Social media offers a communication tool for disseminating and interacting with youth and young adults about HPV vaccination, given their daily message exposure on these platforms (85–87). Preventing cancers caused by HPV through vaccination remains a significant public health priority in the United States (16). Given that young adults’ daily exposure to social media typically encompasses lifestyle, identity, and entertainment messages, vaccine intervention strategies that evoke interest and curiosity about HPV vaccination in the competitive message environment will be needed (87–90). Social media is a powerful tool that has the potential to revolutionize health interventions if used correctly (77, 78, 87, 91, 92), with social media being dubbed the new vital sign (93). Dissemination of HPV vaccine messages will differ depending on the social media platform, but different strategies and a comprehensive strategy are recommended to adapt vaccine interventions, build a following, and increase reach to connect with potential users who may benefit from HPV vaccine messages.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

SH contributed to the study design conception and theory, the development of the adapted intervention, data analysis, and drafting of the manuscript. KP contributed to the social media planning, creation, and dissemination of weekly content posting, data retrieval and analysis, and drafting of the manuscript. MW contributed to data retrieval and analysis. HV contributed to the creation of and weekly posting of social media content and drafting of the manuscript. SA contributed to making graphs and figures and some content posting. SMH contributed to the development of original concepts and theory informing intervention adaptation strategies for the social media study and drafting sections of the manuscript. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fdgt.2022.819228/full#supplementary-material>

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