A Scoping Review of Interventions Supporting Human Papillomavirus (HPV) Vaccination Rates, Knowledge, and Confidence in a Post-COVID-19 US Landscape

Morgan Bergerud

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Public Health

University of Washington

2024

Committee:

Nora B. Henrikson

Molly B. Firth

Program Authorized to Offer Degree:

Public Health, Health Systems and Population Health

University of Washington

Abstract

A Scoping Review of Interventions Supporting Human Papillomavirus (HPV) Vaccination Rates, Knowledge, and Confidence in a Post-COVID-19 US Landscape

Morgan Bergerud

Chair of the Supervisory Committee:

Nora B. Henrikson

Department of Health Systems and Population Health

Objective: The objective of this scoping review is to understand the extent and type of evidence available for interventions aiming to increase Human Papillomavirus (HPV) vaccination rates, knowledge, or confidence since the COVID-19 pandemic.

Introduction: Since the COVID-19 pandemic, childhood vaccination rates have decreased in the United States (US) and exemptions have risen. HPV vaccination coverage varied widely even before the pandemic, with rates falling behind those of other childhood immunizations despite the HPV vaccine's higher efficacy when administered at a younger age. It is unclear how vaccine hesitancy and misinformation during the COVID-19 pandemic has impacted acceptance and uptake for other immunizations like the HPV vaccine, making it imperative to re-evaluate what interventions are successful in this new context.

Methods: A search of English records in the PubMed database was conducted in March 2024 guided by scoping review methodology from the Joanna Briggs Institute. Studies using experimental or quasi-experimental methods to evaluate interventions aimed at increasing HPV vaccination rates, knowledge or confidence were included. Only studies with intervention dates including or after January 1, 2021, were included due to the interest in those published during and after the COVID-19

pandemic. Studies with interventions aimed at individuals 9-26 or parents or clinical providers of these individuals were included.

Results: A total of 1,110 publications were screened at the title and abstract level with 10 identified for inclusion. Four studies (five publications) included educational interventions to individuals or parents of individuals eligible for the HPV vaccine, and two included vaccination reminders to this population. Three studies evaluated interventions at the provider or clinic level, and one at the community level. Consistent with data prior to the COVID-19 pandemic, educational interventions at the individual level are successful at increasing HPV vaccination, knowledge, and confidence when tailored to a specific group whether by culture, race or ethnicity, or sexual orientation. The success of interventions at the community or provider level is mixed.

Conclusions: There is a lack of experimental evidence describing interventions to increase HPV vaccination rates, knowledge, and confidence since the onset of the COVID-19 pandemic, especially at the interpersonal and policy levels. Individual level educational interventions have remained successful at increasing HPV vaccination rates, knowledge and confidence when tailored to a specific group, while the success of interventions at the organizational and community levels is mixed regardless of intervention components. Further evaluation is needed to better understand what efforts to increase HPV vaccination rates and determinants are still successful after the pandemic.

Contents

Introduction

Human Papillomavirus (HPV) is the most common sexually transmitted infection in the United States and is estimated to be responsible for over 630,000 cases of cancer each year, representing 4.5-5.2% of global cancers.[1] While most commonly associated with cervical, vulvar and vaginal cancers, it can also lead to cancer of the throat, anus and penis.[2] While 11.5% of US teens reported HPV infections between 2003 and 2006, this dropped to just 1.1% between 2015-2018 due to a highly effective and available vaccine.[3] The Centers for Disease Control and Prevention (CDC) has recommended the HPV vaccine since 2006 for girls starting at age 11, and since 2011 for boys. The vaccine series can be administered as early as age 9 and is recommended for anyone through age 26, after which vaccination should be discussed with a clinician.[4] HPV vaccination has even been adopted into the World Health Organization's (WHO) global strategy for 2030, aiming for 90% vaccination of girls aged 15 to lead to the ultimate elimination of cervical cancer.[5]

Despite these recommendations, the 2022 National Teen Immunization Survey reported that only 76% of teens aged 13-17 had received one or more HPV vaccination doses, compared to 89.9% for >1 dose against Tdap and 88.6% against Meningococcal bacteria.[6] Though these vaccines are all recommended for children aged 11-12 years, there is a large discrepancy in HPV vaccination coverage even though it is especially important to issue the HPV vaccine at a young age. A 2023 review of the vaccine's effectiveness by age identified that when administered between 9-14-years-old the HPV vaccine has effectiveness between 74%-93%, dropping to 12%-90% when administered between 15-18.[7] HPV vaccination coverage varies widely within the US, with the rate of vaccination in the top 5 covered states ranging from 74.4%-85.2% and the lowest 5 states between 38.5% - 54.4%. Encouraging early and complete vaccination against HPV is key to achieving successful protection in US young adults and bridging these gaps.

Vaccine hesitancy is a key determinant of vaccination uptake and has been listed as a top 10 public health threat by the WHO since 2019.[8] The COVID-19 pandemic is believed to have increased anti-vaccine sentiment and misinformed fears about vaccine safety broadly. Assessment of COVID-19 vaccine hesitancy is varied due to the difficulty of assessing this type of behavior. Some surveys assessing trust in the COVID-19 vaccine showed decreases in hesitancy as the pandemic continued, though uptake of the vaccine among pediatric individuals 12-17 years was slow and plateaued early after approval.[9,10] Importantly, the COVID-19 pandemic resulted in declined kindergarten vaccination coverage for the first time in 10 years, with coverage not fully returning by the 2022-2023 school year. During the same school year, exemption requests for childhood vaccine requirements rose in 41 states to the highest rates ever reported in the US.[11]

Though the HPV vaccine is not required vaccine for school entry in most US states, these indications of decreased compliance with childhood vaccination schedules is concerning for its potential effect on sentiment for other vaccines. 2022 marked the first year since 2013 where HPV vaccination initiation did not increase among 13-17 year olds, which could be indicative of increased hesitancy toward the HPV vaccine coupled with vaccination disruptions due to pandemic shutdowns.[6] The 2021 National Immunization Survey (NIS) evaluating HPV vaccine sentiment reported a 200% increase in the proportion of parents citing safety concerns as reasoning for not vaccinating, despite decreases in adverse events reported in the Vaccine Adverse Event Reporting System (VAERS), establishing a growing need to instil confidence and increase HPV education.[12]

A 2023 review of studies examining the relationship between COVID-19 and HPV vaccine hesitancy found some evidence of correlation between vaccination beliefs and intentions about each disease, but the impact of increased vaccine misinformation due to COVID-19 on the uptake of other vaccinations remains unclear.[13] This presents new and complicated challenges to increasing HPV vaccination rates - a vaccine with already lower uptake than other recommended childhood vaccines - as it is not clear how the COVID-19 pandemic has impacted the efficacy of interventions that were previously successful. Further examination is needed to provide the full landscape of programs and services that contribute to successful increases in HPV vaccination rates in the US in the current landscape.

This thesis and scoping review will identify interventions attempting to increase HPV vaccination rates, knowledge, or confidence in US states since the onset of the COVID-19 pandemic that have been evaluated using experimental and quasi-experimental methods. We expect experimental evidence for interventions since the pandemic to be limited, with previously successful interventions

potentially decreasing in effectiveness due to increased vaccine hesitancy. This landscape will provide new implications for furthering HPV vaccination in US states in a time where vaccine misinformation and hesitancy play a negative role.

A scoping review aims to identify and map the evidence available in the peer-reviewed literature for a specific topic, often to identify gaps in this evidence. This can provide key concepts relating to a topic of choice and provide direction for future research.[14] As the primary goal of this review to establish a landscape of the existing experimental evidence on HPV vaccination interventions since the COVID-19 pandemic, this methodology was chosen over a systematic review. We performed a preliminary review of PubMed and did not identify any current systematic or scoping reviews on this topic.

This study was reviewed by the Human Subjects Division at the University of Washington and determined exempt from IRB review.

Scoping review question

As described above, the full impact of COVID-19 vaccine hesitancy and misinformation on sentiment and uptake of other vaccinations remains unclear. Due to this uncertainty, it is imperative to evaluate new interventions aimed at increasing vaccination uptake and/or to reevaluate previously successful interventions to determine if the pandemic has impacted their success at increasing HPV vaccination and its determinants in the US.

Thus, the main research question guiding the scoping review was: *Since the COVID-19 pandemic, what experimental or quasi-experimental evidence is available regarding interventions to increase HPV vaccination rates, knowledge, or confidence in the US?* The objective of the scoping review is to identify this evidence to describe what types of interventions and populations have been studied in the post-COVID-19 context.

Eligibility criteria

Eligibility criteria for the scoping review is presented in Table 1 and outlined below.

The primary population of interest is youth between the ages of 9-26 of any gender who are eligible for the HPV vaccine. Those eligible for the HPV vaccine are youth who have not received any doses of the HPV vaccine, or those who have received one or more doses of the vaccine but have not completed the vaccine series. We chose this age group to coincide with CDC recommendations for the HPV vaccination, as the series is recommended for initial administration between ages 9 and 11 and can continue without clinical input until age 26. Secondarily, studies with interventions focused on medical providers or parents of the primary population were also included due to the direct connection with HPV vaccination in this population.

For this scoping review, we considered both experimental and quasi-experimental study designs including randomized controlled trials, non-randomized controlled trials, and interrupted time-series studies. Studies were included only if HPV vaccination rates were measured directly, or if determinants of HPV vaccination such as knowledge and confidence were collected using quantitative methods. Studies using only qualitative survey methods or interviews were excluded.

The presence of a controlled comparison group was required for inclusion due to the many health determinants that can impact vaccination rates and are difficult to control for. Thus, studies using only pre-post within-subjects analysis were excluded while interrupted time series analyses were included due to their substantially larger sample sizes and frequency of outcome measurement.

Table 1: Inclusion and exclusion criteria		
Criteria	**Inclusion**	**Exclusion**
Setting	United States	Any population outside the contiguous United States, including territories
Time Period	Intervention dates including or after January 1, 2021	Studies with intervention dates prior to January 1, 2021
Population	Individuals aged 9-26 eligible for the HPV vaccine, OR Parents or clinical providers of individuals aged 9-26 eligible for the HPV vaccine	Studies *only including* Individuals (or providers/parents of) younger than 9 or older than 26, or individuals ineligible for the HPV vaccine
Language	Studies published in English	Studies not published in English
Concept	Interventional studies with a comparison group assessing the impact of any specific program or policy or any of the following outcomes: - HPV vaccination rates - HPV vaccination knowledge (measured quantitatively) - HPV vaccination hesitancy (measured quantitatively)	Review articles, case studies and editorials Articles evaluating vaccine efficacy or only reporting on current vaccination rates (*i.e. not evaluating the impact of a program or policy on vaccination rates, knowledge, or hesitancy)*

Methods

Search Strategy

The scoping review was conducted with methodological guidance from the Joanna Briggs Institute manual for scoping reviews.[15] We conducted a preliminary search in PubMed to identify important key words and MeSH terms for articles related to the research question. After the initial searches, we consulted with a librarian with the Health Sciences Library at the University of Washington for guidance on search terms and input on how to capture studies limited to the US setting. The definitive search was carried out in PubMed on March 31st, 2024. Keywords used in the search included 'Human Papillomavirus' or 'HPV'; 'Vaccination' or 'Vaccine'; and MeSH indexing terms 'Immunization' or 'Papillomavirus Vaccines.' Due to the initially high yield, we used additional terms to limit results to the US setting. These included keywords 'US' or 'USA', MeSH term 'United States' or any mention of either a US state name (Alabama, Alaska, Arizona, etc.) or region (Appalachian, Northwestern, etc.). Finally, we limited the search to articles published on or after January 1, 2020,

due to the interest in the post-COVID-19 timeframe and to allow for retroactive inclusion of studies with interventions between January 1-December 31, 2020, in the case that no evidence was available for interventions after January 1, 2021.

The results of the initial search were screened at the title and abstract level. Next, full text articles were reviewed for eligibility using the established criteria. We completed this process using Covidence software for systematic reviews.[16] Any indecision on individual citation eligibility was resolved through consultation with the thesis committee chair.

Data Abstraction and Analysis

We reviewed included publications using a data abstraction form to identify critical data elements for answering the scoping review question and objectives. This process was iterative, and any additional elements discovered necessary during the abstraction process were added to the form and then retroactively extracted from previously reviewed articles.

Abstracted data included authors, year of publication and state; Intervention details including components, length, setting, level, and comparison group; methods including study design and length of follow up; population type and demographics; and reported outcomes. Abstracted outcomes centered on findings related to HPV vaccination rates, knowledge, or confidence/hesitancy. Authors were not contacted for missing information due to the timeline of the project.

Evidence is summarized by intervention level and type and displayed in an overview table (Table 2). Interventions identified are also displayed in a visual evidence map (Figure 2).

Results

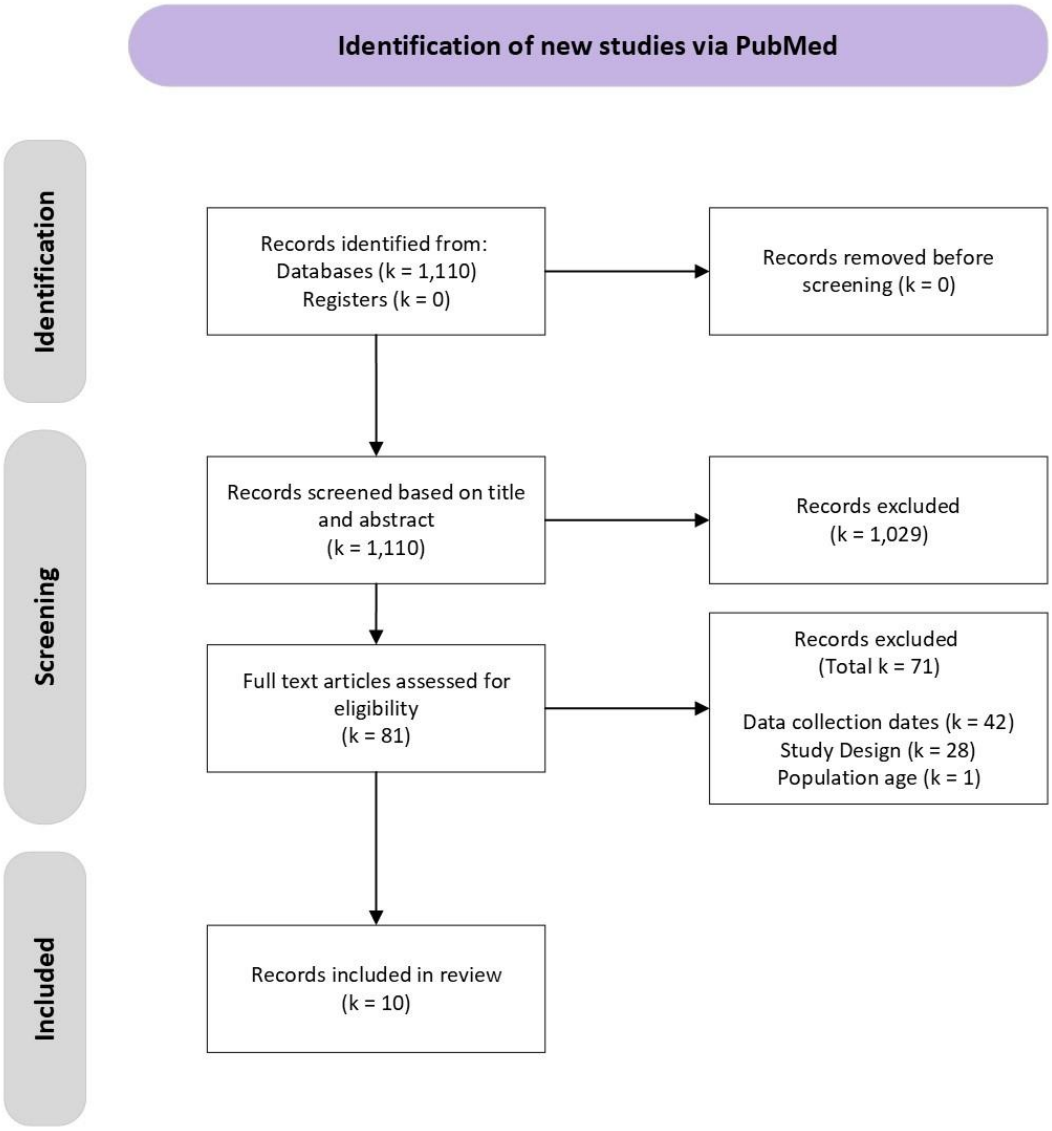

Figure 1: *Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of studies reviewed.*

Overview

As displayed in Figure 1, the final search yielded 1,110 unique records for screening. Most records excluded during title and abstract screening were eliminated due to qualitative methods or for topics related to the HPV vaccine itself rather than interventions to increase vaccination rates, knowledge, or confidence. During full text review of the remaining 81 records, 42 records were excluded due to unreported intervention dates or dates prior to January 1, 2021. A further 28 studies were excluded due to study design and one study was excluded due to the age of evaluated population. This resulted in 10 included publications from 9 distinct studies.

Table 2 displays an overview of included studies. Most studies had intervention dates between 2020 and 2022,[17–25] with the exception implementing the ongoing intervention in January 2023.[26] The

majority (seven studies from eight publications) used randomized controlled methods, with two using interrupted time series analyses. Samples ranged from 63 to 49,403 with all but one study including individuals (or parents and providers of) of some subset of ages between 9-26. The remaining study included mothers aged 22 to 68 but also evaluated HPV-vaccine eligible children under age 12, so it was included. Seven studies were performed in five US states, with the remaining three papers from two studies drawing from multiple locations in the country.

Studies with individual level interventions tended to limit enrollment to a specific nationality or racial/ethnic group. Two used culturally tailored educational interventions focused on Black mothers and Somali women or mothers, respectively, while another two papers from one study limited enrollment to a specific sexual orientation group.[18,19,24,25] The remaining six studies did not limit enrollment by gender, sexual orientation or race or ethnicity. Few studies (three papers from two studies) involved multiple-component interventions, one evaluating education coupled with individual reminders and the other evaluating provider training with clinic vaccination feedback.[21,24,25]

Much of the evidence identified in this scoping review notes impacts of COVID-19 on study design, implementation and/or analysis. Four studies report difficulties with intervention implementation, including changing study settings to virtual and patient reports of difficulty scheduling appointments due to limited availability or staff shortages during the pandemic.[17–19,22] In one case, the shift to a virtual setting was positive, increasing the original study scope to reach more participants.[18] Two studies (three publications) report changes to study design due to the pandemic, in both cases consisting of an extended study pause during the height of the pandemic response. In one of these studies, the pause period occurred between the pre and post assessment for both arms, while in the other the paused period was adapted to become the baseline for this sub-study analysis under a larger parent-study.[22,24,25] Finally, two studies note effects of the COVID-19 pandemic on data analysis. In one case, regressions for the interrupted time series analysis omitted data prior to 2021 due to the significant impact of COVID-19 on vaccination patterns during the 2020 year. The authors note a large decline in vaccinations during early 2020, likely due to pandemic closures of schools and clinics.[26] In the second case, authors note that baseline rates of vaccination may be artificially low due to effects of the pandemic, artificially inflating the intervention's success.[21]

Table 2: Overview of publications included in scoping review

Author and Year	State	Study Dates	Population	Intervention Components	Intervention Level	Study Design	HPV Outcome Measures	Key Results	COVID-19 Impacts or Barriers
Cataldi 2024	Colorado	Late 2019-Nov 2021	n=49,403 Individuals 11-17	County-level implementation of vaccine promotional materials and assistance with distribution strategies after community involved design input	Community	2 Arm Cluster Randomized	HPV Vaccine Series Initiation Up to Date Status on HPV Series for Age	No significant difference among 11–12-year-olds. Significant increase in initiation and up to date status among 13–17-year-olds in both intervention and control, but no significant differences between groups	Planned meetings moved to virtual setting Vaccination messaging may not have adequately addressed new and changing parental concerns as the pandemic continued
Christensen 2023	Washington	Jan 2023 - (ongoing)	n = NR Individuals 9 or 11	Immunization information system update to recommend HPV vaccine at age 9 instead of 11	Organizational	Seasonally Adjusted ITS	HPV Vaccine Series Initiation at age 9 HPV Vaccine Series Initiation at age 11	Weekly rate of HPV initiations at age 9 increased by 97% after controlling for seasonality and underlying weekly trends	Regressions excluded data prior to 2021 due to impacts of pandemic on HPV vaccination patterns during 2020
Dike 2023	Multiple (primarily Texas)	No dates listed*	n = 63 Black mothers with children 9-17	Culturally tailored virtual education session on the importance of HPV vaccination	Individual	2 Arm Randomized	HPV Vaccine Confidence, via: Vaccination Confidence Scale (VCS) Carolina HPV Immunization Attitudes and Beliefs Scale (CHIAS)	Significant difference between intervention and control for both scales immediately post intervention, and significant difference at 4 weeks only on CHIAS	Shift to virtual setting broadened study scope and created opportunity to expand study reach to further participants
Ghebrendrias 2023	California	June 2021-Feb 2022	n = 65 Somali women and mothers	Somali translated cervical cancer screening toolkit including an infographic, video and in-person health seminar	Individual	2 Arm Randomized	Completion of PAP Testing Receipt of HPV Vaccination Dose (Self or Child, Inclusive)	Significant increase in PAP test completion. No significant difference in HPV vaccination for self or child	Participants reported difficulty scheduling preventative health appointments, affecting ability to receive HPV vaccination and PAP smears Participants also reported additional time strain due to home schooling during the pandemic
Khan 2023	California	April - Sep 2021	n = 7411 Individuals 18-26	Secure electronic vaccination reminder followed by either a second, personalized electronic message or personalized printed letter	Individual	3 Arm Randomized	Receipt of HPV Vaccination Dose Within 3 Months of Initial Message	Significant difference in vaccination receipt for group receiving mailed letter. Receipt of personalized EMR message not significantly different than control (p=0.051)	Authors note that the pandemic may have affected patient willingness to attend an in-person appointment for HPV vaccination

Meadows 2024	Texas	May - July 2022	n = 446478, 15680 (pre-, post-intervention) Individuals 9-26 seen at any of 40 participating community health clinics and 1 main hospital	Provider HPV communication training and clinic-level HPV vaccine uptake feedback	Organizational	Seasonally Adjusted ITS	HPV Vaccination Prevalence	No significant changes in vaccination prevalence	Authors note that 'catch up' period of increased vaccinations after low rates during pandemic shutdowns may artificially inflate effectiveness of the intervention
Rand 2023	Various	July 2021-Jan 2022	n = 220 Individuals 11-17 treated by clinicians at 48 participating practices	Provider and clinic-level training on implementation of physical and EMR based vaccination prompts	Organizational	2 Arm Cluster Randomized	HPV Vaccination Missed Opportunities	Increased missed vaccination opportunities in both intervention and control groups during intervention period. At subsequent visits, missed opportunities increased by 4.5 pp less in intervention than control (not significant)	Parent study of this intervention put on pause for 1 year due to pandemic shutdowns, resulting in changes to study design for this intervention Clinics reported understaffing due to pandemic, making them unable to adequately consider the HPV vaccine for each patient Changing burden of work at clinics during the Omicron wave of the pandemic and the approval of the COVID-19 vaccine for ages 5-11 shifted clinic priorities away from HPV vaccination
Redd 2024	Not listed (presumably Utah)	April - June 2022	n = 1241 Christian parents of children under 11	Religious and scientifically focused educational videos about HPV vaccination	Individual	3 Arm Randomized	Intent to Vaccinate for HPV HPV Vaccine Hesitancy due to Culture or Safe Sex Beliefs HPV Knowledge	Significant increase in HPV knowledge for both videos. Significant increase in intent to vaccinate among whole study population and subset of vaccine hesitant participants for both videos, with larger effect from religiously tailored video. Religious video significantly lowered beliefs that safe sex culture warranted not vaccinating.	None reported

Reiter 2022	Multiple	Oct 2019 - June 2021^	n = 1227 Men who have sex with men, aged 18-25	Population targeted "Outsmart HPV" educational content followed by vaccination reminders	Individual	3 arm randomized, analyzed as 2 arm randomized	HPV Knowledge HPV Attitudes and Beliefs	Significant increase in HPV knowledge for 5 of 7 survey questions. Significant decrease in belief that participant didn't have enough information to make a vaccination decision.	Study put on pause from March - August 2020 due to pandemic, with this period becoming the baseline for intervention comparison
Reiter 2023	Multiple	Oct 2019 - June 2021^	n = 1227 Men who have sex with men, aged 18-25	Population targeted "Outsmart HPV" educational content followed by vaccination reminders	Individual	3 arm randomized, analyzed as 2 arm randomized	HPV Vaccination Rates	Significantly greater proportion of vaccine initiation in intervention group	Study put on pause from March - August 2020 due to pandemic, with this period becoming the baseline for intervention comparison

* Sufficient evidence in article that intervention took place during the COVID-19 pandemic

^ with pause March-August 2020 due to COVID-19 pandemic

Key Findings by Intervention Level

Figure 2 visually displays the distribution of interventions in included studies by level and components according to the Social Ecological Model.[27]

Individual Level or Parent Interventions

Five papers from four studies evaluated educational interventions to either individuals or parents of individuals eligible for the HPV vaccine.[18,19,23–25] All educational interventions were tailored to their specific study population by either religion, race, nationality or sexual orientation. Of these five papers, three measured outcomes via survey to evaluate HPV vaccine knowledge, attitudes, or hesitancy, one measured intent to vaccinate for HPV and two measured HPV vaccination rate directly. Of the three papers utilizing quantitative surveys, all found significant differences with the interventions successful at increasing vaccine confidence, decreasing vaccine hesitant beliefs and increasing HPV vaccine knowledge compared to control conditions.[18,23,24] The paper measuring intent to vaccinate found significant increases in vaccination intention compared to controls among both the whole study population and a subgroup comprised of individuals classified as currently hesitant to vaccinate.[23] Of the two papers evaluating HPV vaccination rates or proportions directly, only one found significant differences between the intervention and control groups.[19,25]

Two papers evaluated the effect of some form of individual vaccination reminder on receipt of the HPV vaccine.[20,25] The first evaluated both mailed letters and personalized EMR messages sent after an initial EMR alter on the receipt of any HPV vaccine dose within three months of the second contact. Only mailed letters were found to significantly increase vaccine receipt compared to the control group, though it is worth mentioning that the personalized EMR messages were on the edge of significance at p=0.051.[20] The second study found reminder text messages significantly increased both vaccine series initiation and completion compared to control groups.[25]

Organizational Level Provider and Clinic Interventions

Three studies evaluated interventions delivered at the clinic and/or provider level, with two evaluating provider reminder related interventions and one evaluating clinician communication training.[21,22,25] The first study evaluated rates of HPV vaccine series initiation at age nine after changing the provider reminder within the statewide immunization information system from 'optional' to 'due now' at this age. The authors found a 97% increase in HPV series initiation at age nine after adjusting for both seasonal trends and clinic abnormalities.[26] The second study evaluated the effect of clinician HPV communication training and clinic level vaccination rate feedback on individual's HPV vaccination prevalence. No significant changes in vaccine prevalence were observed during analysis.[21] The third study evaluated provider and clinic level vaccination reminder prompt training for both physical and EMR prompts on the rate of missed opportunities for HPV vaccination at each clinic. Importantly, the study did not control how or to what extent the clinics or providers implemented the vaccination prompts after receiving the training. The authors found that missed opportunities for HPV vaccination worsened at both control and intervention clinics. Missed opportunities for vaccination *worsened less* at intervention clinics compared to controls, though not significantly.[22]

Community Level Interventions

One study evaluated a county level intervention including creation of and assistance with implementation of vaccine promotional materials on both initiation and up to date status of the HPV vaccine series.[17] The authors found no significant changes in initiation or up to date status among 11–12-year-olds but found significant increases among 13–17-year-olds for both measures in both intervention *and* control counties. There was no significant difference in the changes between intervention and control groups.[17]

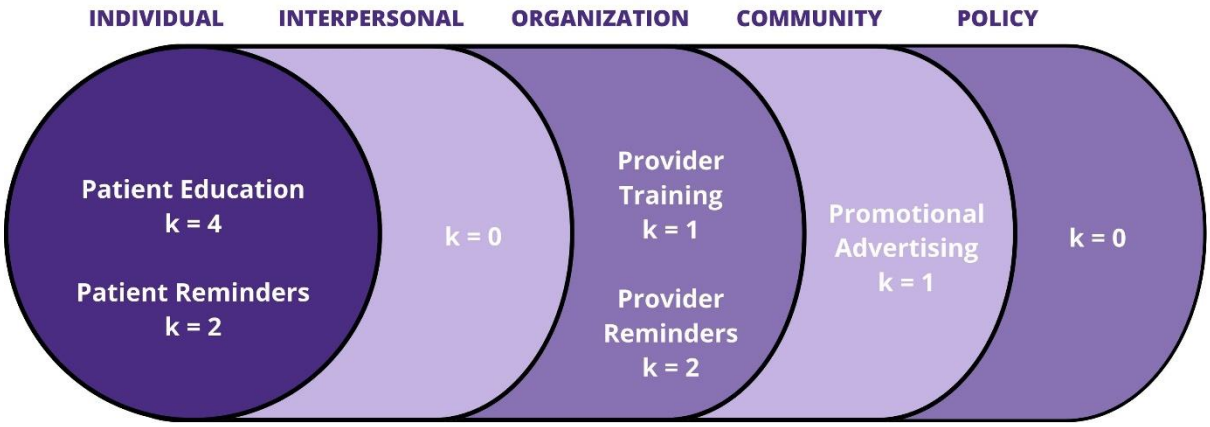

Figure 2: *Map of evidence available for post-COVID-19 interventions aiming to increase HPV vaccination rates, knowledge, or confidence, grouped by intervention level on the Social Ecological Model and intervention type. Interventions with multiple components are listed twice, and interventions evaluated through multiple papers are listed once.*

Discussion

This scoping review sought to identify evaluated interventions for increasing HPV vaccine rates, knowledge, or confidence that went into effect during or after the COVID-19 pandemic in the US. Previous reviews have identified interventions to increase HPV vaccination rates or positively affect determinants of HPV vaccination such as knowledge or confidence/ hesitancy, but none have been performed since the COVID-19 pandemic in an era of increased vaccine hesitancy and misinformation compared to prior years. We find minimal evidence supporting interventions to increase HPV vaccination rates and determinants since the pandemic, with no evaluations of interpersonal or policy level interventions as displayed in Figure 2.

The majority (6/10) of papers included evaluated interventions at the individual level on the social ecological model, followed by the organizational (3/10) and community (1/10) levels. No evidence of experimentally evaluated interventions at the interpersonal or policy levels of the social ecological model was identified. This is somewhat consistent with reviews of HPV vaccination interventions prior to the pandemic, where individual level interventions appear most common and interventions at the policy level are scarce. However, contrary to the findings of this review, provider focused interventions and those at the interpersonal, organizational and community levels of the social ecological model were much more mixed in prevalence.[28–30] While we expected to find that the number of interventions evaluated would be reduced due to the pandemic, this reduction was

expected to be proportionate to the spread of pre-pandemic intervention levels. Instead, the amount (and success) of interventions at the interpersonal, clinic and community levels (primarily provider-focused) decreased. This is likely due to shutdowns, staff shortages and difficulty performing research in clinical settings during the COVID-19 pandemic. There may also be publications in development assessing interventions at these levels that were not identified in this scoping review due to the short timeframe since the pandemic. Further research in the coming years should evaluate the success of these types of interventions as these barriers to implementation resolve.

The most prevalent intervention type included in this scoping review was tailored individual or parent education.[18,19,23–25] The results of these studies are consistent with pre-pandemic findings that culturally tailored education can be successful at increasing HPV knowledge, reducing misconceptions and increasing vaccine uptake.[31,32] However, the tailored educational interventions included in this scoping review are limited to Black mothers, Somali women and mothers, Christian parents and MSM. Further research is needed to understand the current success of tailored education in other groups, especially among men and minority groups with low rates of HPV vaccination. Reevaluation of broad, non-specific educational interventions will also be useful in understanding which remain effective after the pandemic, as these interventions have the potential to reach the largest amount of HPV vaccine-eligible individuals in this new landscape.

Similarly to pre-pandemic evaluations, this scoping review finds individual or parent reminders to vaccinate were successful in increasing vaccination rates, especially when part of multicomponent interventions combining reminders with HPV vaccination education.[25,28,33] Alternatively, vaccination reminder interventions focused on providers had mixed success.[28,34] Results of the studies included in this scoping review are consistent with these findings, with differing results between the two interventions aimed at clinician reminders within the EHR or statewide immunization systems.[22,26] However, the positive results of Christensen et al indicate that the type of provider reminder may be imperative for success; reminders *suggesting* vaccination in the EHR may not be as effective as alerts emphasizing the vaccine as “Due Now” or “Overdue” for the patient.[26] This is an important development, as pre-pandemic reviews of provider focused interventions do not appear to differentiate between types of provider reminders or language used.[34] More research into the effect of provider reminders and differences in success of various alert types is needed to better understand these results. It will also be important to understand how misinformation and hesitancy resulting from the COVID-19 pandemic can most effectively be combated by clinicians, so that when reminded to offer vaccination these clinicians have the highest chance of success with vaccine initiation from patients and/or parents.

The majority of results from the initial search used qualitative methods or lacked a comparison group. While not included in this review, qualitative studies during the aftermath of COVID-19 may provide important insight into individual and parent perceptions regarding HPV vaccination during this time. This may provide important context regarding why the effectiveness of some HPV vaccination interventions has changed after the pandemic. Experimental evaluation of newly implemented interventions or re-evaluation of previously successful interventions also remains necessary to understand how changes in vaccine sentiment due to COVID-19 have (or have not) impacted efforts to increase HPV vaccination and associated determinants. This will be especially

important in regions and demographics that experienced high rates of vaccine hesitancy toward the COVID-19 vaccine, as it is not yet clear how this hesitancy has affected beliefs about other vaccines. For instance, correlations have been identified between both Republican partisanship and rural location with decreased COVID-19 vaccination.[35,36] This is important as rurality was already associated with decreased HPV vaccination prior to the COVID-19 pandemic, and perceptions of politicization of the HPV vaccine are shown to significantly impact support for HPV related policy.[30,37] Once it is understood how and where vaccine hesitancy has been affected by the COVID-19 pandemic, interventions targeting these areas can be established or evaluated.

Evaluation of policy level interventions implemented during and after the pandemic is also needed. For example, Hawaii's implementation of a school entry requirement for the HPV vaccine in 2020 has not yet been evaluated, though other school entry requirements showed success in increasing HPV vaccination rates prior to the pandemic.[38] Rigorous evaluation of this policy and of other HPV school-entry requirements is needed to understand their success (or lack of) at raising youth HPV vaccination rates in the wake of decreased childhood immunization rates and increased exemptions since the pandemic's onset. Understanding the success of these policies in the post-COVID-19 era will provide important implications for other states considering these types of requirements.

Conclusion

Overall, this scoping review finds a lack of published experimental research about increasing HPV vaccination rates, knowledge, or confidence in the post-COVID-19 timeframe. Educational interventions that are tailored to specific populations remain effective at increasing vaccination rates, knowledge, and confidence, especially when combined with individual reminders to vaccinate. Interventions at the provider or clinic level have mixed success, though this evidence is likely marred by staffing shortages and changing priorities during and after pandemic shutdowns. Little evidence is available for community level interventions, with no evidence evaluating interpersonal or policy level interventions since the pandemic's onset. Targeting efforts to re-evaluating the efficacy of low cost, widespread interventions will be imperative in increasing HPV vaccination rates to pre-pandemic levels and encouraging their continued increase toward the rates of other childhood vaccinations.

Acknowledgements

I would like to express my deepest appreciation to the chair of my thesis committee, Nora B. Henrikson, for her guidance throughout this process and her invaluable feedback. I could not have undertaken this project without her support and encouragement.

I would also like to thank my professor and committee member, Molly B. Firth, for her encouragement in my research interests and feedback along the way. I would also like to express my thanks to the Health Sciences librarians at the University of Washington for their assistance with the formulation of the search string at the foundation of this project. I am grateful to my classmates and cohort members for their moral support, laughs, and review of barely drafted figures.

Finally, I give thanks to my parents and partner for their unwavering support throughout the entirety of my degree pursuit and for always offering a listening ear when I needed it most.

Funding

This project and its contributors received no funding or financial support from the University of Washington or any other entity.

Conflicts of interest

There is no conflict of interest in the project.

References

1. de Martel C, Plummer M, Vignat J, Franceschi S. Worldwide burden of cancer attributable to HPV by site, country and HPV type. *Int J Cancer*. 2017;141(4):664-670. doi:10.1002/ijc.30716

2. CDC. HPV Can Cause Certain Cancers in Men and Women. Centers for Disease Control and Prevention. Published March 17, 2023. Accessed February 13, 2024. https://www.cdc.gov/hpv/parents/cancer.html

3. Rosenblum HG, Lewis RM, Gargano JW, Querec TD, Unger ER, Markowitz LE. Declines in Prevalence of Human Papillomavirus Vaccine-Type Infection Among Females after Introduction of Vaccine - United States, 2003-2018. *MMWR Morb Mortal Wkly Rep*. 2021;70(12):415-420. doi:10.15585/mmwr.mm7012a2

4. HPV Vaccination Recommendations | CDC. Published May 22, 2023. Accessed May 26, 2024. https://www.cdc.gov/vaccines/vpd/hpv/hcp/recommendations.html

5. Global strategy to accelerate the elimination of cervical cancer as a public health problem. Accessed May 24, 2024. https://www.who.int/publications-detail-redirect/9789240014107

6. Pingali C. Vaccination Coverage Among Adolescents Aged 13–17 Years — National Immunization Survey–Teen, United States, 2022. *MMWR Morb Mortal Wkly Rep*. 2023;72. doi:10.15585/mmwr.mm7234a3

7. Ellingson MK, Sheikha H, Nyhan K, Oliveira CR, Niccolai LM. Human papillomavirus vaccine effectiveness by age at vaccination: A systematic review. *Hum Vaccin Immunother*. 2023;19(2):2239085. doi:10.1080/21645515.2023.2239085

8. Ten health issues WHO will tackle this year. Accessed May 26, 2024. https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019

9. Daly M, Jones A, Robinson E. Public Trust and Willingness to Vaccinate Against COVID-19 in the US From October 14, 2020, to March 29, 2021. *JAMA*. 2021;325(23):2397-2399. doi:10.1001/jama.2021.8246

10. Hammershaimb EA, Campbell JD, O'Leary ST. Coronavirus Disease-2019 Vaccine Hesitancy. *Pediatr Clin North Am*. 2023;70(2):243-257. doi:10.1016/j.pcl.2022.12.001

11. Routine Child Vaccination Rates Lower Than Pre-Pandemic Levels. National Conference of State Legislatures. Accessed May 26, 2024. https://www.ncsl.org/state-legislatures-news/details/routine-child-vaccination-rates-lower-than-pre-pandemic-levels

12. Sonawane K, Lin YY, Damgacioglu H, et al. Trends in Human Papillomavirus Vaccine Safety Concerns and Adverse Event Reporting in the United States. *JAMA Network Open*. 2021;4(9):e2124502. doi:10.1001/jamanetworkopen.2021.24502

13. Vraga EK, Brady SS, Gansen C, et al. A review of HPV and HBV vaccine hesitancy, intention, and uptake in the era of social media and COVID-19. *eLife*. 12:e85743. doi:10.7554/eLife.85743

14. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*. 2018;18(1):143. doi:10.1186/s12874-018-0611-x

15. Scoping Reviews - Resources | JBI. Accessed May 19, 2024. https://jbi.global/scoping-review-network/resources

16. Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org.

17. Cataldi JR, Suresh K, Brewer SE, et al. Boot Camp Translation using Community-Engaged messaging for adolescent Vaccination: A Cluster-Randomized trial. *Vaccine*. Published online January 21, 2024. doi:10.1016/j.vaccine.2024.01.042

18. Dike S, Cesario SK, Malecha A, Nurse R. An Education Intervention to Increase Human Papillomavirus Vaccination Confidence and Acceptability: A Randomized Controlled Trial. *Oncol Nurs Forum*. 2023;50(4):423-436. doi:10.1188/23.ONF.423-436

19. Ghebrendrias S, Mody S, Washington S, Hussein B, Jama F, Jacobs M. A Cervical Cancer Screening Toolkit for Somali Women: A Pilot Randomized Controlled Trial. *J Immigr Minor Health*. 2023;25(6):1307-1314. doi:10.1007/s10903-023-01455-8

20. Khan AA, Tran HN, Lai JA, et al. A Learning Health System Approach to Increasing Human Papillomavirus Immunizations Among Young Adults. *Perm J*. 2023;27(2):31-36. doi:10.7812/TPP/22.094

21. Meadows RJ, Gehr AW, Lu Y, et al. Effectiveness of provider communication training for increasing human papillomavirus vaccine initiation at a safety-net health system. *Preventive Medicine Reports*. 2024;39:102660. doi:10.1016/j.pmedr.2024.102660

22. Rand CM, Stephens-Shields AJ, Kelly MK, et al. Clinician Prompts for Human Papillomavirus Vaccination: A Cluster Randomized Trial. *Acad Pediatr*. Published online November 2, 2023:S1876-2859(23)00401-1. doi:10.1016/j.acap.2023.10.011

23. Redd DS, Altman JD, Jensen JL, et al. A Randomized Study to Determine the Effect of a Culturally Focused Video Intervention on Improving HPV Vaccine Intentions in a Christian Population in the

United States. *J Community Health*. Published online February 23, 2024. doi:10.1007/s10900-024-01327-8

24. Reiter PL, Gower AL, Kiss DE, et al. Effects of a web-based HPV vaccination intervention on cognitive outcomes among young gay, bisexual, and other men who have sex with men. *Hum Vaccin Immunother*. 2022;18(6):2114261. doi:10.1080/21645515.2022.2114261

25. Reiter PL, Gower AL, Kiss DE, et al. Efficacy of the Outsmart HPV Intervention: A Randomized Controlled Trial to Increase HPV Vaccination among Young Gay, Bisexual, and Other Men Who Have Sex with Men. *Cancer Epidemiol Biomarkers Prev*. 2023;32(6):760-767. doi:10.1158/1055-9965.EPI-23-0007

26. Christensen T, Zorn S, Bay K, Treend K, Averette C, Rhodes N. Effect of immunization registry-based provider reminder to initiate HPV vaccination at age 9, Washington state. *Hum Vaccin Immunother*. 2023;19(3):2274723. doi:10.1080/21645515.2023.2274723

27. The Social-Ecological Model: A Framework for Prevention |Violence Prevention|Injury Center|CDC. Published January 18, 2022. Accessed March 13, 2024. https://www.cdc.gov/violenceprevention/about/social-ecologicalmodel.html

28. Bennett C, Edwards D, Sherman SM, et al. Which interventions improve HPV vaccination uptake and intention in children, adolescents and young adults? An umbrella review. *Sex Transm Infect*. 2022;98(8):599-607. doi:10.1136/sextrans-2022-055504

29. Escoffery C, Petagna C, Agnone C, et al. A systematic review of interventions to promote HPV vaccination globally. *BMC Public Health*. 2023;23:1262. doi:10.1186/s12889-023-15876-5

30. Brandt HM, Vanderpool RC, Pilar M, Zubizarreta M, Stradtman LR. A narrative review of HPV vaccination interventions in rural U.S. communities. *Prev Med*. 2021;145:106407. doi:10.1016/j.ypmed.2020.106407

31. Rani U, Darabaner E, Seserman M, Bednarczyk RA, Shaw J. Public Education Interventions and Uptake of Human Papillomavirus Vaccine: A Systematic Review. *J Public Health Manag Pract*. 2022;28(1):E307-E315. doi:10.1097/PHH.0000000000001253

32. Zhang X, Tang L. Cultural adaptation in HPV vaccine intervention among racial and ethical minority population: a systematic literature review. *Health Education Research*. 2021;36(5):479-493. doi:10.1093/her/cyab034

33. Francis DB, Cates JR, Wagner KPG, Zola T, Fitter JE, Coyne-Beasley T. Communication technologies to improve HPV vaccination initiation and completion: A systematic review. *Patient Education and Counseling*. 2017;100(7):1280-1286. doi:10.1016/j.pec.2017.02.004

34. Oliver K, Frawley A, Garland E. HPV vaccination: Population approaches for improving rates. *Hum Vaccin Immunother*. 2016;12(6):1589-1593. doi:10.1080/21645515.2016.1139253

35. Ye X. Exploring the relationship between political partisanship and COVID-19 vaccination rate. *J Public Health (Oxf)*. 2023;45(1):91-98. doi:10.1093/pubmed/fdab364

36. Sun Y, Monnat SM. Rural-urban and within-rural differences in COVID-19 vaccination rates. *J Rural Health*. 2022;38(4):916-922. doi:10.1111/jrh.12625

37. Saulsberry L, Fowler EF, Nagler RH, Gollust SE. Perceptions of politicization and HPV vaccine policy support. *Vaccine*. 2019;37(35):5121-5128. doi:10.1016/j.vaccine.2019.05.062

38. McKeithen MC, Gilkey MB, Kong WY, et al. Policy Approaches for Increasing Adolescent HPV Vaccination Coverage: A Systematic Review. *Pediatrics*. 2024;153(5):e2023064692. doi:10.1542/peds.2023-064692

Appendices

Appendix I: Search strategy

Full search string used in the PubMed Database on March 31st, 2024:

((Human Papillomavirus[Title/Abstract] OR HPV[Title/Abstract]) AND (Vaccination[Title/Abstract] OR Vaccine[Title/Abstract] OR (Immunization[MeSH]) OR (Papillomavirus Vaccines[MeSH)) AND ((United States[Title/Abstract]) OR (US[Title/Abstract]) OR (USA[Title/Abstract]) OR (Appalachian[Text Word] OR “Great Lakes”[Text Word] OR Mid-Atlantic[Text Word] OR Midwestern[Text Word] OR “New England”[Text Word] OR Northwestern[Text Word] OR Pacific[Text Word] OR Southeastern[Text Word] OR Southwestern[Text Word]) OR ("United States"[MeSH]) OR (Alabama[Text Word] OR Alaska[Text Word] OR Arizona[Text Word] OR Arkansas[Text Word] OR California[Text Word] OR Colorado [Text Word] OR Connecticut[Text Word] OR Delaware[Text Word] OR Florida[Text Word] OR Georgia [Text Word] OR Hawaii[Text Word] OR Idaho[Text Word] OR Illinois[Text Word] OR Indiana[Text Word] OR Iowa[Text Word] OR Kansas[Text Word] OR Kentucky[Text Word] OR Louisiana[Text Word] OR Maine[Text Word] OR Maryland[Text Word] OR Massachusetts[Text Word] OR Michigan[Text Word] OR Minnesota[Text Word] OR Mississippi[Text Word] OR Missouri[Text Word] OR Montana[Text Word] OR Nebraska[Text Word] OR Nevada[Text Word] OR New Hampshire[Text Word] OR New Jersey[Text Word] OR New Mexico[Text Word] OR New York[Text Word] OR North Carolina[Text Word] OR North Dakota[Text Word] OR Ohio[Text Word] OR Oklahoma[Text Word] OR Oregon[Text Word] OR Pennsylvania[Text Word] OR Rhode Island[Text Word] OR South Carolina[Text Word] OR South Dakota[Text Word] OR Tennessee[Text Word] OR Texas[Text Word] OR Utah[Text Word] OR Vermont[Text Word] OR Virginia[Text Word] OR Washington[Text Word] OR West Virginia[Text Word] OR Wisconsin[Text Word] OR Wyoming[Text Word])) AND (("2020/01/01"[Date - Publication] : "3000"[Date - Publication]))