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The Impact of Digital Technologies on HPV Vaccination Uptake and Intention Among Adolescents, Young Adults, and their Parents: A Systematic Review.

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Abstract

Background: *Human papillomavirus (HPV) is a preventable sexually transmitted infection and a leading cause of cervical cancer, with high global prevalence, especially in low- and mid-income countries (LMIC). Although HPV immunization has been shown to reduce cancer incidence, vaccination uptake remains insufficient. Digital media offers a promising avenue to address vaccine hesitancy and improve vaccination rates among adolescents and their parents.*

Aim: *To evaluate the effectiveness of digital media interventions on HPV vaccination rate and intention.*

Methods: *We undertook a comprehensive search for PubMed, Scopus, Web of Science, and Cochrane databases through May 2024. After including Randomized Controlled Trials (RCTs) and observational studies (OS) focusing on adolescents, young adults (9-26 years), and their parents, we investigated the impact of digital interventions on HPV vaccination rate and intention. Quality assessment was conducted using the Cochrane Risk of Bias 2 tool for RCTs and an adapted Newcastle-Ottawa Scale for OS. Data extraction included study design, demographics, intervention types, and outcomes.*

Results: *From 2350 records, 23 studies (19 RCTs and 4 OSs) met the inclusion criteria. Digital interventions (SMS, mobile apps, video, and web-based platforms) increased HPV vaccination intention in 46% of studies – Odds Ratio up to 2.5 –, and uptake in 27% – Odds Ratio up to 1.82.*

Conclusion: *Digital interventions showed some potential in increasing short-term HPV vaccination intention and, less expressively, vaccination rates. Future research should focus on long-term strategies to improve HPV immunization uptake.*

Introduction

Human papillomavirus (HPV) is a preventable sexually transmitted infection and the major risk factor for cervical cancer (Pimple et al., 2022). The global prevalence of HPV infection in women is 11%–12%, with higher rates in sub-Saharan Africa (24%), Eastern Europe (21%) and Latin America (16%) (Martel et al., 2020). Globally, an estimated 620,000 new cancer cases in women and 70,000 new cancer cases in men were attributed to HPV in 2018, including cancer of the cervix uteri, anus, penis, vulva, vagina, and oropharynx (Martel et al., 2020).

HPV immunization has been shown to reduce high-grade cervical cancer lesions and cancer incidence up to 2-8 times in one large cohort (Lei et al., 2020). Although cervical cancer prevention in reproductive-age females has traditionally been the focus of such campaigns, since 2006, the World Health Organization (WHO) has expanded recommendations to include females up to 45 years old in certain circumstances and males as a secondary target for HPV vaccination (WHO, 2017). Female-only programs have limitations as they overlook the spread of HPV through bisexual, same-sex contact and digital or oral transmission, highlighting the need for a pan-gender approach to HPV vaccination (Dykens et al., 2023).

Despite these HPV vaccination programs being initiated in 2006, between 2008 and 2020, HPV vaccination coverage in high-income countries declined from 89% to 41%, while in low- and middle-income countries, it increased from 0.8% to 5.2%, remaining insufficient (Dorji et al., 2021). In addition, competing health priorities may be inferred from WHO's data on HPV vaccination coverage in 2018 – it was missing from over half of members' reports(Spayne & Hesketh, 2021).

Given the widespread prevalence of HPV and the persistent challenges in achieving adequate vaccination coverage, it is crucial to explore innovative approaches to overcome known barriers to vaccination uptake, including digital intervention (Spayne & Hesketh, 2021). In this context, modern digital media continuously evolves and widely influences adolescents, young adults, and parents' search for health-related information. Thus, the increased accessibility to smartphones, the internet, and social media could be an opportunity for addressing vaccine hesitancy and increased uptake (Stellefson et al., 2020).

The potential of social media for HPV vaccination awareness and uptake has previously been reviewed, assessing a variety of outcomes such as immunization rates, intention, information/knowledge, motivation, and behavioral skills regarding HPV vaccination. However, in one study, the population was not clearly defined, and only the efficacy of social media was assessed (Ortiz et al., 2018). Another review focused exclusively on mobile digital health intervention, showing its efficacy. Moreover, 95% (n=18) of the trials were conducted in the United States, and the majority of the studies could not be conclusively considered low risk regarding methodological bias (Ilozumba et al., 2021). A recent systematic review published in 2023 included experimental trials and found a variety of digital interventions, including video games. Nevertheless, it measured narrow outcomes such as HPV knowledge instead of HPV vaccination rate, and populations were not described in detail, thus limiting the external validity of the results (Choi et al., 2023).

Therefore, it is essential to investigate the broader effectiveness of diverse digital interventions on HPV immunization across distinct cultural and socioeconomic contexts.

Materials and Methods

This systematic review followed the statements for the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) guideline (Page et al., 2021).

Inclusion and Exclusion Criteria

The inclusion criteria for participants were either female or male early adolescents and young adults (9-26 years old) and/or their parents, as this age range aligns with the primary target population for HPV vaccination recommended by the WHO (WHO, 2017). We included studies with any or no digital intervention, as defined by the WHO – specific technology functions designed to address health system challenges, such as ensuring vaccinations or follow-up appointments (WHO, 2023). The primary outcomes of interest were vaccination intention and vaccination rates. Intention to vaccinate was measured by different questions in each study. Eligible study designs included randomized controlled trials (RCTs) and observational studies.

We excluded trials that lacked control groups, involved participants outside the specified age range, did not obtain proper consent, were published in languages other than English, or had unavailable full

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texts.

Search Strategy

A systematic search was conducted across PubMed (Medline), Scopus, Web of Science, and Cochrane databases to identify studies published from inception to May 2024. In addition, references of included studies were manually searched for inclusion. The full search strategy is presented in the Appendix. Inclusion and exclusion criteria were initially assessed by screening all abstracts and titles, followed by full-text screening of selected articles. Two authors independently reviewed each article, and disagreements were resolved after consultation with a third reviewer. The screening was performed using COVIDENCE, a web-based collaboration software platform that streamlines the production of systematic and other literature reviews (Veritas Health Innovation).

Data Extraction

Data extraction was conducted independently by one author (SVG) and any discrepancies were resolved in frequent meetings in the presence of the supervisor (BT) which was finally reviewed by the medical expert (NJ). We evaluated Overall Survival (OS), Event-Free Survival (EFS), and Complete Remission (CR) as primary endpoints for analysis. We also assessed Complete Remission with partial hematologic recovery (CRh), Complete Remission with incomplete hematologic recovery (CRi), Complete Remission with incomplete platelet recovery (CRp), and Overall Response Rates (ORR), if available. We compared grade 3 or higher treatment-emergent adverse events (TEAEs) published among these research studies.

Identification: Study details include the first author, contact information, sponsorship source, country and year of publication, and study duration.
Population: Number of participants, inclusion/exclusion criterion, baseline characteristic (age, sex, ethnicity, setting, education, income.), group differences, number of withdrawals, and reason for withdrawal.
Study Design: Study design (RCTs or observational studies).
Intervention/Exposure: Setting, device, and content of the intervention.
Outcomes: Vaccination rate and intention.
Methods: VIn RCTs, random sequence generation, allocation concealment, blinding, attrition rates, rates of missing data and its handling, outcome analysis methods, and adjustment for confounders. Also, recruitment strategy, number of non-responders, method of outcome assessment, adjustment for confounders, and the reporting of statistical analysis were extracted to assess bias in the observational studies. Disagreements during data extraction were resolved by a third author after consultation.

Data Synthesis

A qualitative data synthesis was conducted, as quantitative analysis was not feasible due to the heterogeneity of the included studies.

Assessment of risk of bias

Two authors independently assessed the risk of bias in the included reports, using Version 2 of the Cochrane risk-of-bias (RoB2) tool (Sterne et al., 2019) and the Newcastle-Ottawa Scale (NOS) (Wells et al., 2014). Disagreements were resolved after consultation with a third author. Since all observational reports included in this review were cross-sectional studies, we used an adapted version of NOS (Patra et al., 2015).

Results

Description of the Studies

The initial database search identified 2350 records after title and abstract review. Duplicate articles were excluded (n=404), resulting in 1946 records included for abstract and title screening. A total of 119 records were sought for retrieval and eligibility through a full-text review. Ninety-six articles were excluded since they did not meet the inclusion criteria. A final set of records (n=23) was included in this systematic review for data extraction and analysis. (Figure 1).

Randomized Controlled Trials

Nineteen (83%) RCTs, including 100,117 participants, were reported. The majority were country-specific, with studies primarily conducted in the United States (57.8%, n=11) and China (21%, n=4), followed by Taiwan, Japan, Netherlands, and Australia (Table 1). Most RCTs used a parallel-group design with two or more arms (n=12), followed by a factorial (n=4) and cluster design (n=3). Subjects were mainly recruited through online platforms, such as social media and web ads, national registers, and institutional panels. A combination of telephone calls and online advertisements, together with printed ads, was also used to recruit participants.

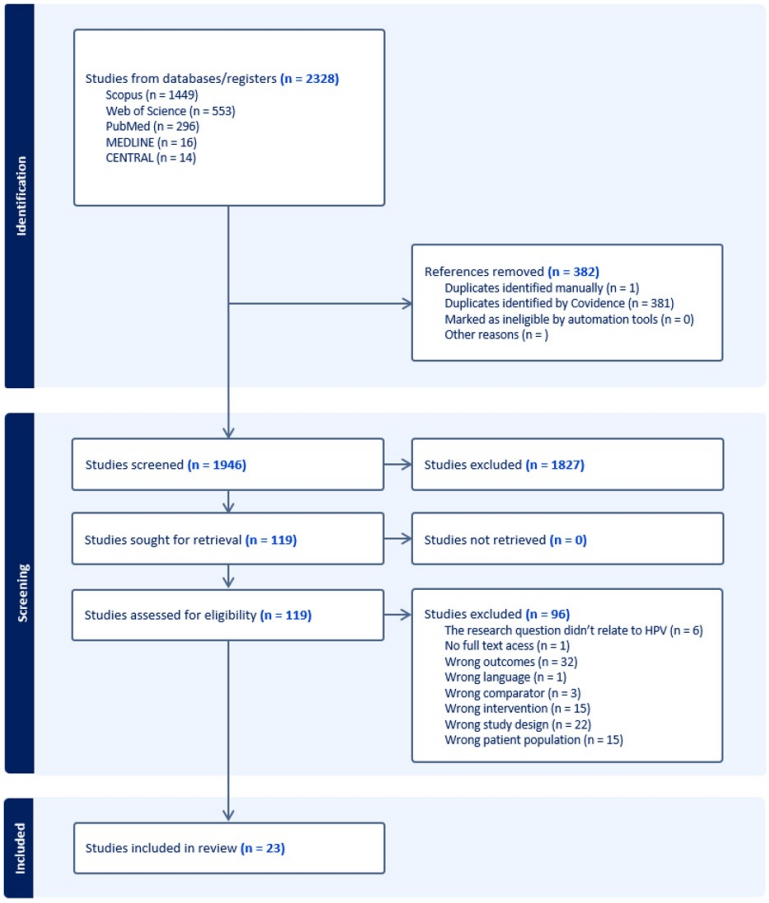

Figure 1: *PRISMA Flow diagram for the systematic review.*

Observational Studies

Four cross-sectional studies were retrieved, three in the USA and one in Italy, involving a total of 2,658 participants (Table 1). All participants were recruited through online platforms, and data was collected through surveys.

Population

RCTs

Young adults and adolescents were the study population in 52.6% (n=10) of the trials, parents of adolescents in 36% (n=7), and both parents and adolescents in the remaining 10.5% (n=2) (Table 1). Out of the 10 trials featuring only young adults and adolescents, 60% (n=6) included exclusively females (DiClemente et al., 2015; Lai et al., 2015; Si et al., 2022; Sun et al., 2022; Wang & Zhang, 2021; Zhang et al., 2019). Among the remaining 40% (n=4), one study had a majority of females (Harper et al., 2023), another had a significantly higher male population (Hofstetter et al., 2017), and the remaining two had a balanced male and female population (Szilagyi et al., 2020; Tull et al., 2019). In the subset of trials featuring parents, three studies included exclusively parents of female children (Panozzo et al., 2020; Pot et al., 2017; Suzuki et al., 2021). Among the studies featuring both parents and adolescents, one included exclusively female dyads (Dempsey et al., 2019). Overall, 52.6 % (n=10) of the RCTs included exclusively females. Regarding baseline characteristics, 52.6% (n=10) of trials failed to report levels of HPV knowledge or HPV vaccination rate, 21% (n=4) described prior HPV vaccination knowledge, and 26.3% (n=5) reported at least one dose of HPV immunization. Concerning ethnicity, 21% (n=4) had a predominantly Asian population, 5.2% (n=1) exclusively Latinos, 5.2% (n=1) exclusively African-Americans, and the remaining (n=6) had mixed ethnicity, with a majority of Caucasians (Table 1). Ethnicity was not mentioned in 36.8% (n=7) of trials. The mean age of participants in each study ranged from 11 to 26 years old for early-to-late adolescents and 22 to 62 for parents. (Table 1) A description of socio-economic features, such as education, family income, and community setting, is provided in Table 1.

Observational Studies

Cross-sectional studies included only parents of adolescents (Table 1). All records reporting ethnicity included mixed-race participants, with a majority of Caucasians (n=3) (Table 1). Educational level and family income were reported in three studies (Table 1). Prior vaccination status and knowledge of HPV immunization were reported in two studies (Manganello et al., 2023; McRee et al., 2012).

Intervention/Exposure and Control Characteristics

RCTs

Digital intervention methods were varied. Text messages were sent via social media platforms (n=1), mobile device apps (n=6), or automated voice calls (n=1) (Table 2). The content was educational (n=2) (Hofstetter et al., 2017; Kim et al., 2022), emotion-driven (n=1) (Reno & Dempsey, 2023), or simple nudging as vaccination invitations (n=3) (Dempsey et al., 2019; Rand et al., 2015; Tull et al., 2019). Multi-level interventions combined HPV factual information, educational modules, and appointment reminders (n=1) (Shegog et al., 2022).

Video and other multimedia content included traditional HPV education (n=2) (Dixon et al., 2019; Panozzo et al., 2020) and educational-emotional testimonies (n=1) (Suzuki et al., 2021). Web-based and social media-based interventions featured personalized and tailored content (n=2) (DiClemente et al., 2015; Pot et al., 2017) and group sessions (n=2) (Harper et al., 2023; Lai et al., 2015). Other approaches included educational courses (n=2) (Si et al., 2022; Sun et al., 2022) and the comparison of different content types, such as negative vs. positive or narrative vs. static content (n=2) (Wang & Zhang, 2021; Zhang et al., 2019).

Control groups generally received basic information about HPV (n=6) (Dempsey et al., 2019; Harper et al., 2023; Lai et al., 2015; Panozzo et al., 2020; Suzuki et al., 2021; Wang & Zhang, 2021), general vaccination knowledge (n=2) (Si et al., 2022; Sun et al., 2022) or general health-education (n=3) (DiClemente et al., 2015; Kim et al., 2022; Rand et al., 2015), while others used reminders (n=3) (Hofstetter et al., 2017; Szilagyi et al., 2020; Tull et al., 2019) or provided 'usual care' without specific details (n=3) (Dixon et al., 2019; Pot et al., 2017; Shegog et al., 2022).

The highest intervention frequency was daily for a week (Si et al., 2022), followed by five times weekly for six months (Hofstetter et al., 2017) and monthly for 12 months (Szilagyi et al., 2020). The longest follow-up periods were one year (Tull et al., 2019) and 6-9 months (Shegog et al., 2022). Video interventions were the shortest, with no more than 10 minutes (Dixon et al., 2019; Panozzo et al., 2020; Suzuki et al., 2021).

Observational Studies

Among cross-sectional studies, descriptive variables such as social perception, socio-economic factors, age, knowledge and confidence about HPV, and type of digital exposure were assessed for association with vaccination intention (n=4) (Llavona-Ortiz et al., 2022; Manganello et al., 2023; McRee et al., 2012; Sommariva et al., 2023).

The cross-sectional studies listed a variety of confounders, ranging from parental beliefs and knowledge to socio-demographic factors such as age, gender, education level, socioeconomic status, and ethnicity. Health access and patients' trust in healthcare or other sources, community type, health, and media literacy, prior vaccination status, internet usage, parental health behaviors, and social media engagement were also listed as covariates.

Outcomes and Main Results

RCTs

Outcomes

Eight trials reported vaccination intention, eight vaccination uptake, and the remaining three studies reported both. Significant improvement in vaccination intention or uptake from digital interventions was reported in 53% of trials (n=10), while 47% saw no significant improvement in any outcome (n=9) (Table 2).

Text and Voice Messages

Sending an SMS reminder was effective at increasing HPV vaccination rates in two trials but not effective in the other two trials. SMS content did not influence vaccination uptake in all trials. Similarly, intention was not increased after exposure to 'fear eliciting" messages on genital warts or cancer. Reminders through automated voice messages had no impact on HPV immunization completion and only a small impact on vaccination initiation (Table 2).

Video

In two trials, video education on HPV was not efficient in increasing HPV vaccination uptake when compared to video education on other health issues, even though vaccination intention did immediately increase after the intervention in some trials (Table 2). When the video was offered in the waiting room of health clinics, it substantially increased vaccination uptake (Dixon et al., 2019).

Web-Based

Web-based tailored messages aiming at specific preferences and needs were not effective in increasing vaccination uptake, just as web-based educational messages were not better than psychosocial intervention or control (Table 2). Content delivery (interactive vs. static) significantly influenced vaccination intention, and the effect was in opposite directions, depending on the type of content (narrative or data-based) (Wang & Zhang, 2021).

Social-Media

Group discussions using social media significantly increased immediate and 1-month post-trial vaccination intention, but not after 3 months (Si et al., 2022). Social media comments' valence (positive vs. negative) or format (narrative vs. descriptive) played a role in parents' decisions, and these were negative narrative comments by sharing personal stories about risks and concerns, increased vaccination intention (Zhang et al., 2019). In addition, social media messaging increased positive attitudes toward HPV vaccination, which, in turn, was associated with increased intention to vaccinate (Lai et al., 2015). Of note, after using an app-based educational intervention, despite the significant increase in knowledge, vaccination initiation was not increased when compared to control (Shegog et al., 2022; Sun et al., 2022).

Observational Studies

Demographic, Socio-Economic

Several factors, including employment status, political affiliation, education level, household income, and Twitter (X) usage, were significantly associated with HPV vaccination intention/uptake, but those effects were no longer significantly associated in the multivariate model after adjustment (Manganello et al., 2023).

Internet Usage

Past internet usage as a source of information was also positively associated with parents' intention to vaccinate daughters but not sons, while future internet usage was not associated with the intention to vaccinate daughters. These results remained consistent after adjustment for parent's gender, age, race/ethnicity, education, household income, urban setting, and child's age (McRee et al., 2012).

Figure 2: *Bias assessment of RCTs.*

Social-Media

Being exposed to positive content about HPV vaccination on social media was positively associated with HPV immunization initiation, while exposure to negative content was associated with vaccination delay and refusal. Negative content seemed to hinder exposure to positive content and influence parent's decisions. All models were adjusted for the child's sex, child's age group, parent's race/ethnicity, parent's education, and parent's age group (Llavona-Ortiz et al., 2022).

Intervention Content

When parents were clustered in groups based on what feature of the digital exposure they considered the most influential, those who placed almost all the importance on image had the highest proportion of individuals being very likely to vaccinate a future child against HPV. Results were not adjusted for other variables (Sommariva et al., 2023) (Table 3).

Assessment of risk of bias in individual studies

RCTs

Most RCTs were classified as having some concerns of bias (n=11), while high risk (n=6) and low risk (n=2) were the classification of the remaining articles (Table 2). The high risk of bias was mostly due to missing outcome data (n=5) (Figure 2). There were no reports of a high risk of bias in the randomization process or the measurement of the outcome domain. The risk of deviation from the intended intervention was mostly low (n=8) or with some concerns (n=8), while a high risk of deviation from the intended intervention was seen in 3 reports (Figure 2).

Observational Studies

The study sample was considered representative of the target population in 75% of the studies (n=3). These studies also reported adjusted results with appropriate statistical analysis. However, all three relied on self-reported data (surveys) and non-validated tools to collect data. One study had a high non-response rate and did not report adjustments for confounding factors. (Sommariva et al., 2023). Overall, one study was judged to have a high risk of bias, while the remaining three (n=3) raised some concerns. (Table 3).

Discussion

This comprehensive review examined the effectiveness of multiple digital interventions among early-to-late adolescents, young adults, and their parents in increasing HPV vaccination rates and intention. Our findings indicate that digital approaches such as text messages, video content, web-based information, and social media platforms show some effectiveness when used to improve HPV vaccination intention and, to a lesser extent, immunization uptake. These findings broaden the tools available to public health policymakers fighting against this prevalent cause of morbidity worldwide.

The ubiquitous use of smartphones with social

Study	Location	Design	Population	Age	Setting	Ethnicity	Education	Income
Sommariva et al., 2023	Italy	Cross sectional	Parents of adolescents	N/A	N/A	N/A	N/A	N/A
McRee AL et al., 2012	United States	Cross sectional	Parents of adolescents	45 (M)	Urban 50%-81% Rural 19%-50%	Non-latino white 69%-74%, Black 9%-20%, Latino 6%-23%	High School or below 18%-42% At least some college 58%-82%	< 60K 44% > 60K 56% (USD)
Manganello et al., 2023	United States	Cross sectional	Parents of adolescents	N/A	Suburban 55%, Rural 25%, Urban 20%	White 82%, Black 14%, Latino 9%, Asian 4%	High school or below 24%, At least some college 71%, Technical 5%	< 50k 42%, 50-150K 48%, >150K 10% (USD)
Llavona-Ortiz et al., 2022	United States	Cross sectional	Parents of adolescents	18-46 (R)	N/A	Non-Latino white 71%, Black 12%, Latino 11%	High school or below 23%, At least some college 77%	<40K 30%, 40-80K 32%, >80K 34% (USD)
Tull et al., 2019	Australia	RCT	Adolescents	13.19 (M)	N/A	N/A	High school or below 100%	N/A
Szilagyi et al., 2020	United States	RCT	Adolescents	11-18 (R)	Urban 75%-87% Rural 13%-25%	N/A	N/A	N/A
DiClemente et al., 2015	United States	RCT	Adolescents	16.47 (M)	N/A	Black 100%	High school or below 100%	N/A
Hofstetter et al., 2017	United States	RCT	Adolescents	11-17 (R)	N/A	Latino 82% Non-latino Black 13%, white 2%	N/A	N/A
Suzuki et al., 2021	Japan	RCT	Parents of Adolescents	30-59 (R)	N/A	N/A	High school or below 24%, At least some college 76%	Mean = 7.4 Million (JPY)
Pot et al., 2017	Holland	RCT	Parents of adolescents	43.64 (M) 24-62 (R)	N/A	N/A	Low 14%, Middle 43%, High 43%	N/A
Kim et al., 2022	United States	RCT	Parents of adolescents	35.39 (M)	Rural 23%	N/A	No college 14%	<50k 38% (USD)
Shegog et al., 2022	United States	RCT	Parents of adolescents	40.8 (M)	N/A	Non-latino white 56%, Black 13%, Latino 22%, Asian 6%	High School or below 32%, At least some college 62%	N/A
Dixon et al., 2019	United States	RCT	Parents of adolescents	12.2 (M)	N/A	Black 55%. White 9%	N/A	N/A
Panozzo et al., 2020	United States	RCT	Parents of adolescents	Parents: 31-51 (R), Adolescents: 12.4 (M)	N/A	Non-Latino white 82%, Black 9%, Latino 10%	High School or below 19%, At least some college 81%	<50k 37%, 50-100K, 43% >100K 20% (USD)
Rand et al., 2015	United States	RCT	Parents of adolescents	11-16 (R)	Urban 59%, Rural 41%	N/A	N/A	N/A
Reno et al., 2023	United States	RCT	Parents of adolescents, Young adults	Parents: 35.18 (M) Young adults: 23.9 (M)	N/A	Latino 98%	N/A	N/A
Dempsey et al., 2019	United States	RCT	Parents of adolescents, Young adults	Parents: 23 (M) Young adults: 12 (M)	N/A	Parents: Non-Latino white 6%, Latino 93% Young adults: Non-Latino white 12%, Latino 85%	N/A	N/A
Lai et al., 2015	Taiwan	RCT	Adolescents	15.35 (M)	N/A	N/A	Father: High School or below 71%, At least some college 29%. Mother: High School or below 73%, At least some college 27%.	Poor 34%, Average 66%
Si et al., 2022	Republic of China	RCT	Young adults	19.12 (M)	Urban 63%, Rural 37%	Asian, Han 88%	Young adults: At least some college 100%, Parents: High school or below 75%, At least some college 25%	<1K 21%, 1K-2K 71%, >2k 8% (RMB, monthly expenses)
Wang et al., 2021	Republic of China	RCT	Young adults	18-22 (R)	N/A	Asian, Han 100%	At least some college 100%	N/A
Sun et al., 2022	Republic of China	RCT	Young adults	18+ (R)	Urban 69%. Rural 31%	Asian, Han 98%	High School or below 74%, At least some college 26%	<1k 29%, 1k-2k 65%, >2k 6%, (CNY, monthly expenses)
Harper et al., 2023	United States	RCT	Young adults	18-26 (R)	N/A	Latino 39%, Non-Latino, White 60.3%	N/A	N/A
Zhang et al., 2019	Republic of	RCT	Young adults, adolescents	19.83 (M)	N/A	Asian, Han 100%	At least some college 100%	N/A

M = mean; R = range; N/A = missing data.
CNY, RMB = Chinese Yuan; USD = United States Dollars; JPY = Japanese Yen.

Table 1: *Characteristics of the included studies.*

Study	Design	Type of Intervention	Intervention	Results	Risk of Bias
Reno et al., 2023	Randomized Controlled Trial	Web-based Text message	Fear-appeal messages with content about cancer, genital warts, or control with vague HPV content	**Vaccination intention** Parents of adolescents: (B = 0.04, p = 0.73) **Young adults:** (B = 0.17, p = 0.06)	Some Concerns
Kim et al., 2022	Randomized Controlled Trial	Text message on simulated social-media environment	Social-media message countering 5 themes: "side effects, risks"; "distrust of the system"; "effectiveness concerns"; "connection to sexual activity"; "misinformation", and control: "risks associated with vaping cigarettes"	**Change in attitudes**: (t = 3.03, p=0.003) Vaccination intention: correlation with change in attitudes (B = 1.14, p = 0.05)	Some concerns
Shegog et al., 2022	Randomized Controlled Trial	Mobile app Text message	Mobile app designed to provide parent educational contents, and control: standard of care	**Vaccination initiation**: (MD = 6.9, p = 0.24)	Some concerns
Sun et al., 2022	Randomized Controlled Trial	Mobile app text message	Daily mobile phone-based education on HPV, and control with education on COVID-19	**Vaccination intention**: Immediately: (OR = 1.3, p = 0.2) 1 month: (OR = 0.9, p = 0.7) 3 months: **Vaccination rates:** Immediately (OR = 1, p = 0.99) 1 month: (OR = 0.45, p = 0.36) 3 months: (OR = 0.95, p = 0.93)	High
Tull et al., 2019	Randomized Controlled Trial	Text messages	Self regulatory reminder, motivational reminder, and control with no reminder of vaccine appointments	**Vaccination rates** (OR = 1.31, p = 0.01) between SMS groups (OR = 1.07, p = 0.58)	High
Dempsey et al., 2019	Randomized Controlled Trial	Text messages	Tailored messages, untailored messages and control standard of care	**Vaccination rates and vaccination intention:** no differences, data not shown	Some concerns
Hofstetter et al., 2017	Randomized Controlled Trial	Text messages	Educational text message compared to general population control with simple text reminder	**Vaccination rates** General population: (66% higher) Between arms: (OR = 1.73, p = 0.2)	High

Table 2: *Intervention, outcomes, and risk of bias in RCTs.*

Rand et al., 2015	Randomized Controlled Trial	Text messages	Reminders of vaccine appointments compared to control with general adolescent health information	**Vaccination rates**: 1 dose: (HR = 1.3, p = 0.04) 2 doses: (HR = 1.2, p = 0.27) 3 doses: (HR = 1.3, p = 0.43)	High
Szilagyi et al ., 2020	Randomized Controlled Trial	Voice messages	1,2 or 3 calls to remind of HPV vaccine and control with standard of care (no calls)	**Vaccination initiation:** Colorado: 1 call RR = 1.07 (CI 1.04 – 1.10), 2 calls RR = 1.01 (CI 0.98 – 1.04), 3 calls RR = 1.04 (CI 1.01 – 1.06) **Vaccination rates:** (full schedule) not significant (p>0.05) RR not shown	Some concerns
Wang et al., 2021	Randomized Controlled Trial	Web-based	Information on HPV in four arms: interactive data visualization; interactive narratives; static data visualization; static narratives	**Vaccination intention**: Narratives: interactive vs. static (M = 5.51, SD = 1.47, vs. M = 4.72, SD = 1.46) Data visualization: interactive vs. static (M = 4.63, SD = 1.81, vs. M = 5.21, SD = 1.71)	Low
Harper et al., 2023	Randomized Controlled Trial	Web-based	Psychological intervention, online intervention, and control with no intervention	**Vaccination intention**: (F(2, 108) = 2.95, p = .06)	Some concerns
Pot et al., 2017	Randomized Controlled Trial	Web-based	Computer-based interaction with tailored information about the HPV vaccines, and control with standard of care	**Vaccination rates:** (OR = 1.03, p = 0.60)	Some concerns
Diclemente et al., 2015	Randomized Controlled Trial	Video	Computer-delivered video on HPV vaccination and control video on physical activity and nutrition	**Vaccination initiation**: (OR = 1, p = 1.0) **Vaccination rates:** (full) (OR = 1.7, p = 0.12)	Some concerns

Table 2: *(continued) Intervention, outcomes, and risk of bias in RCTs.*

Suzuki et al., 2022	Randomized Controlled Trial	Video	Video of a colon cancer survival testimony compared with Basic information about the benefits and adverse effects of HPV vaccination	**Vaccination intention.**: immediately: (OR = 1.54, p < 0.0001) 3 months: (OR = 1.15, p = 0.45) **Vaccination rates:** 3 months: (OR = 0.9, p = 0.45)	Some concerns
Dixon et a ,l 2019	Randomized Controlled Trial	Video	Videos in tablet at waiting room, and control with standard of care	**Vaccination rates**: (OR = 1.82, p < 0.001).	Low
Panozzo et al., 2020	Randomized Controlled Trial	Video	Video tailored to main concern, or video tailored to all concerns , and control video emphasizing bundled recommendation for HPV vaccination	**Vaccination intentio:** (MD = 5.2, p=0 .01) Between arms (MD = 1.8, p = 0.18)	High
Lai et al., 2015	Randomized Controlled Trial	Social-media	In-class lecture on cervical cancer prevention followed by Facebook-assisted online discussions, and control without access to the online discussions	**Vaccination intention**: Payed vaccine (OR = 1.847, p= .039) Free vaccine (OR=2.531, p = 0.046)	High
Zhang et al., 2019	Randomized Controlled Trial	Social-media Text message	Exposure to different HPV educational content: positive descriptive; negative descriptive; positive narrative; negative narrative	**Narrative comments** increase perceived HPV risk. (B = -0.26, CI=-0.46 – 0.06) **Perceived HPV risk increases vaccination intention:** (B = 0.22, CI= 0.09 – 0.34)	Some Concerns
Si et al., 2022	Randomized Controlled Trial	Social-media Text message	7-day online HPV education program based on information, motivation, behavioral skills (IMB) model-based online intervention, on DingTalk platform, and control with no HPV education	**Vaccination intention**: immediately: (B = 0.32, p < 0.001) 1 month: (B= 0.183,p = 0.01) 3 months: (B= 0.140, p = 0.13)	Some Concerns

HR = Hazard Ratio, OR = Odds Ratio, CI= Confidence Interval, MD= Mean Difference, t = student's t-statistic, p = p-value.

Table 2: *(continued) Intervention, outcomes, and risk of bias in RCTs.*

Study	Design	Exposure and Outcomes measured	Results	Risk of Bias
McRee et al., 2012	Cross-sectional	Parents' vaccination intention (1-5 scale) correlation with internet use as a source of information	Past internet usage by parents of females **Vaccination Intention:** (M = 3.03, b = 0.08, p < 0.05)	Some concerns
Somarriva et al., 2023	Cross-sectional	Parents' vaccination intention correlation with features of digital information	**Vaccination Intention**: Segment 1 (49%)* Segment 2 (46%)* Segment 8 (51%)* Segment 3 (41%)* Segment 4 (50%)* Segment 5 (44%)* Segment 6 (37%)* Segment 7 (39%)* p = 0.033	High
Manganello et al., 2023	Cross-sectional	Parents' vaccination intention correlation with gender, social media usage, bond with physician, political affiliation, region, beliefs, income and education	Vaccine confidence **Vaccination Intention:** (OR = 2.18, p < 0.0001)	Some concerns
Llavona-ortiz	Cross-sectional	Parents vaccination correlation with features of digital information content on social media	Positive content **Vaccination Intention:** (OR = 1.74 , CI = 1.24-2.4)	Some concerns

M = Mean, OR = Adjusted Odds Ratio, MD = Mean difference, p = p-value.

* Segments classified by parental perception of digital feature importance 1 (Highest importance image-high text), 2 (highest image-high source/popularity, 8 (highest image), 3 (highest text) , 4 (highest source), 5 (highest source-high text), 6 (highest text-highest source/popularity), 7 (high popularity-high source).

Table 3: *Exposure, outcomes, and risk of bias in observational studies.*

apps and instant messaging may have made web-based intervention outdated and ineffective as a tool influencing health-related behavior. Our review showed social media was effective in increasing vaccination intention, probably due to its acceptance and mobile availability among adolescents. However, web-based educational programs were not effective in terms of both vaccination intention and uptake in the long term. Multimedia intervention - both video and image - showed some potential in increasing immediate vaccination intention, but this trend did not hold up in the long term and was not effectively translated to vaccination uptake. In addition, socio-economic factors, such as income and education level, could also play a crucial role in vaccination uptake (Manganello et al., 2023).

The observational studies included in our review of traditional SMS text messages showed conflicting results regarding their effectiveness in our study. Although a previous review focusing only on mobile intervention showed better results on vaccination uptake, the inclusion of quasi-experimental studies, restricted ethnicities, ages, and countries limit the validity of these findings (Ilozumba et al., 2021). Our review suggests simple nudging might be as effective as other more elaborated text messages, in line with the results published by Choi et al., 2023.

The observational studies included in our review broadened our understanding of the association between multiple factors with vaccination intention or uptake. Healthcare access and geographic regions, trusted sources of information, and trust in the medical provider are associated with vaccine behavior and decisions (McRee et al., 2012) (Manganello et al., 2023). In addition, specific internet usage patterns, engagement with social media content, and peer influence, especially how information is framed and shared, are also important factors to be considered when analyzing immunization behaviors (Sommariva et al., 2023; McRee et al., 2012). Finally, the cross-sectional studies listed a variety of confounders, highlighting the multifaceted nature of vaccination decision-making and the wide range of factors to be considered before considering public health policies aimed at vaccination uptake and intention. One interesting strategy to address these issues could be the one used by Dixon et al., 2019, offering the video intervention in a setting with readily available vaccines, such as in the health facility waiting room, substantially improving HPV immunization rates.

The strengths of this review are the large sample size and representativeness: a total of 100,117 participants in RCTs and 2,648 in observational studies. In addition, a variety of world regions and ethnicities were included despite the strict language criteria. Excluding experimental designs that were not designed as RCTs gave additional robustness to our results. Furthermore, the inclusion of cross-sectional studies provided new insights into content features that may be associated with digital intervention effectiveness.

There were some limitations to our study. Several articles measured only vaccination intention, which is known to be biased by the questionnaire measuring this outcome (Fishman et al., 2024). Moreover, intention did not entirely translate into increased vaccination rates. Only a few studies included reported previous HPV vaccination rates and knowledge, which could clearly influence HPV intention or uptake outcomes. Finally, gaming intervention was not included in the search strategy of our systematic review, and it could be explored in future research.

The reviewed studies share common limitations that are potential sources of bias leading to effect size overestimation – lack of blinding and high attrition rates –or underestimation – small sample sizes and short-term follow-ups. In addition, limitations to the external validity could arise from the exclusively female population and homogeneous middle to upper-middle-class economic backgrounds in some studies. It remains unclear whether digital media would have a different effect on these underrepresented populations.

Future research should aim to overcome these limitations with a diverse socio-economic and ethnic representation, strategies for long-term behavioral change, and effective translation from intention into HPV vaccination uptake.

Conclusion

Digital interventions have shown some potential in increasing HPV vaccination intention, influencing vaccination rates to a lesser extent. However, low-income countries and male patients were not extensively studied. Policies and funding should be directed to research focusing on these populations, not just as a matter of equity but also of public health necessity, given the high burden of HPV-related diseases in these groups.

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Supplementary Materials

Search strategy

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Conflicts of Interest

The authors declare no conflict of interest.

References

Choi, J., Tamí-Maury, I., Cuccaro, P., Kim, S., & Markham, C. (2023). *Digital Health Interventions to Improve Adolescent HPV Vaccination: A Systematic Review*. Vaccines, 12(2), 249. https://doi.org/10.3390/vaccines11020249

Dempsey, A. F., Maertens, J., Sevick, C., Jimenez-Zambrano, A., & Juarez-Colunga, E. (2019). *A randomized, controlled, pragmatic trial of an iPad-based, tailored messaging intervention to increase human papillomavirus vaccination among Latinos*. Human Vaccines & Immunotherapeutics, 15(7–8), 1577–1584. https://doi.org/10.1080/21645515.2018.1559685

DiClemente, R. J., Murray, C. C., Graham, T., & Still, J. (2015). *Overcoming barriers to HPV vaccination: A randomized clinical trial of a culturally-tailored, media intervention among African American girls*. Human Vaccines & Immunotherapeutics, 11(12), 2883–2894. https://doi.org/10.1080/21645515.2015.1070996

Dixon, B. E., Zimet, G. D., Xiao, S., Tu, W., Lindsay, B., Church, A., & Downs, S. M. (2019). *An Educational Intervention to Improve HPV Vaccination: A Cluster Randomized Trial*. Pediatrics, 143(1), e20181457. https://doi.org/10.1542/peds.2018-1457

Dorji, T., Nopsopon, T., Tamang, S. T., & Pongpirul, K. (2021). *Human papillomavirus vaccination uptake in low-and middle-income countries: A meta-analysis*. eClinicalMedicine, 34. https://doi.org/10.1016/j.eclinm.2021.100836

Dykens, J. A., Peterson, C. E., Holt, H. K., & Harper, D. M. (2023). *Gender neutral HPV vaccination programs: Reconsidering policies to expand cancer prevention globally*. Frontiers in Public Health, 11, 1067299. https://doi.org/10.3389/fpubh.2023.1067299

Fishman, J., Schaefer, K. A., Scheitrum, D., Robertson, C. T., & Albarracin, D. (2024). *Common measures of vaccination intention generate substantially different estimates that can reduce predictive validity*. Scientific Reports, 14(1), 22843. https://doi.org/10.1038/s41598-024-69129-5

Harper, K., Short, M. B., Bistricky, S., & Kusters, I. S. (2023). *1-2-3! Catch-Up for HPV: A Theoretically Informed Pilot Intervention to Increase HPV Vaccine Uptake among Young Adults*. American Journal of Health Education, 54(2), 119–134. https://doi.org/10.1080/19325037.2022.2163005

Hofstetter, A. M., Barrett, A., Camargo, S., Rosenthal, S. L., & Stockwell, M. S. (2017). *Text message reminders for vaccination of adolescents with chronic medical conditions: A randomized clinical trial*. Vaccine, 35(35 Pt B), 4554–4560. https://doi.org/10.1016/j.vaccine.2017.07.022

Ilozumba, O., Schmidt, P., Ket, J. C. F., & Jaspers, M. (2021). *Can mHealth interventions contribute to increased HPV vaccination uptake? A systematic review*. Preventive Medicine Reports, 21, 101289. https://doi.org/10.1016/j.pmedr.2020.101289

Kim, S. J., Schiffelbein, J. E., Imset, I., & Olson, A. L. (2022). *Countering Antivax Misinformation via Social Media: Message-Testing Randomized Experiment for Human Papillomavirus Vaccination Uptake*. Journal of Medical Internet Research, 24(11), e37559. https://doi.org/10.2196/37559

Lai, C.-Y., Wu, W.-W., Tsai, S.-Y., Cheng, S.-F., Lin, K.-C., & Liang, S.-Y. (2015). *The Effectiveness of a Facebook-Assisted Teaching Method on Knowledge and Attitudes About Cervical Cancer Prevention and HPV Vaccination Intention Among Female Adolescent Students in Taiwan*. Health Education and Behavior, 42(3), 352–360. https://doi.org/10.1177/1090198114558591

Lei, J., Ploner, A., Elfström, K. M., Wang, J., Roth, A., Fang, F., Sundström, K., Dillner, J., & Sparén, P. (2020). *HPV Vaccination and the Risk of Invasive Cervical Cancer*. New England Journal of Medicine, 383(14), 1340–1348. https://doi.org/10.1056/NEJMoa1917338

Llavona-Ortiz, J. Y., Spanos, K. E., Kraschnewski, J. L., D'Souza, G., Myrick, J. G., Sznajder, K. K., & Calo, W. A. (2022). *Associations Between Human Papillomavirus Vaccine Decisions and Exposure to Vaccine Information in Social Media*. Cancer Control, 29, 10732748221138404. https://doi.org/10.1177/10732748221138404

Manganello, J. A., Chiang, S. C., Cowlin, H., Kearney, M. D., & Massey, P. M. (2023). *HPV and COVID-19*

vaccines: Social media use, confidence, and intentions among parents living in different community types in the United States. Journal of Behavioral Medicine, 46(1–2), 212–228. https://doi.org/10.1007/s10865-022-00316-3

Martel, C. de, Georges, D., Bray, F., Ferlay, J., & Clifford, G. M. (2020). *Global burden of cancer attributable to infections in 2018: A worldwide incidence analysis*. The Lancet Global Health, 8(2), e180–e190. https://doi.org/10.1016/S2214-109X(19)30488-7

McRee, A. L., Reiter, P. L., & Brewer, N. T. (2012). *Parents' Internet use for information about HPV vaccine*. Vaccine, 30(25), 3757–3762. https://doi.org/10.1016/j.vaccine.2011.11.113

Ortiz, R. R., Shafer, A., Cates, J., & Coyne-Beasley, T. (2018). *Development and Evaluation of a Social Media Health Intervention to Improve Adolescents' Knowledge About and Vaccination Against the Human Papillomavirus*. Global Pediatric Health, 5, 2333794X18777918. https://doi.org/10.1177/2333794X18777918

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). *The PRISMA 2020 statement: An updated guideline for reporting systematic reviews*. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

Panozzo, C. A., Head, K. J., Kornides, M. L., Feemster, K. A., & Zimet, G. D. (2020). *Tailored Messages Addressing Human Papillomavirus Vaccination Concerns Improves Behavioral Intent Among Mothers: A Randomized Controlled Trial*. The Journal of Adolescent Health, 67(2), 253–261. https://doi.org/10.1016/j.jadohealth.2020.01.024

Patra, J., Bhatia, M., Suraweera, W., Morris, S. K., Patra, C., Gupta, P. C., & Jha, P. (2015). *Exposure to Second-Hand Smoke and the Risk of Tuberculosis in Children and Adults: A Systematic Review and Meta-Analysis of 18 Observational Studies*. PLOS Medicine, 12(6), e1001835. https://doi.org/10.1371/journal.pmed.1001835

Pimple, S., & Mishra, G. (2022). *Cancer cervix: Epidemiology and disease burden*. CytoJournal, 19, 21. https://doi.org/10.25259/CMAS_03_02_2021

Pot, M., Paulussen, T. G., Ruiter, R. A., Eekhout, I., de Melker, H. E., Spoelstra, M. E., & van Keulen, H. M. (2017). *Effectiveness of a Web-Based Tailored Intervention With Virtual Assistants Promoting the Acceptability of HPV Vaccination Among Mothers of Invited Girls: Randomized Controlled Trial*. Journal of Medical Internet Research, 19(9), e312. https://doi.org/10.2196/jmir.7449

Rand, C. M., Brill, H., Albertin, C., Humiston, S. G., Schaffer, S., Shone, L. P., Blumkin, A. K., & Szilagyi, P. G. (2015). *Effectiveness of centralized text message reminders on human papillomavirus immunization coverage for publicly insured adolescents*. The Journal of Adolescent Health, 56(5 Suppl), S17–S20. https://doi.org/10.1016/j.jadohealth.2014.10.273

Reno, J. E., & Dempsey, A. F. (2023). *Promoting HPV vaccination among Latinx: An application of the extended parallel processing model*. Journal of Behavioral Medicine, 46(1–2), Article 1–2. https://doi.org/10.1007/s10865-022-00293-7

Shegog, R., Savas, L. S., Healy, C. M., Frost, E. L., Coan, S. P., Gabay, E. K., Preston, S. M., Spinner, S. W., Wilbur, M., Becker, E., Teague, T., & Vernon, S. W. (2022). *AVPCancerFree: Impact of a digital behavior change intervention on parental HPV vaccine-related perceptions and behaviors*. Human Vaccines & Immunotherapeutics, 18(5), 2087430. https://doi.org/10.1080/21645515.2022.2087430

Si, M., Su, X., Jiang, Y., Wang, W., Zhang, X., Gu, X., Ma, L., Li, J., Zhang, S., Ren, Z., Liu, Y., & Qiao, Y. (2022). *An Internet-Based Education Program for Human Papillomavirus Vaccination Among Female College Students in Mainland China: Application of the Information-Motivation-Behavioral Skills Model in a Cluster Randomized Trial*. Journal of Medical Internet Research, 24(9), e37848. https://doi.org/10.2196/37848

Sommariva, S., Beckstead, J., Khaliq, M., Daley, E., & Martinez Tyson, D. (2023). *An approach to targeted promotion of HPV vaccination based on parental preferences for social media content*. Journal of Social Marketing, 13(3), 341–360. https://doi.org/10.1108/JSOCM-08-2022-0164

Spayne, J., & Hesketh, T. (2021). *Estimate of global human papillomavirus vaccination coverage: Analysis of country-level indicators*. BMJ Open, 11(9), e052016. https://doi.org/10.1136/bmjopen-2021-052016

Stellefson, M., Paige, S. R., Chaney, B. H., &

Chaney, J. D. (2020). *Evolving Role of Social Media in Health Promotion: Updated Responsibilities for Health Education Specialists*. International Journal of Environmental Research and Public Health, 17(4), 1153. https://doi.org/10.3390/ijerph17041153

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H.-Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. P. T. (2019). *RoB 2: A revised tool for assessing risk of bias in randomised trials*. BMJ, 366, l4898. https://doi.org/10.1136/bmj.l4898

Sun, L., Hu, J., Gao, H., Wang, S., Wang, B., Wang, J., Li, H., Wang, J., Yuan, C., & Zhang, X. (2022). *Long-term effect of mobile phone-based education and influencing factors of willingness to receive HPV vaccination among female freshmen in Shanxi Province, China*. Human Vaccines & Immunotherapeutics, 18(5), 2051990. https://doi.org/10.1080/21645515.2022.2051990

Suzuki, Y., Sukegawa, A., Ueda, Y., Sekine, M., Enomoto, T., & Miyagi, E. (2021). *Effect of a Brief Web-Based Educational Intervention on Willingness to Consider Human Papillomavirus Vaccination for Children in Japan: Randomized Controlled Trial*. Journal of Medical Internet Research, 23(9), e28355. https://doi.org/10.2196/28355

Szilagyi, P., Albertin, C., Gurfinkel, D., Beaty, B., Zhou, X., Vangala, S., Rice, J., Campbell, J. D., Whittington, M. D., Valderrama, R., Breck, A., Roth, H., Meldrum, M., Tseng, C.-H., Rand, C., Humiston, S. G., Schaffer, S., & Kempe, A. (2020). *Effect of State Immunization Information System Centralized Reminder and Recall on HPV Vaccination Rates*. Pediatrics, 145(5), e20192689. https://doi.org/10.1542/peds.2019-2689

Tull, F., Borg, K., Knott, C., Beasley, M., Halliday, J., Faulkner, N., Sutton, K., & Bragge, P. (2019). *Short Message Service Reminders to Parents for Increasing Adolescent Human Papillomavirus Vaccination Rates in a Secondary School Vaccine Program: A Randomized Control Trial*. The Journal of Adolescent Health, 65(1), 116–123. https://doi.org/10.1016/j.jadohealth.2018.12.026

Veritas, H. I. (n.d.). *Covidence systematic review software* [Computer software]. www.covidence.org

Wang, Q., & Zhang, W. (2021). *The use of Web-based interactive technology to promote HPV vaccine uptake among young females: A randomized controlled trial*. BMC Women's Health, 21(1), 277. https://doi.org/10.1186/s12905-021-01417-y

Wells, G., Wells, G., Shea, B., Shea, B., O'Connell, D., Peterson, J., Welch, V., Losos, M., Tugwell, P., Ga, S. W., Zello, G., & Petersen, J. (2014). *The Newcastle-Ottawa Scale (NOS) for Assessing the Quality of Nonrandomised Studies in Meta-Analyses*. https://www.semanticscholar.org/paper/The-Newcastle-Ottawa-Scale-(NOS)-for-Assessing-the-Wells-Wells/c293fb316b6176154c3fdbb8340a107d9c8c82bf

World Health Organization. Electronic address: sageexecsec@who.int (2017). *Human papillomavirus vaccines: WHO position paper, May 2017-Recommendations*. Vaccine, 35(43), 5753–5755. https://doi.org/10.1016/j.vaccine.2017.05.069

WHO, W. H. O. (2023, October 24). *Classification of digital interventions, services and applications in health: A shared language to describe the uses of digital technology for health* (2nd ed.). https://www.who.int/publications/i/item/9789240081949

Zhang, W., & Wang, Q. (2019). *The failure of news coverage supportive of human papillomavirus vaccination: The investigation of the effects of online comments on female college students' vaccination intention*. Vaccine, 37(38), 5681–5687. https://doi.org/10.1016/j.vaccine.2019.08.007