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Digital Health Interventions to Improve Vaccination Rates and Awareness Among Immigrant Populations: Barriers, Facilitators, and Outcomes - A Scoping Review

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Abstract

Background: *Digital health interventions have been shown to improve vaccine coverage and awareness in the general population. However, there is a lack of knowledge of their impact on migrant populations. This scoping review aims to identify existing evidence on digital health interventions designed to improve vaccination among this group.*

Methods: *We analyzed studies on digital health interventions targeting vaccination rates and awareness among migrants, evaluating barriers and facilitators. Searches were conducted in CENTRAL, PubMed, and Scopus for observational studies and randomized controlled trials (RCT). Two independent reviewers screened articles, performed data extraction and synthesis, and assessed bias using Covidence(R). Bias was evaluated using the Cochrane RoB 2, Newcastle-Ottawa Scale (NOS), or JBI tool.*

Results: *Of the 673 studies initially identified, 19 met the inclusion criteria. These studies, published between 2012 and 2024, included six quasi-experimental studies, five cross-sectional studies, four randomized control trials, three qualitative studies, and one survey. They originated from several different countries, and most interventions were culturally adapted and targeted specific populations. Key barriers to vaccination were socioeconomic status, education, language, cultural beliefs, distrust in healthcare systems, and legal concerns like the fear of deportation.*

Conclusions: *Digital health interventions show promise in improving vaccination awareness among migrant populations. Our findings suggest that these interventions need to be customized for specific populations to be effective, considering the challenges faced by these groups, facilitators, and cultural beliefs.*

Introduction

Digital health, defined by the World Health Organization as the use of digital technologies to improve health, is increasingly central in medical practice (Marzo et al., 2022; World Health Organization, 2022). However, its benefits are not equitably distributed, particularly among vulnerable groups like migrants (Radu et al., 2023).

With approximately 281 million migrants worldwide, or 3.6% of the global population (McAuliffe, 2024), this population faces unique healthcare challenges, many of which digital health interventions could help address (Rosenkrands et al., 2020). Despite high smartphone usage among migrants and

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minorities, digital health tools often lack designs tailored to their needs (Radu et al., 2023).

Vaccination is a critical issue in this context. Migrants and refugees encounter significant barriers—personal, social, and physical, such as distrust in healthcare systems, cultural barriers, and financial constraints—that impede their access to vaccines, leading to lower vaccination rates (Deal et al., 2023). Newly arrived migrants, those with precarious status, and individuals in camps or detention are particularly affected.

While digital health interventions have been shown to improve vaccination awareness and coverage in the general population (Abdullahi et al., 2020; Dumit et al., 2018; Athey et al., 2022; Choi et al., 2023), This scoping review aims to synthesize existing literature on the effect of digital health interventions on vaccination coverage in migrant populations. Our primary aim is to investigate whether these digital health interventions can increase vaccination coverage in this group. In addition, we seek to explore the facilitators and barriers encountered by migrants in engaging with digital health interventions and identify knowledge gaps in order to provide a foundation for future research.

Materials and Methods

Search strategy

This scoping review was conducted in May of 2024. Multiple databases were used: Cochrane Controlled Register of Trials (CENTRAL) of the Cochrane Library, PubMed, and Scopus. The search strategy, formulated according to the PICO format, was adapted to each database with keywords that can be found in annex Supplementary Table 4. The review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Scoping Reviews (PRISMA-ScR) checklist.

Inclusion and exclusion criteria

We primarily looked for articles that evaluated how the use of digital interventions can improve vaccination coverage and health among migrant populations and included them if they addressed the migrant population exposed to digital health interventions and measured outcomes relating to vaccine uptake, an increase in vaccination coverage, and associated factors. This review includes studies that are either observational (descriptive) or interventional. We excluded systematic reviews, narrative reviews, comments, and editorials in order to focus on original studies. Case series and case reports were excluded due to their inherent limitations, such as generalizability and high risk of bias. We also excluded non-migrant populations and interventions unrelated to digital health. During the search, we applied no restrictions based on language, publication status, time of publication, or geographic location.

Selection of studies and data extraction

We primarily looked for articles that evaluated how the use of digital interventions can improve vaccination coverage and health among migrant populations and included them if they addressed the migrant population exposed to digital health interventions and measured outcomes relating to vaccine uptake, an increase in vaccination coverage, and associated factors. This review includes studies that are either observational (descriptive) or interventional. We excluded systematic reviews, narrative reviews, comments, and editorials in order to focus on original studies. Case series and case reports were excluded due to their inherent limitations, such as generalizability and high risk of bias. We also excluded non-migrant populations and interventions unrelated to digital health. During the search, we applied no restrictions based on language, publication status, time of publication, or geographic location.

Data synthesis

Based on the summary provided by Covidence(R), we conducted a comprehensive narrative synthesis of findings, objectively summarizing the settings, socioeconomic, demographic, and clinical characteristics of the migrants sampled, along with their social and cultural determinants of health, behaviors, values, and beliefs. Additionally, we analyzed the types of digital interventions and how their use modified vaccination coverage, personal understanding, and awareness of this topic, while also identifying the facilitators and barriers involved in immigrants' vaccination.

Risk of bias assessment

Groups of two reviewers independently assessed bias using the Cochrane Risk of Bias assessment tool (Sterne et al., 2019) for evaluating randomized control trials, the Newcastle-Ottawa Scale (Ottawa Hospital Research Institute, 2024) for cohort and case-control studies, and the JBI tool for quasi-experimental studies (Barker et al., 2024). Discrepancies were resolved by consensus among the parties. If a consensus was not reached, then a third independent reviewer was

consulted to make an independent assessment and make the final decision. Risk of bias assessment was classified as high, low, or unclear for each assessed domain according to the Newcastle Ottawa Scale for observational studies, the JBI Appraisal tool for randomized trials, and the Risk of Bias (Rob -2) Tool for randomized controlled trials.

Results

Description of the studies

Of 673 studies identified, 139 duplicates were removed, and 465 were excluded by title and abstract. After a full-text review of 69 articles, 50 were excluded, mainly due to a lack of digital health interventions. Nineteen studies met the criteria for data extraction and synthesis, as detailed in the PRISMA flowchart (Figure 1).

All studies were published between 2012 and 2024, with the majority published in 2023. Among interventional studies, quasi-experimental (n= 6) were the most frequent study design, followed by Randomized-control trial (RCT) (n = 4). Among the observational studies, cross-sectional (n=5) predominated. Additionally, three qualitative studies were also found. Paradis et al. (2018) conducted a survey to assess the knowledge of vaccination and the acceptance of a mobile application as a tool to increase vaccine uptake among immigrants in Canada. Figure 2.

North America was the most frequent study setting (n=13), followed by Germany (n=2) (Additionally, our search revealed one study each from China, Jordan, Turkey, and Uganda. Figure 3.

Specifically, studies were conducted on the COVID-19 vaccine (n = 6), Human Papillomavirus vaccine (n = 5) (Hepatitis B (n=2), Influenza vaccines (n = 2), and childhood vaccinations (n = 2). Two studies did not specify which vaccines were assessed but rather analyzed the possible outcomes of vaccine uptake due to a mobile app, and the barriers and facilitators faced by migrants in their host country (Figure 4).

The sample sizes varied from 8 to 889,000 participants, with a median number of 229 subjects per study. Convenience sampling was the primary method of patient recruitment. Table 1 presents the summary of study characteristics included in this review.

Population

The review included studies focused on first-generation immigrants (n =8), second-generation immigrants (n = 1), and specifically on the refugee population (n =3), while others did not document migrant status (Figure 5).

Most studies included young adults, and only two included an older population (Lee et al., 2023; Seo et al., 2022). Although most studies had balanced male/female ratios, three targeted only females (Meyer et al., 2022; Chen et al., 2023; Chen et al., 2022). Only one study reported gender identity, in which 2% of the participants identified as transgender (Logie et al., 2024). The most represented groups were from the Middle East (n =3), the Hispanic/Latinx population (n = 3), and South and East Asia (n = 2). Studies also included individuals from Europe, Africa, and immigrants from multiple regions or multiethnic descent (Seo et al., 2022). Eight studies did not report ethnicity (Figure 6).

There was considerable diversity in social determinants of health across the eligible studies. Education status was reported in 14 studies (Carpenter et al., 2023; Chen et al., 2022; Chen et al., 2023; DeCamp et al., 2020; El-Halabi et al., 2023; Frick et al., 2023; Juon et al., 2016; Kim et al., 2023; Logie et al., 2023; Meyer et al., 2022; Mueller et al., 2011; Panameno et al., 2023; Seo et al., 2022; Xu et al., 2022), with participants ranging from illiterate to those with postgraduate degrees; however, most were middle school or incomplete high school graduates. Economic status was detailed in 5 studies (Chen et al., 2023; DeCamp et al., 2020; Lee et al., 2023; Meyer et al., 2022; Panameno et al., 2023), predominantly indicating low household incomes. Healthcare coverage was addressed in all but one study, with over 50% of participants covered either through government or private means. Marital status was reported in six studies (DeCamp et al., 2020; Lee et al., 2023; Meyer et al., 2022; Mueller et al., 2011; Ponce-Gonzalez et al., 2021; Seo et al., 2022), consistently showing higher proportions of married or partnered individuals. Employment rates varied widely, ranging from 25% to 99%, across eight studies (Chen et al., 2022; Chen et al., 2023; Juon et al., 2016; Meyer et al., 2022; Panameno et al., 2023; Seo et al., 2022; Shah et al., 2023; Xu et al., 2022). Religious beliefs were mentioned in four studies, reflecting diverse affiliations (Buddhism, Christianity, Islam, or Hinduism) (Frick et al., 2023; Lee et al., 2023; Meyer et al., 2022; Xu et al., 2022). Other social determinants, such as water sources, health literacy, internet access, English proficiency, and tobacco exposure, were also noted, while social capital was not reported in any study.

Duration

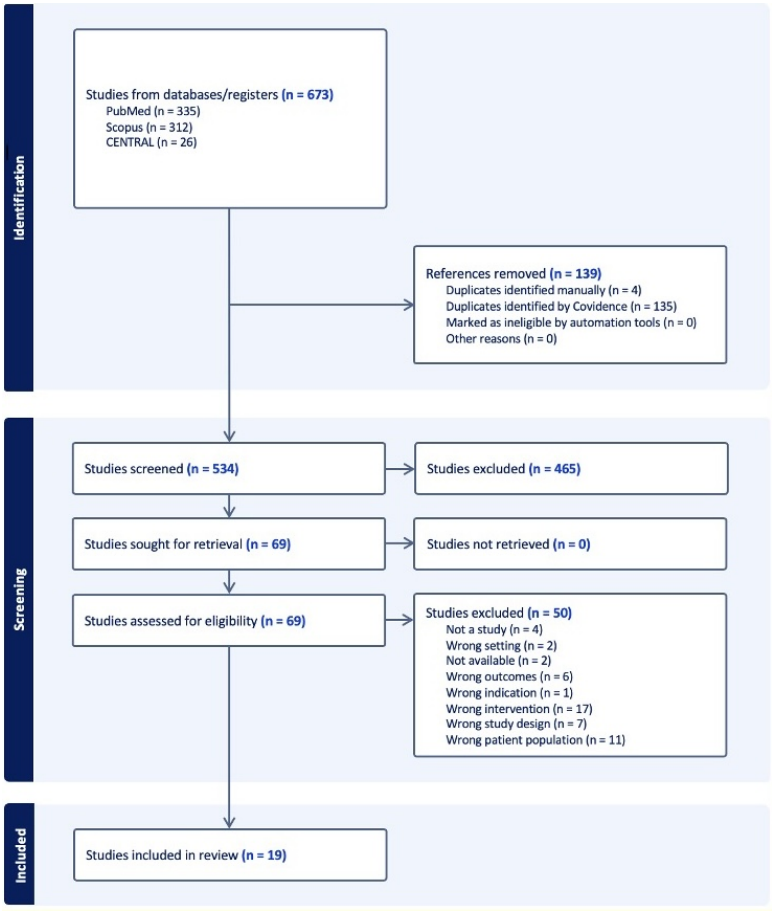

Figure 1: *PRISMA-ScR flowchart.*

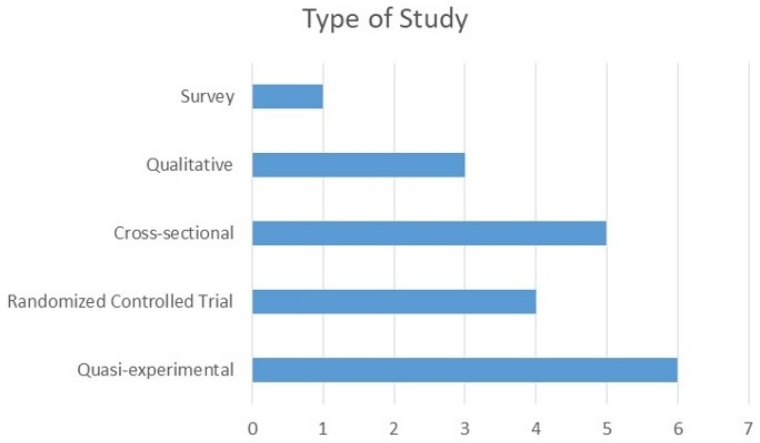

Figure 2: *Study designs and publication trends (2012–2024).*

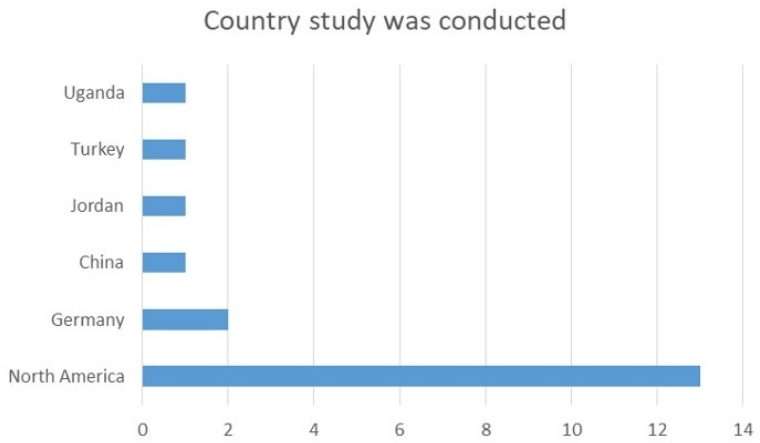

Figure 3: *Study settings by region (2012–2024).*

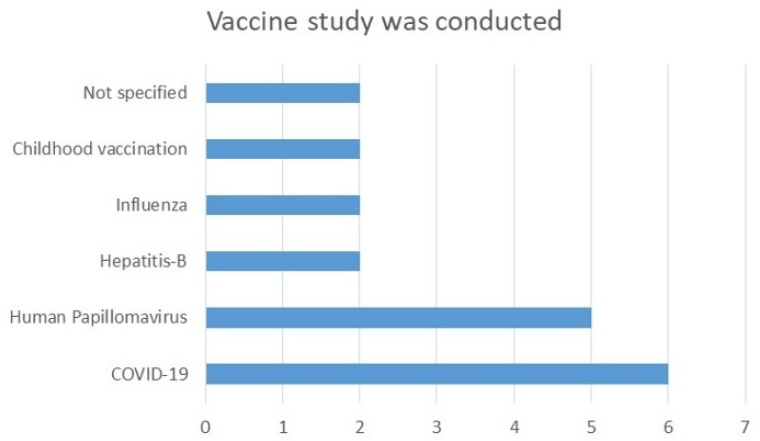

Figure 4: *Vaccines studied across research (2012–2024).*

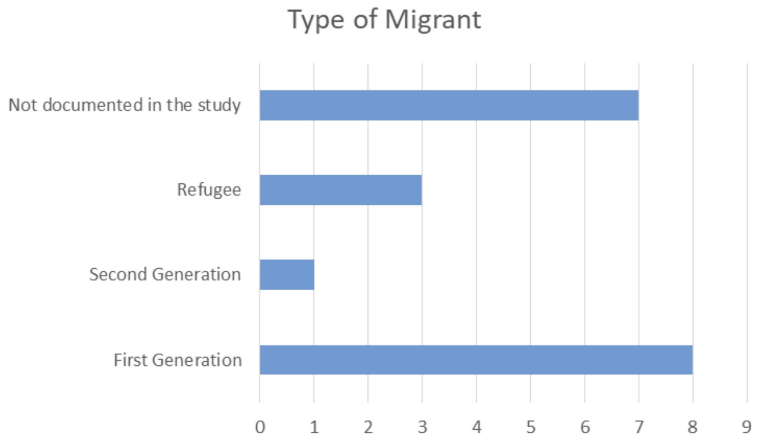

Figure 5: *Target populations in selected studies (2012–2024).*

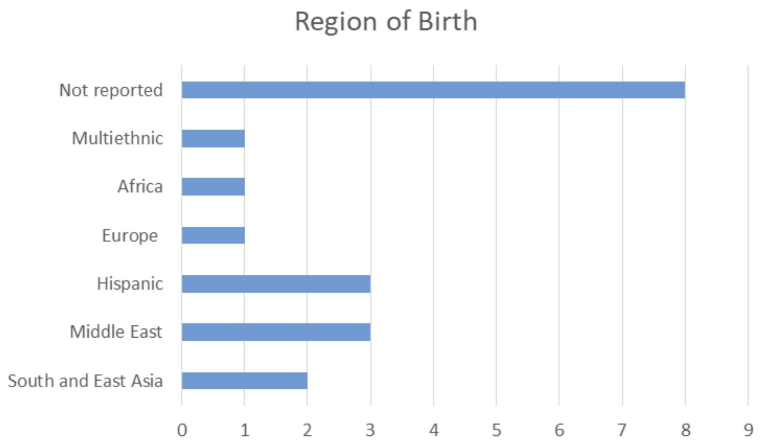

Figure 6: *Participant demographics across studies (2012–2024).*

The average study duration varied greatly by country, the shorter being in Germany (10 months) and the longer Netherlands (47 months). The duration of these trials varied depending on the aim of the study. Studies focusing on the effects of fasting on patients averaged about 47 months, while trials focusing on the safety, feasibility, and metabolic effects of fasting lasted an average of 30 months. Feasibility and impact studies averaged 19 months, while anti-tumor efficacy trials, which require more rigorous follow-up, lasted the longest with an average duration of 156 months. In contrast, studies of short-term fasting and chemotherapy toxicity averaged 10 months. Trials evaluating the effect of fasting on both toxicity and efficacy lasted an average of 47 months, while those focusing on the safety and acceptability of fasting lasted an average of 13 months.

Overview of Interventions and Exposures in the Studies

The interventions in the experimental studies varied significantly. All four randomized controlled trials (DeCamp et al., 2020; Juon et al., 2016; Tjaden et al., 2022; Xu et al., 2022) used appointment reminder systems, including phone calls, SMS, and mobile apps. DeCamp et al. (2020) personalized text messages with the child's name and sex and included an educational video for the intervention group. Juon et al. (2016) ensured all participants underwent hepatitis screening and received educational programs to motivate them. Xu et al. (2022) provided a flexible app that allowed doctors to share health information with parents outside of visiting hours. Tjaden et al. (2022) uniquely utilized social media, tailoring advertisement images for different language groups to target doctors, religious leaders, and families. Most randomized studies did not blind participants due to practical and ethical reasons.

Among the quasi-experimental trials, El-Halabi et al. (2023) used appointment reminder systems, including phone calls, SMS, and mobile applications, standing up for using an automated reminder integrated in an app for vaccination appointments. Three studies assessed the effectiveness of informative mobile applications (Frick et al., 2023) and messaging platforms like SMS or WhatsApp (Logie et al., 2024; Ponce-Gonzalez et al., 2021). Two studies (Chen et al., 2022; Chen et al., 2023) evaluated storytelling through digital platforms, creating personalized audiovisual stories about HPV vaccination for mothers of vaccinated children, focusing on Vietnamese American mothers in 2022 and Korean American and Vietnamese American mothers in 2023. Table 2 summarizes the main interventions and outcomes from these studies.

Qualitative studies included Meyer et al. (2022), who explored the effectiveness of informative mobile applications by capturing individual user experiences. Kim et al. (2023) described a Digital Storytelling (DST) workshop, producing digital content referenced in earlier studies (Chen et al., 2022; Chen et al., 2023). Panameno et al. (2023) provided online health information about vaccination and the factors influencing vaccination decisions.

Importantly, none of these interventions were validated before implementation. Surveys were used in ten studies to evaluate outcomes, gather sociodemographic information and assessing or increasing vaccine awareness (Seo et al., 2022; Paradis et al., 2018; Mueller et al., 2011; Carpenter et al., 2023; Panameno et al., 2023; Lee et al., 2023; Shah et al., 2023; Chen et al., 2022; Chen et al., 2023; Meyer et al., 2022).

Specific Intervention's Results

1. Internet Seeking: Three studies (Panameno et

Study	Design	Study setting	Vaccine of interest	Sample size	Inclusion criteria	Exclusion criteria	Method of recruitment	Follow up
DeCamp et al., 2020	Randomized controlled trial	Evaluating the Salud al Día Intervention: Educational Videos and Interactive Text Messages to Reduce Emergency Department Visits among Latino Families and vaccination adherence from birth to 15 months in an Urban Pediatric Primary Care Setting in Baltimore, Maryland, USA.	Flu Vaccine	157	Parent or legal guardian of a singleton US-born infant ≤ 2 months of age Parent or legal guardian age 18 or older Parent or legal guardian foreign-born Parental report of Spanish as their preferred healthcare language Plan to select Medicaid/Priority Partners insurance for their child with the Johns Hopkins Bayview Medical Center Children's Medical Practice as the primary care site Have a working cellular phone with text message capability and parent reports prior use of text messaging	NA	Convenience sampling	February 2016 to December 2017
Juon et al., 2016	Randomized controlled trial	In the Baltimore-Washington area, Asian American community members were screened for hepatitis B. Those without protection against the virus were randomly given resources with reminders or just resources. Afterward, health workers checked their vaccination status over the phone.	HepB	232	1) Foreign- born Asian American adults 2) 18 years and older 3) Unprotected for HBV (HBsAg-HBsAB-) after a free Hepatitis B screening	1) Protected for HBV after Hepatitis B screening 2) Not Asian American adults	Convenience sampling	7 months
Tjaden et al., 2022	Randomized controlled trial,	Migrant communities in Germany using targeted Facebook campaigns to share	COVID-19	889	1)Native Arabic, Turkish, Russian; 2)Age:18-65	1)children and teenagers under 18	Probabilistic	NO
Xu et al, 2022	Randomized controlled trial	Mobile application intervention in Jiulongpo district, Chongqing, China, analyzing changes in vaccine knowledge and behaviors among caregivers of vaccinated migrant children.	HepB; BCG; IPV; bOPV; DPT; MR; MMR; JE-L; MenA; HepA-L	246	1)Man and women as Caregivers Children Age 2 month to 24 month, mobile phone, Migrant children referred to children whose household registration were in foreign districts and who had lived temporarily with their parents or other caregivers in JLP district	1) Kids older than 2 years; 2) Nannies	Convenience sampling	NO
1.2 Interventional studies – Quasi experimental								
Study	**Design**	**Study setting**	**Vaccine of interest**	**Sample size**	**Inclusion criteria**	**Exclusion criteria**	**Method of recruitment**	**Follow up**
Chen et al., 2022	Quasi-experimental	Digital stories on HPV vaccination were developed during a 2-day workshop with Vietnamese American mothers in the Phoenix Metropolitan area, Arizona, USA, to assess their impact on vaccination intentions. Surveys were conducted before and after the intervention.	HPV	114	Women were recruited if they (1) self-identified as VA or Vietnamese immigrants, (2) were 18 years old or older, and (3) had one or more children ages 11–14 years old who had not been vaccinated for HPV.	NA	Convenience sampling	NO
Chen et al., 2023	Quasi-experimental	Participants recruited from community organizations, social media, and local Asian venues in Arizona, USA, were assessed for a culturally tailored digital storytelling intervention's feasibility, acceptability, and initial effects on HPV vaccination attitudes among Korean American and Vietnamese American mothers. Web-based measures were used for pre- and post-intervention data collection..	HPV	164	Adult women (aged 18 years or older) were recruited if they 1) self-identified as Korean American or Vietnamese American or as Korean or Vietnamese immigrants, 2) were first-generation immigrants born outside of the United States, and 3) had 1 or more children aged 9-14 years old who had not been vaccinated against HPV	1) Child's age (under 9, over 14); 2) Mother not sure about vaccination	Convenience sampling	NO
El-halabi et al., 2023	Quasi-experimental	Assessing the effectiveness of the Children Immunization App (CIMA) in increasing immunization coverage among Syrian children at the Zaatari refugee camp in Jordan through a non-randomized controlled trial.	All childhood vaccine	936	1)Having at least one child age 0–5 years of age; 2) being a local resident of the camp and 3) having an Android smartphone that can allow CIMA app installation.	NA	Convenience sampling	NO
Frick et al., 2023	Quasi-experimental	Examining a culture-sensitive approach using mobile app interventions and face-to-face group sessions to enhance COVID-19 knowledge and vaccination readiness among Arabic-speaking asylum seekers in Germany during the pandemic through a "quasi "dosage finding" study."	COVID-19	65	16 to 26 years, possess a mobile phone,peak Arabic, be living in a collective housing facility, and not have a psychiatric condition requiring hospitalization	Not meeting inclusion criteria	Convenience sampling	6 weeks
Logie et al., 2024	Quasi experimental single arm trial	A pre-post trial of an interactive informational mobile health intervention aimed at increasing COVID-19 prevention practices among community-recruited refugee youth in Kampala, Uganda.	COVID-19	346	1) Being a Tushirikiane participant (cluster randomized HIV self-testing trial); 2) age 16–24 y at the time of Tushirikiane enrolment; 3) living in one of five informal settlements in Kampala (Kabalagala, Kansanga, Katwe, Nsambya, Rubaga); 4) identifying as a refugee or displaced person; 5) speaking one of the study languages (English, French, Swahili, Luganda, Kinyarwanda, Kirundi) 6) and owning or having access to a mobile phone for the duration of the study.	1) Not being part of the Tushirikiane trial (cluster randomized HIV self-testing trial)	Purposive sampling	16 weeks
Ponce-gonzalez et al., 2021	Quasi-experimental	In a multimedia campaign in the USA's Washington State, migrant and refugee communities were educated about influenza and vaccination using phone surveys to assess participant knowledge before and after each workshop.	Influenza	183	1) Participated to the workshop, participants were Latinx families living in underserved communities throughout Washington state	NA	Convenience sampling	NO

Table 1: *Characteristics of the included studies.*

1.3 Observational studies – Cross sectional

Study	Design	Study setting	Vaccine of interest	Sample size	Inclusion criterion	Exclusion criterion	Method of recruitment	Follow up
Carpenter et al., 2023	Cross- sectional	Studying the association between using the internet as a primary health	HepB	867	Residents of Ohio 21–74 years of age	Not being residents of Ohio 21–74 years	Probability sampling for	NO
Lee et al.,, 2023	Cross sectional	Survey of Korean Americans in Alabama, USA, to assess HPV and HPV vaccine awareness	HPV	278	1) 21 years or older; 2) resident of Alabama; 3) participants who identified themselves as Korean American	NA	Convenience sampling	NO
Mueller et al.,, 2012	Cross sectional	Survey exploring information channels associated with awareness about human papillomavirus (HPV) among Central and South American immigrant Latinos attending safety-net clinics throughout the USA.	HPV	1334	Eligible participants: 1)self-identified as Latino; 2) ≥21 years old; 3) clinic (nine clinics providing services to uninsured, low-income immigrant Latinos)users or individuals accompanying a registered patient	1)Women enrolled in the Women Infants and Children (WIC) program	Convenience sampling	NO
Seo et al., 2022	Cross- sectional that employed a mixed-methods design	Online surveys and in-depth interviews focusing on American immigrants and their experiences with COVID-19 vaccination uncertainties.	COVID-19	226	1)International migrants aged 18-64 years who moved to the United States in 2011 or later, living in midwestern	1)Participants who had already received the COVID-19 vaccine at the time of data collection.	Convenience sampling	NO
Shah et al., 2023	Cross-sectional	Community-engaged social marketing campaign aimed at improving COVID-19 outcomes among Latino populations in Maryland, USA (Sin Duda campaign).	COVID-19	9607	Latino adults and children in Maryland, with a focus on those with limited English proficiency	NA	Convenience sampling	From March 1, 2021, to March 1, 2022 (1 year)

1.4 Qualitative studies and survey

Study	Design	Study setting	Vaccine of interest	Sample size	Inclusion criterion	Exclusion criterion	Method of recruitment	Follow up
Kim et al., 2023	Qualitative	Assessing the feasibility and acceptability of interventions through digital storytelling workshops, analyzing cultural influences on HPV attitudes, and exploring workshop insights for future interventions among Vietnamese American and Korean American mothers of HPV-vaccinated children recruited from the community in Phoenix, Arizona, USA	HPV	8	Adult women ≥ 18 years, and: (1) self-identified as Vietnamese American or Korean American; (2) first-generation immigrants born outside of the United States; (3) mothers or female primary caregivers with one or more boys or girls aged 11-14 years old who had fully completed the HPV vaccination; (4) spoke English, Korean, or Vietnamese	1) Inability to adhere to the study protocol (2-day virtual workshop)	Snowball sampling	NO
Meyer et al., 2022	Qualitative	Examining healthcare barriers through an exploratory survey, and perceptions of a maternal-child health mobile application focused on antenatal care and vaccinations among Syrian refugees in Istanbul, Turkey, recruited from non-profit organizations and specialized clinics.	Not specified	14	1)Syrian refugee women living in Turkey who either had at least one child under the age of 2 years old or was pregnant at the time of recruitment; 2)Individuals who had not attended a previous training session from the application developers on using the mobile application.	1)Non-Refugee Status; 2)Refusal to Consent	Purposive sampling	NO
Panameno et al.,, 2023	Qualitative	Investigating the use of digital technology to bolster COVID-19 vaccine confidence among Latinx parents of children under-resourced communities across Los Angeles County, USA.	COVID-19	47	Parents having a child in the 5-11 year age, enrollment in MVLA intervention	1)Participants who did not consent	Purposive sampling	NO
Paradis et al., 2018	Survey	Government-assisted refugees at an Ottawa health clinic completed a survey on household demographics, spoken languages, country of origin, technology use, and vaccination history tracking methods.	Not specified	50	All government assisted refugees, privately sponsored refugees or refugee claimants attending The Ottawa Newcomer Clinic (ONC) in Ottawa, Canada who were 16 years of age or older were eligible to participate in this study	NA	Convenience sampling	NO

Table 1: *(continued) Characteristics of the included studies.*

al., 2023; Lee et al., 2023; Mueller et al., 2011) demonstrated a positive correlation between seeking online health information and vaccine uptake. In contrast, Carpenter et al. (2023) found no association between online health information seeking and vaccine intake.

2. Informative Platforms: Various platforms such as mobile applications, social media advertisements, workshops, and messaging systems (SMS/WhatsApp) were assessed. Frick et al. (2023) concluded that informative mobile applications did not significantly enhance knowledge about the virus. Meyer et al. (2022) indicated that contextual challenges and past healthcare experiences could influence migrant populations' attitudes toward these applications. Conversely, Tjaden et al. (2022) and Shah et al. (2023) noted that social media interventions raised awareness among migrants, helping to address potential barriers to vaccination. However, Logie et al. (2024) reported that the immediate increase in vaccine acceptance from messaging platforms diminished after 16 weeks.

3. Appointment Reminder Systems: The effectiveness of appointment reminder systems was evaluated in four studies (DeCamp et al., 2020; Juon et al., 2016; El-Halabi et al., 2023; Xu et al., 2022). These interventions, which included SMS, phone calls, and mobile applications, significantly improved overall vaccination rates, completion of vaccine series, and adherence to timely vaccination schedules.

4. Storytelling Platforms: The impact of storytelling platforms on vaccine uptake was evaluated in three studies (Kim et al., 2023; Chen et al., 2022; Chen et al., 2023). Findings indicated that storytelling interventions could increase intentions to vaccinate and reduce negative attitudes toward vaccines.

Outcomes and Results According to Study Design

Interventional Studies: Among the four randomized controlled trials (RCTs) (DeCamp et al., 2020; Juon et al., 2016; Tjaden et al., 2022; Xu et al., 2022), three were parallel-arm studies comparing digital interventions with standard care, while one (Xu et al., 2022) was a cluster RCT. All RCTs reported vaccination rates, with Xu et al. also assessing vaccine knowledge. The study concluded that app-based interventions were more effective in promoting vaccinations and timely dissemination compared to manual methods.

Seven quasi-experimental studies reported various outcomes, including vaccination rates (Frick et al., 2023), awareness (Logie et al., 2024), intent/willingness (Chen et al., 2022; Chen et al., 2023; Frick et al., 2023; Shah et al., 2023), attitude (Chen et al., 2022; Chen et al., 2023), adherence (El-Halabi et al., 2023), knowledge (Ponce-Gonzalez et al., 2021), and acceptance (Logie et al., 2024). Chen et al. (2022) emphasized the role of digital tools in enhancing vaccination rates, particularly through personalized messaging. Table 2 summarizes the main interventions and outcomes reported in interventional studies.

Descriptive Studies: Among Descriptive studies, cross-sectional designs (n=4) were prevalent, reporting outcomes such as awareness (Lee et al., 2023; Mueller et al., 2012), intent/willingness (Seo et al., 2022), adherence (Carpenter et al., 2023), and knowledge (Paradis et al., 2018). Seo et al. (2022) focused on perceived uncertainty, emotions, outcome expectancy, efficacy, and information-seeking behavior.

Vaccination Uptake: Insights and Influencing Factors

While not all studies reported vaccination uptake rates, variations were noted. DeCamp et al. (2020) found no significant differences in immunization rates between intervention and control groups, although the intervention group had a higher proportion of vaccinated participants. In contrast, Xu et al. (2020) reported over 90% vaccination rates, Frick et al. (2023) noted a 77% rate, and Juon et al. (2016) demonstrated that the intervention group was three to seven times more likely to complete the vaccination series compared to the control group.

Factors influencing vaccination rates included direct communication with healthcare providers, notifications from digital applications, and participation in educational programs (Logie et al., 2024; Ponce-Gonzalez et al., 2021; Chen et al., 2022; Kim et al., 2023). Support from individuals of the same nationality and the use of multilingual applications also facilitated vaccine uptake (Frick et al., 2023; Meyer et al., 2022).

Barriers to vaccination included language difficulties, costs, long wait times, scheduling challenges, and lack of transportation. Concerns regarding data security and interface usability were also raised (Kim et al., 2023). Juon et al. reported that among 96 participants who did not get vaccinated, 46% cited time constraints, 19% were unaware of vaccination locations, 13% lacked health insurance, 11% did not perceive vaccinations as important, and 9% simply

Design	Study	Intervention	Control	Outcomes reported	Results
	DeCamp et al., 2020	Interactive text messages and an educational video	Standard information	Up to date immunization (UTD) and Emergency Department (ED) visit	There were no differences in UTD immunizations between groups. A greater proportion of infants in the intervention group received 2 doses of the flu vaccine compared with the control group-64 (81%) 52 (67%) P=0.04 ED visit mean (SD) 1.23 (1.66) in Salud al Dia vs 1.82 (1.64) in control group, p value 0.003 Incidence rate ratio for ED use for the control vs interventional group 1.48 (95% CI: 1.04-2.12) 34% of intervention group participants having 1 or more no-shows compared with 49% of usual care (P = .06)
Randomized Control Trial	Juon et al., 2016	Telephonic reminders for vaccination	Standard information	Vaccination rate	Those in the intervention group were more likely to complete a series of 3 vaccinations than the control group (51% vs. 15%). Those in the intervention group were about three times more likely to have 1 or more vaccines than the control group (OR = 3.04, 95% CI 1.16, 8.00) compared to those who had never received a hepatitis B vaccination. Those in the intervention group were seven times more likely to complete a series of vaccinations than those in the control group (OR = 7.29, 95% CI 3.39, 5.67) compared to those who never received a vaccination. 70.8% (n = 63) reported our screening program and educational program(e.g., reading photo novels) motivated them
	Tjaden et al., 2022	1. FB Ads in Arabic/Russian 2. FB ads with Religious leaders, Doctor or Family as representative	1. FB ads in German (active control) 2. FB ads with Government official as representative (Active control)	1. Reach by the campaign 2. Click rates (vaccination rates - assuming conversion rate is true) 3. Cost effectiveness 4.Click through rates between advertisements	In Germany, Arabic- and Russian-speakers were 2.4 (95% confidence interval [CI]: 1.9; 2.9) and 1.8 times (95% CI: 1.3; 2.4) more likely to click on vaccine advertisements in their respective languages compared to German language advertisements. Compared to advertisements showing a doctor, a religious leader or a family, Arabic and Russian speakers were more likely to click on the advertisement depicting the government official (p < 0.001 for Arab speakers, p < 0.05 for Russian speakers; (Berlin -Doctor vs. GR OD 0.6 (0.5 - 0.7) N=56,303, Germany excluding berlin OD 0.6 (0.5- 0.6) N= 100,288)
	Xu et al., 2022	Mobile app	Standard information	Vaccination rate, Inoculation rate, vaccine awareness,	No significant difference in vaccination coverage between APP group and non-APP group except for 2ndbOPV and 2ndMenA. The result showed the distribution of inoculation interval was significantly different between two groups (P < .05) except for 4th DPT and HepA-L. Most migrant children above 6 months in the APP group got vaccinations on time, often within a month of their appointment. While the children in the non-APP group mostly delayed vaccination, often three months or more after the scheduled date Less than 50% of guardians clearly knew the vaccine classification policy, with 15.6% in the non-APP group and 44.3% in the APP group, respectively (P = .000).
Quasi experimental studies	Chen et al., 2022	Digital storytelling	Same individual (before-after study)	Attitude to vaccination Intention to get vaccinated	Examination of change in composite attitude scale scores showed no significant difference from pre-intervention to post-intervention (pretest M 2.24; posttest M 2.16), t(113) 1.108),.DST intervention changed VA mothers' attitudes toward HPV vaccination in relation to absence of child's physical symptoms (i.e., if nothing is physically wrong, then my child does not need the vaccines) and sexual engagement (i.e., it is shameful to have my child vaccinated because people may think they are already sexually active in this young age). After the intervention, 74% of the VA mothers intended to vaccinate their children against HPV versus 53% prior
Quasi experimental study	Chen et al., 2023	Digital storytelling	Same individual (before-after study)	Change in attitudes toward vaccination Rates of intention to vaccinate	The mothers' intention to vaccinate their children increased significantly from 62.8% to 78.7% after the intervention The mother's negative attitudes toward HPV vaccination decreased significantly from pre- to post-intervention (pretest mean = 2.21; posttest mean = 2.06), t(163) = 2.49, P = .014.) Logistic regression model showed that the composite measure of mother's negative attitudes toward HPV and the vaccine was significantly associated with vaccination intention, such that more negative attitudes (i.e., higher composite scores) were associated with a lower likelihood of intending to have the child vaccinated (OR = 0.27; 95% CI = 0.14, 0.51; P < .001)
Quasi experimental study	El-Halabi et al., 2023	Mobile app	Standard information	Adherence to the vaccination schedule	In the intervention group, 24.6% (n = 116/471) of babies came back on time, versus 20.7%. (n = 96/465) of babies in the control group (p = 0.01). Babies who never came back, during the study period, were 22.5% (n = 106/471) and 27.8% (n = 129/465) in the intervention and control groups, respectively The relative risk reduction rate in the chance to come back late for the vaccination appointment was 19% for the intervention group Risk of coming late to vaccine appointment, using Kaplan Meier survival analysis, showed a statistically significant reduction in coming back, within 0–14 days, within the vaccine appointment period (p < 0.01)
	Frick et al., 2023	Mobile App	Same individual (Before – After Study)	Vaccination rate willingness	20% (13/65) of participants stated their willingness to get vaccinated as soon as possible. Only 5% (3/65) of participants were reluctant to be vaccinated
	Logie et al., 2024	Mobile app	Same individual (before-after study)	Vaccine acceptance	At baseline, participants reported low levels of acceptance towards a COVID-19 vaccine (mean: 2.1, SD: 1.1). In adjusted analyses, COVID-19 vaccine acceptance increased significantly after the intervention at T2 (a β= 0.15; 95% CI 0.02 to 0.29; p = 0.022), but attenuated at T3 (a β= 0.13; 95% CI -0.01 to 0.27; p = 0.065) At the 16-wk follow-up, most participants reported using the Wel- Tel SMS informational messages (n = 256, 84.8%), with those using the service reporting a positive user experience (mean: 2.7,0.3)
	Ponce-Gonzalez et al., 2021	Virtual workshops	Same individual (before-after study)	Reach, knowledge of vaccine	Knowledge of the existence of a vaccine for influenza increased from 61% to 81% and knowledge of the existence of oral influenza vaccines increased from 45% to 75%.proportion of participants who identified vaccination as effective for influenza increased from 29% to 47.7%. The post-survey also inquired about participant satisfaction and showed there were generally favorable opinions of the workshops; 76% rated their workshop as "excellent" and 83% said the trainer was a "very good educator."
	Shah et al., 2023	Social media campaign of FB, instagram and whatsapp	NA	Click rates, reach, Service Utilization, Website Visits, Survey Responses	Facebook was the most common means of exposure (n = 102; 84% of those exposed), followed by WhatsApp (n = 64; 53%). Of the respondents exposed to the campaign, 61% (n = 74) reported that it influenced their decision to get vaccinated, 32% (n = 39) reported that it helped them understand how to obtain vaccination or testing, 12% (n = 14) reported that it influenced their decision to undergo COVID-19 testing, and 16% (n = 19) reported that it did not influence them.

Table 2: *(Interventional studies: Intervention, outcome and main results.*

forgot.

Regarding the effectiveness of digital health interventions, studies recorded metrics such as acceptability, feasibility, participation rates, cost-effectiveness, and user perceptions.

In observational studies, common confounders included socioeconomic status, education level, and language barriers, which impacted access to healthcare and understanding of vaccination benefits. Cultural beliefs contributed to vaccine hesitancy, with some immigrants expressing distrust in the healthcare system. Legal status and fear of deportation further complicated access to services.

Despite variability in study designs, the evidence suggests that lack of knowledge is a significant barrier to improving vaccination rates among immigrants.

Assessment of risk of bias

The analysis identified several key sources of bias.

•Confounders: Many studies failed to identify potential confounding variables.
•Self-Reported Outcomes: A reliance on self-reported data was prevalent.
•Statistical Methods: Inappropriate statistical techniques were commonly used.

Additional concerns included small cohort sizes with high dropout rates, leading to selection bias, and a predominance of qualitative approaches in immigration settings.

Among the studies reviewed, only one case-control study exhibited a high risk of bias.

While RCTs and quasi-experimental designs can reduce confounding factors, some studies exhibited high risks of bias, necessitating careful consideration in future analyses. Notable issues included a lack of blinding, inadequate allocation concealment, and no strategies for addressing missing data.

For quasi-experimental studies, the primary sources of bias involved the selection process and the absence of a control group.

Discussion

This scoping review analyzed 19 studies focusing on the impact of digital health interventions on vaccination rates and awareness among migrant populations. The results of this study indicated a rise in vaccination rates and adherence by using various digital tools like mobile applications, reminder systems, and social media campaigns. More specifically, interventions, including SMS reminders, stories platforms, and health information workshops, were associated with increased vaccine knowledge, acceptance, and participation. However, the review also identified several persistent barriers, such as limited healthcare access, language challenges, and trust issues, which impact the effectiveness of these interventions. These findings underscore the need for targeted, culturally sensitive strategies to improve vaccination outcomes in different migrant communities.

There are several areas of opportunity to improve vaccination practices in migrant populations. As an example, a critical area is vaccination awareness, as lack of access to culturally-adapted information, safety concerns, and misinformation have been underlined as factors influencing it (Daniels et al., 2022). The different digital health interventions identified in our review showed an overall positive impact on vaccination awareness. Digital health interventions informed some stakeholders' decision-making (e.g., individuals, the health workforce, and health systems) to enhance health and wellness and to reinforce toughness to disease (Digital Health and Innovation (DHI), 2023), providing a potential solution to tackle the existing barriers. These interventions resulted in better outcomes by promoting direct communication with healthcare professionals, providing reminders, and encouraging active program participation. Moreover, highlighting findings from previous studies underlining the impact of vaccination knowledge of vaccines on coverage (Wong et al., 2024), we observed that assistance from individuals with similar characteristics, such as nationality and language, was a facilitating factor contributing to digital health intervention effectiveness. Nevertheless, there are several challenges to implementing digital health interventions, such as their financial burden, lack of healthcare coverage in target populations, data security uncertainties, and inexperience (Juon et al., 2016).

A noteworthy strength of the studies included in our review was that most of the interventions targeted specific migrant populations. They were either conducted in a language understood by the target population, or translators were provided, underscoring the importance of cross-cultural adaptation in caring for the migrant population (Tang & Zhang, 2024).

We observed some limitations in the review's studies. First, the migrant populations evaluated in the 19 included studies were heterogeneous. Although studies were conducted in multiple countries across four continents and included migrants from different ethnicities and socio-economic backgrounds, the generalizability of the individual studies is limited due to diverse cultural beliefs, attitudes, and idiosyncrasies. Moreover, there were considerable differences in outcome measurement, limiting standardization. For

Study	Associations found	Outcomes reported	Results
Carpenter et al., 2023	Internet Use	Adherence to HBV vaccination	26.6% of respondents received at least three doses of the HBV vaccine.
	Race		A significant association was found between the primary exposure, using the internet as a source for health information, and having received at least three doses of the HBV vaccine (OR: 1.75; 95% CI: 1.30, 2.38; P Value = 0.0003), However when adjusted for race and education the association was not found to be significant.
	Education		Hispanics had lower odds (OR = 0.35) of completing the HBV vaccination compared to whites.
			African Americans had lower odds (OR = 0.53) compared to whites.
			Individuals with a high school diploma or less had lower odds (OR = 0.33) compared to college graduates
Lee et al., 2023	Age Gender Marital status Internet use for health	HPV and HPV vaccine awareness	Having annual health check-ups. Participants who were older than 50 years were less likely to hear of HPV (OR=0.16, CI=0.06-0.43, P<0.05) and HPV vaccine (OR=0.26, CI=0.10–0.66, P<0.05),
			Females were more likely to hear of both HPV (OR=5.95, CI=2.77- 12.80, P<0.05) and HPV vaccine (OR=5.20, CI=2.45- 11.03, P<0.05).
			Participants who were married or partnered were less likely to hear of HPV (OR=0.23, CI=0.07-0.77, P<0.05) or HPV vaccine (OR=0.23, CI=0.07-0.77, P<0.05).
			Participants using the internet for health purposes had a higher likelihood of being aware of the HPV vaccine (OR=1.15, CI=1.00-1.32, P<0.05).
Mueller et al., 2012	Internet access. Increased use of media for health information.	HPV awareness and HPV Vaccine awareness	Most reported hearing about HPV and its vaccine through Spanish language television (38 and 52%, respectively). 71% trusted television health information.
			The adjusted odds of HPV infection awareness (vs. no awareness) were 1.47 (95% CI: 1.10–1.96) times higher among participants with internet access compared to those without
			Greater vaccine awareness was associated with internet use (OR1.59; 95% CI 1.18–2.13).
			Vaccine awareness was also higher among those with increased use of media for health information (OR 1.27; 95% CI 1.09–1.49), considering covariates
Seo et al., 2022	Education. Perceived uncertainty. Emotion. Outcome expectancy Information seeking behavior	COVID 19 Vaccine willingness	Education was the only variable that was significantly associated with perceived uncertainty ($\beta=-0.37$, $t=-2.91$, $p < 0.01$).
			Higher perceived uncertainty about COVID-19 vaccinations was negatively associated with positive emotions (e.g., excitement, interest). This means that the more uncertain participants felt, the less positive emotion they experienced ($\beta=-0.43$, $t=-4.59$, $p < 0.001$).
			Positive emotions were significantly associated with outcome expectancy ($\beta=0.30$, $t=2.98$, $p < 0.01$) and efficacy ($\beta=0.28$, $t=2.79$, $p < 0.01$).
			Negative emotions were not significantly associated with outcome expectancy ($\beta=-0.17$, $t=-1.26$, $p=0.21$) or efficacy ($\beta=-0.06$, $t=-0.67$, $p=0.51$).
			There was no significant association between perceived uncertainty and negative emotions (e.g., worry, anxiety) ($\beta=0.13$, $t=-1.27$, $p=0.21$).
			Both outcome expectancy ($\beta=0.25$, $t=2.95$, $p < 0.05$) and efficacy ($\beta=0.53$, $t=5.88$, $p < 0.001$) were positively associated with seeking information about COVID-19 vaccinations.
			Information seeking itself was not directly associated with vaccine willingness ($\beta=-0.02$, $t=-0.25$, $p=0.80$).
			The relationship between information seeking and vaccine willingness was moderated by issue salience.
			For participants with low issue salience, increased information seeking was associated with lower vaccine willingness.
			For those with high issue salience, increased information seeking was associated with higher vaccine willingness.

Table 3: *Descriptive studies: Exposure, outcome and main results.*

instance, various methods were utilized to measure vaccine uptake and facilitators. In addition, few studies measured the actual influence on vaccine coverage on their respective interventions, hindering the assessment of their clinical significance. Furthermore, heterogeneity in the methodologies challenges evaluating the comparative effectiveness of different interventions, particularly regarding eligibility criteria, sampling, and follow-up periods.

A considerable proportion of the studies had a high risk of bias assessment. The domains that were found to be most high risk were "no identification of confounders, self-reported outcomes, and inappropriate statistical methods". Therefore, their results may be impacted by confounders, limiting the ability to draw conclusions on the effect of the interventions. Additional randomized controlled trials are necessitated to assess the impact of digital health interventions to improve vaccination in migrant populations.

Despite the high risk of bias and variability in our findings, our review indicates that raising awareness about diseases and prevention strategies can help address disparities and enhance vaccination access, particularly for immigrants. Digital health approaches allow for effective monitoring, adjustment, and targeted implementation, potentially leading to improved health outcomes. The insights gained from this review, along with existing evidence, underscore the importance of tailoring digital health interventions to specific populations. By developing culturally appropriate and user-friendly solutions, policymakers can better integrate these interventions into healthcare systems.

Our scoping review also identifies key areas for future research. Important questions include the impact of digital health interventions on vaccine coverage among migrant populations and their long-term effects. Additionally, exploring the relationship between social determinants of health and vaccine uptake could inform the design of more effective digital health strategies.

Conclusion

This scoping review details digital health interventions aimed at improving vaccination in diverse populations, offering insights into existing evidence and identifying gaps in knowledge. While these interventions show promise in increasing vaccination awareness among migrants, they must address specific barriers and cultural beliefs. Our findings highlight several evidence gaps, including limited global representation and the need for comparative effectiveness studies. Further research is essential to explore the long-term effects of digital health interventions on vaccination coverage.

Supplementary Materials

Supplementary Table 4: Search strategy

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Conflicts of Interest

The authors declare no conflict of interest.

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