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Systematic Reviews

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Interventions to increase vaccination against COVID-19, influenza and pertussis during pregnancy: a systematic review and meta-analysis

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Abstract

Background: Pregnant women and their babies face significant risks from three vaccine-preventable diseases: COVID-19, influenza and pertussis. However, despite these vaccines' proven safety and effectiveness, uptake during pregnancy remains low.

Methods: We conducted a systematic review (PROSPERO CRD42023399488; January 2012–December 2022 following PRISMA guidelines) of interventions to increase COVID-19/influenza/pertussis vaccination in pregnancy. We searched nine databases, including grey literature. Two independent investigators extracted data; discrepancies were resolved by consensus. Meta-analyses were conducted using random-effects models to estimate pooled effect sizes. Heterogeneity was assessed using the I^2 statistics.

Results: From 2681 articles, we identified 39 relevant studies ($n = 168\,262$ participants) across nine countries. Fifteen studies (39%) were randomized controlled trials (RCTs); the remainder were observational cohort, quality-improvement or cross-sectional studies. The quality of 18% (7/39) was strong. Pooled results of interventions to increase influenza vaccine uptake (18 effect estimates from 12 RCTs) showed the interventions were effective but had a small effect (risk ratio = 1.07, 95% CI 1.03, 1.13). However, pooled results of interventions to increase pertussis vaccine uptake (10 effect estimates from six RCTs) showed no clear benefit (risk ratio = 0.98, 95% CI 0.94, 1.03). There were no relevant RCTs for COVID-19. Interventions addressed the 'three Ps': patient-, provider- and policy-level strategies. At the patient level, clear recommendations from healthcare professionals backed by text reminders/written information were strongly associated with increased vaccine uptake, especially tailored face-to-face interventions, which addressed women's concerns, dispelled myths and highlighted benefits. Provider-level interventions included educating healthcare professionals about vaccines' safety and effectiveness and reminders to offer vaccinations routinely. Policy-level interventions included financial incentives, mandatory vaccination data fields in electronic health records and ensuring easy availability of vaccinations.

Conclusions: Interventions had a small effect on increasing influenza vaccination. Training healthcare providers to promote vaccinations during pregnancy is crucial and could be enhanced by utilizing mobile health technologies.

Key words: Vaccine hesitancy, strategies, maternal immunization, vaccine confidence, public policy, antenatal care, maternal health

Introduction

Unvaccinated pregnant women face an elevated risk of severe illness, complications and death from infection with the viral pathogens SARS-CoV-2 and influenza.[1–9]

Similarly, pertussis (whooping cough) bacterial infection poses a considerable threat to infants, resulting in high rates of hospitalization and mortality.[10–12] Vaccination during pregnancy provides a high level of protection against these adverse outcomes.[13–21] Most importantly, vaccination in pregnancy is safe[3,4,22–25] and is strongly recommended for all three vaccines: COVID-19, influenza and pertussis.[26,27]

Historically, the US Centers for Disease Control and Prevention (CDC) first recommended influenza vaccination for pregnant women in 1997, followed by Australia in 2009 and the UK in 2010. This is typically administered seasonally.[28,29] Pertussis vaccination (usually at 16–32 weeks gestations for each pregnancy) was added to the CDC's maternal immunization recommendations in 2010, with the UK following in 2012 and Australia in 2015.[28] COVID-19 vaccination (effective against early pandemic strains) is offered seasonally to pregnant women.[28] While the pertussis vaccine mainly aims to protect the infant by passive transfer of maternal antibodies, influenza and COVID-19 vaccines are designed primarily to protect the mother, indirectly benefiting the infant. This may necessitate tailored messaging for pregnant women.

Despite the well-established benefits, low vaccine uptake during pregnancy and high levels of vaccine hesitancy (delay in acceptance or refusal of safe vaccines despite availability of vaccine services) are reported across the world.[3,24,30–44] Vaccine hesitancy is recognized as a top 10 global health threat by the World Health Organization.[45] This complex phenomenon manifests differently across time, regions and sociodemographic factors.[45] Lower vaccination rates during pregnancy are associated with younger age,[3,24,33] lower socioeconomic status,[3,24,33] minority ethnicities, particularly Black and Latino populations,[3,38,43,44] and migrant groups.[34,46–49] Other barriers include concerns over vaccines' long-term safety, side effects and efficacy, conflicting guidance from healthcare professionals, distrust of vaccines and healthcare providers, limited knowledge about vaccines and practical challenges like inconvenient vaccination schedules and locations.[37,39,45,50,51] The COVID-19 pandemic highlighted the importance of vaccination during pregnancy and revealed health disparities amongst different ethnic and socioeconomic groups.[48,52,53] It is crucial to address these inequalities through effective interventions.

Previous systematic reviews showed that healthcare professionals' recommendations, vaccination reminders in antenatal records and midwives administering vaccines might be effective[30,54–56]; however, most interventions lack robust evaluation.[30,45,54,57–61] A knowledge gap exists regarding effective interventions to enhance the uptake of all recommended vaccinations during pregnancy. In 2022–23, we conducted the first-ever systematic review of studies of interventions to increase vaccination in pregnancy against three vaccine-preventable diseases: COVID-19, influenza and pertussis.

Methods

Search strategy and selection criteria

A systematic literature review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[62] The review protocol was registered on PROSPERO (International Prospective Register of Systematic Reviews; CRD42023399488). The primary outcome was pregnant women's vaccination status and intention to vaccinate. We restricted the search to high-income countries with well-established vaccination programmes. Secondary outcomes were factors associated with vaccine acceptance or refusal (e.g. ethnicity, age, setting, vaccine type and socioeconomic status).

We conducted a comprehensive search of relevant literature, encompassing both peer-reviewed and grey literature. A Boolean search strategy was applied across multiple databases for primary research reporting on interventions to increase vaccination (influenza, pertussis, COVID-19) in pregnancy between 1 January 2012 to 15 December 2022 (see Appendix 1 for full search terms) with no language restrictions. We searched Embase, Web of Science, Oxford Academic Journals, PubMed NIH, Clinical Trials, China CDC, CDC reports and the WHO COVID-19 global literature database for COVID-19 literature.[63] Influenza/pertussis literature was searched using Embase, CINAHL, PsycINFO and Medline. Supplementary grey literature was identified through a thorough examination of key institutional websites such as the Royal College of Obstetrics & Gynaecology and the UK Health Security Agency, as well as Google Scholar, manual searches and backwards and forwards citation checking.

Inclusion criteria were quantitative papers related to the outcome measures, including grey literature (e.g. government guidelines, preprints) reporting vaccination or intention to vaccinate in currently pregnant and recently post-partum women (within 12 weeks of childbirth). We included papers that presented primary data from randomized controlled trials (RCTs), as well as observational studies (such as cross-sectional, case–control, quality improvement or cohort studies). In quasi-experimental studies such as quality improvement and audit, we allowed the control groups of either standard/usual care, historical control groups or pre-and-post-intervention assessments. We excluded conference abstracts, systematic reviews, comments, editorials, literature reviews and letters. We included countries in the World Bank's list of high-income countries.[64]

Data screening, extraction and analysis

M.S.R. carried out title and abstract screening and performed full-text screening, data extraction and quality assessment. In line with PRISMA guidelines, all steps were duplicated by an independent second investigator (R.M., C.M.A., S.F. or K.R.). Once the abstracts were regarded as relevant, the full paper was reviewed and scrutinized using strict inclusion/exclusion criteria. Any discrepancies were resolved by discussion between authors (M.S.R., R.M.).

Data extraction from each study was conducted according to predefined criteria. The extracted information included the first author, year of publication, study design, location (online, community, hospital) and date. The vaccine of interest (e.g. COVID-19, influenza, pertussis), sample and effect size, basic demographic characteristics of participants (ethnicity and age), gestational age, vaccination rate and intent to vaccinate were also collected. For RCTs, we extracted relative risks (RRs) from intention-to-treat analysis. When RRs and CIs were not presented, we calculated them from available data using STATA.[65] In cases of multiple comparisons within a single study, such as multiple vaccines and interventions, effect sizes were not combined. We used a random-effects meta-analysis with STATA (version 18)[65] to calculate pooled log risk ratio estimates and associated 95% confidence intervals (95% CI), using a restricted maximum likelihood method.[66] Results were back-transformed to risk ratios. Statistical heterogeneity was assessed using the I^2 and Chi^2 statistics. An I^2 value under 40% suggests statistical heterogeneity might not be important.[67]

Quality assessment was conducted independently by two reviewers (M.S.R., R.M. or P.K.) using the Effective Public Health Practice Project's (EPHPP) Quality Assessment Tool for Quantitative studies.[68,69] Where decisions could not be reached, a third reviewer (P.O.) arbitrated. This tool was chosen because it allows for the assessment of both RCTs and observational studies using a single framework and has demonstrated strong agreement amongst raters in systematic reviews. The EPHPP framework evaluates the quality of studies based on criteria such as selection bias, design, confounding, blinding, data collection, participant withdrawal and opt-out, intervention integrity and analysis. Each paper was assigned a score of 'weak', 'moderate' or 'strong' based on its design and analysis.[69] To ensure transparency, we did not exclude any study based on quality assessment.

Results

Overview of included studies

Figure 1 shows the PRISMA flow diagram.[62] There was a total of 39 eligible studies ($n = 168\,262$ participants). A summary of the descriptive characteristics of these studies is shown in Table 1. Most studies were observational (e.g. cohort, quality improvement and cross-sectional $n = 24/39$, 61%), and the remaining were RCTs (15/39, 39%). The sample size of the studies ranged from 67 to 78 898 participants (median 518). Most studies were conducted in the USA (24/39, 61.5%), followed by Australia and New Zealand (6/39, 15%) and the UK (3/39, 8%) (Figure S1). The majority of studies were on influenza and pertussis (37/39, 95%) with only two focusing on COVID-19. Twenty-four studies reported the ethnicity of participants (the majority were White).

The quality of seven studies (18%) was assessed as strong (Figure S2). The remaining 32 had weaknesses such as inadequate study designs, insufficient consideration or control of confounding factors and lack of clarity about the reliability or validity of data collection methods. Most RCTs (9/15, 60%) did not report any significant effect from the interventions.

Narrative summary of included studies by intervention types

The interventions were broadly categorized into patient-level, provider-level, policy-level and multi-modal strategies (outlined below and summarized in Table 1 and Supplementary Figure S1). Most studies (18/39) were patient-level interventions such as providing pregnant women with information or verbal counselling, prompting through reminders and tailored messages. Provider-level interventions (5/39) included training healthcare professionals and setting reminders for healthcare staff. Policy-level interventions (5/39) included funding community pharmacies to vaccinate pregnant women, implementing guidelines and enforcing electronic alerts in medical records. Multi-modal interventions (11/39) using a combination of two or three domains were common, highlighting the multipronged approach to vaccination. We provide intervention details and their effectiveness below.

Patient-level interventions (n = 18). Twelve out of 18 studies reported positive effects of the interventions, seven of which were significant. Only five studies explicitly referenced a health behaviour change technique[70] that underpinned their interventions.[71–75]

Three educational trials showed benefits. An RCT of pamphlets and statements of benefits of vaccination improved influenza vaccine uptake and perception of vaccine safety.[75] Another RCT demonstrated improved vaccination uptake for influenza amongst participants given a leaflet and a one-to-one education session.[76] A further trial showed that a patient educational video and iBook for pertussis information increased vaccination rates. Lack of recommendations from healthcare professionals and awareness were identified as reasons for not receiving the vaccine.[71]

Three trials using technology showed benefits, including a study in less affluent pregnant women. Interactive education and reminder text messages increased uptake of influenza vaccination.[74] Text message reminders and influenza vaccine information increased vaccination rates in urban low-income women, especially in the early third trimester.[77] Another RCT where participants were given access to a vaccine information website with interactive social media content increased influenza vaccine uptake but not pertussis, compared to controls.[78]

However, four patient-level interventions did not show benefits. These included twice-weekly text messages recommending the influenza vaccine[79]; video case studies and interactive educational tutorials for patients based on affective and cognitive messaging[80]; an educational video developed by the CDC[81]; modifying CDC information leaflets to lower literacy levels[82]; and 12 weekly text messages about the importance of having the influenza vaccine.[83]

Table 1. Details of 39 included studies including quality assessment

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Baxter et al. (2013)[98]	UK Community Clinic	Ecological Study	Weak	Not reported	Influenza	Multi-modal community awareness campaign (e.g. media, radio, newspaper, leaflets, posters, direct contact) Community pharmacy programme (advice and immunization) GP financial incentive (if 75% of pregnant women vaccinated)	England 2010/2011 At risk: 56.6% Not at risk: 36.6%) 2011/2012 At risk: 50.8% Not at risk: 25.5%	Stockport 2010/2011 At risk: 65% Not at risk: 53% 2011/2012 At risk: 79.7% Not at risk: 63.4%	• Following the intervention, Stockport (an affluent part of Manchester) had the highest influenza vaccine coverage in England. • Real-life case stories used during community campaigns to address myths and misconceptions about vaccination were effective. • The enthusiasm, support and confidence of staff (midwives, GPs and practice nurses) were crucial. • GP incentive scheme encouraged GPs to meet specific targets and increase uptake.
Bechini et al. (2019)[84]	Italy Obstetric Clinic	Cohort 2017–18	Moderate	Size: 201 Age: 24 Ethnicity: Italian: 198 (98%) Foreign: 3 (1.5%)	Influenza Tdap	Patient education A 30-min presentation on vaccination by experts with handouts of slides for patient participants	[a]72/210, 34% [vaccination intention]	[a]130/201, 65% [vaccination intention]	• After the intervention, hesitancy in the intention to vaccinate during pregnancy decreased and the number of pregnant women with poor knowledge of vaccination decreased by 30% (no *P*-value provided).
Cham-berlain et al. (2015)[97]	USA Obstetric Clinic	RCT 5 months (2012–13)	Moderate	Size: 325 Age: 27.2 ± 5.6 Ethnicity: White: 154 (47%) Black: 133 (41%) Asian: 7 (2%) Other: 31 (10%) Hispanic: 20 (6%)	Influenza Tdap	Multi-modal Practice-, provider- and patient-focused package (e.g. talking points on coloured papers, vaccine champions, lapel buttons for staff, provider education, posters, brochures and iPad tutorials for patients and maps to vaccination sites)	Influenza: 11/151 (7%) Tdap: 13/151 (9%)	Influenza: 16/149 (11%) Tdap: 19/140 (14%)	• A non-significant increase in vaccination in the intervention group (influenza RD: 3.6%, 95% CI: −4.0, 11.2; Tdap RD: 1.3%, 95% CI: −10.7, 13.2). (raw data for influenza vaccination; intervention: control; 16/149: 11/151) • A non-significant increase in likelihood (50%) to receive any Tdap vaccine in the intervention than the control group (RR = 1.47, 95% CI: 0.70, 3.12), with 13.1% design-adjusted absolute difference. (raw data for pertussis vaccination: intervention: control; 19/140: 13/151) • Most intervention components positively associated with vaccine receipt • Provider recommendation was most strongly associated with actual receipt regardless of study group or vaccine

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Chang et al. (2022)[73]	Taiwan Hospital Clinic	RCT 2 months (2020–21)	Moder-ate	Size: 2092 Age: Control: 32.1 ± 5.6 Intervention: 31.9 ± 5.1 Ethnicity: not reported	Influenza	Patient education and prompting The app uploads announcements, news, epidemic prevention policies, and health information. It reminds pregnant women about influenza vaccines and requests vaccination status feedback every 2 weeks.	[a]9/117 (8%) [vaccination intention]	[a]22/126 (17%) [vaccination intention]	• Women in the intervention group had 2.41-times higher odds of experiencing a positive change in vaccination intention compared to the control group (OR = 2.41, 95% CI: 1.04–5.55, $P = 0.03$). • The intervention group showed a 11.64% increase in knowledge scores regarding influenza vaccine vs 7.39% in control group. Intervention was significantly more effective than standard maternal education
Costantino et al. (2021)[116]	Italy Hospital Clinic	Cross sectional 2019–20	Weak	Size: 326 Age: 18–24: 5, 1.5% 25–34: 215, 66% 35–40: 94, 28.8% 40+: 12, 3.7% Ethnicity: not reported	Influenza Tdap	Patient education Healthcare professionals provided 1-h education on immunization and vaccination during childbirth classes in-person or online and offered counselling to those with questions and concerns	Influenza: 10/326, 3.1% Tdap: 24/326, 7.4%	Influenza: 96/201, 47.8% Tdap: 116/201, 57.7%	• After intervention, influenza vaccine recipients increased by 44.8%, Tdap recipients increased by 50.7 and 64.2% received both vaccines (a 54.8% increase). • Increased vaccination was associated with higher education, employment, prior accurate knowledge about vaccination and previous vaccine uptake. • After intervention, reasons for refusal were fear of adverse events (47.6%), vaccines not recommended by obstetrician (43.4%) and intervention conducted outside of seasonal vaccination campaign (9%). Additionally, 43% of pregnant women who refused vaccination were discouraged by their obstetrician
Dehlinger et al. (2021)[99]	USA Obstetric Clinic	Pre–post QI 2019–20	Moder-ate	Size: 2967 Age: not reported Ethnicity: Controls Asian: 89, 6.0% AA: 561, 37.9% Hispanic: 86, 5.8% Multiracial: 28, 1.8% Other: 24, 1.6% White: 688, 46.4% Intervention Asian: 87, 5.8% AA: 522, 35.2% Hispanic: 78, 5.2% Multiracial: 28,1.8% Other: 32, 2.1% White: 741, 49.8%	Influenza	Multi-modal Patients received written information dispelling myths and highlighting the benefits of influenza vaccination for infants and mothers. Posters from the CDC promoting vaccination were displayed in patient restrooms. Clinicians were educated on patient barriers, vaccine recommendations, positive messaging, best practices and received periodic reminders. The electronic health record included a prompt via a best-practice advisory.	870/1480, 58.7%	940/1487, 63.2%	• After the intervention, 940 (63.2%) influenza vaccines were identified (2019–20 season) in patients' records compared to 870 (58.7%) in 2018–19. • The number of records without a vaccination code was significantly less after the intervention in 2019–20 season compared to the 2018–19 season (13.9 vs 22.9%; $P < 0.001$).

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Deverall et al. (2018)[31]	New Zealand Hospital Clinic	Pre–post audit 2017	Moderate	Size: 111 Age: <25: 50 (45%) >25: 58 (52%) Ethnicity: Māori: 54 (48%) European: 32 (29%) Other: 25 (23%)	Pertussis	Multi-modal Maternity units notify GPs about their patient's pregnancy for vaccination discussions. A nurse attends antenatal classes for opportunistic immunization. After-hours vaccination is available at the pharmacy and the community child health nurse vaccinates pregnant women at a monthly clinic.	31/69 (45%)	16/21 (76%)	• The multi-modal approach in the intervention areas resulted in improved vaccine uptake. • A woman not being recalled to the GP for vaccination was the biggest reason for not being vaccinated.
DiTosti et al. (2021)[100]	USA Women's Hospital	Cohort 2011–15	Strong	Size: 2294 Age: Control: 32.8 ± 5.2 Intervention: 33.2 ± 4.8 Ethnicity Controls White: 369, 53.6% Black: 92, 13.9% Asian: 100, 15.2% Hispanic: 70, 9.1% Other: 58, 8.3% Intervention: White: 924, 57.6% Black: 199, 12.1% Asian: 186, 10.9% Hispanic: 119, 7.7% Other: 182 11.7%	Influenza Tdap	Multi-modal updated vaccination guidelines (2012) recommending universal Tdap in pregnancy: electronic medical record reminders, increased stocking of vaccines, routine sharing of information with providers to increase knowledge	Tdap: 324/684, 47.4% Influenza: 419/684, 61.2%	Tdap: 1385/1610, 86.1% Influenza: 1159/1610, 72%	• After guidelines, Tdap uptake increased (47.4 vs 86.1%, $P < 0.001$). Post-guideline cohort had 4.50-times greater adjusted odds of receiving the vaccine compared to pre-guideline cohort (95% CI 3.54–5.72). Receiving the Tdap vaccine within the recommended time improved from 52.5 to 91.8%. • Post-guidelines, influenza vaccine frequency improved (61.2 vs 72%, $P < 0.001$). Post-guideline cohort had an adjusted 70% increased odds of receiving the vaccine compared to pre-guidelines cohort (aOR 1.71, 95% CI 1.40–2.07). • Non-Hispanic Whites were more likely to receive both vaccines ($P = 0.017$) compared to Non-Hispanic Blacks. • An increased number of prenatal visits was associated with receiving both vaccines (respective, aOR 1.09 95% CI 1.05–1.13; aOR 1.50 95% CI 1.17–1.94).
Frew et al. (2016)[80]	USA Antenatal Clinic	RCT 2 months in 2013	Moderate	Size: 95 Age: 26.1 ± 5.5 Ethnicity Black/AA: 94, 99% Other: 1, 1%	Influenza	Patient education Video case studies and interactive educational tutorials. Group 1: 'Pregnant Pause' video, affective messaging Group 2: 'Vaccine for Healthy Pregnancy' video, cognitive messaging	4/34 (12%)	1: 4/31 (13%) 2: 2/30 (7%)	• No significant difference in vaccination rate between groups. Log binomial regression models showed no association in intention to receive vaccine during future pregnancies based on any group. (Influenza vaccine administered during pregnancy; risk ratio compared to control for (a) pregnant pause movie: 1.10 (0.30, 4.01; (b) iBook 0.57 (0.11, 2.88) • Main reasons for not receiving the influenza vaccine: – Vaccine safety concerns (47%, $n = 40$) – low perceived risk of influenza infection (31%, $n = 26$).

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	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (n) –age (mean ± SD) –ethnicity (n, %)	Vaccine	Intervention	Control vaccination rate (n, %)	Intervention vaccination rate (n, %)	Findings
Goodman et al. (2015)[81]	USA Obstetric Clinic	RCT 2013–14	Moderate	Size: 100 Age: 31 ± 5.4 Ethnicity: Control Black 23.1% Asian 1.9% White 71.2% Hispanic 1.9% Multi-race 1.9% Refused 0% Other 0% Intervention: Black: 20.8% Asian 0% White 73.6% Hispanic 1.9% Multi-race 0% Refused 1.9% Other 1.9%	Influenza	Patient education Educational video developed by the CDC: 'Protect Yourself, Protect Your Baby' (3 ½ min) based on the Health Belief Model	13/52 (25%)	15/53 (28%)	• No significant difference in vaccination rate between groups. (Raw data for influenza vaccination; intervention: control; 15/53: 13/52) • Multivariate analysis showed two beliefs independently associated with vaccination: – 'Flu shot protects me' (OR = 2.19, 1.08-4.44, $P = 0.003$) and – 'Flu shot protects my baby' (OR = 2.04,1.14–3.66, $P = 0.02$). • Forty-five (46%) received recommendation from a healthcare professional. Those with recommendation were more likely to be vaccinated (21/45, 47% vs 6/52, 12%, $P < 0.001$) • Intervention positively influenced four health beliefs with significant differences in mean pre- vs post-video scores (intervention vs control, respectively): – Flu shot may harm me (−0.36 vs 0.14, $P = 0.009$), – Flu shot may harm my baby (−0.36 vs 0.09, $P = 0.015$), – Flu shot protects me against flu (0.43 vs −0.06, $P = 0.003$), – Flu shot protects baby against flu (0.82 vs 0.23, $P = 0.001$).
Healy et al. (2015)[101]	USA Hospital Clinic	Pre–post QI 2013–14	Weak	Size: 6577 Age: 29.8 Ethnicity White: 43.6% Hispanic: 27% Black/AA: 21% Asian: 7.1% Native: 0.5% Other: 0.8%	Tdap	Multi-modal implementation of American College of Obstetricians and Gynaecologists (ACOG) Guidelines recommending universal Tdap vaccination in pregnancy (2013). Educating healthcare staff about recommendations and providing ACOG toolkit	Not reported, 36%	3678/6577, 56%	• Tdap vaccination rate increased from 36% in women who delivered in April 2013 to a sustained rate of more than 61% since November 2013. • Vaccination rate based on gestational age – 95% received Tdap during weeks 27–36 of pregnancy – 71.6% during weeks 28–32. – 3621 (98.5%) received Tdap at least 7 days before delivery – Of 19 women who had two deliveries within the 15-month study period, four (21%) received Tdap in both pregnancies • Demographic associations – Black women were less likely than other ethnicities to receive Tdap (41 vs 59%; $P < 0.001$) – Older maternal age was a positive predictor of receiving Tdap (OR 1.05 for each additional year older, 95% CI 1.04–1.06) – Being Black (OR 0.44, 95% CI 0.38–0.51) or having a preterm infant (OR 0.14, 95% CI 0.09–0.22) were negative predictors

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	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Hirschberg et al. (2021)[96]	USA Obstetric Clinic	Pre–post QI 4 weeks in 2021	Weak	Size: 87 Age: Control: 28.6 Intervention: 29.4 Ethnicity: Controls Hispanic: 2, 6.1% Black: 21, 63.6% White: 12, 36.4% Intervention Hispanic: 3, 5% Black: 44, 73.3% White: 16, 26.7%	COVID-19	Policy Onsite vaccination availability once a week at two high-risk obstetric clinics	1/32, 3%	6/55, 10%	• Onsite vaccination availability did not significantly increase the vaccination rates (3 vs 11%; $P = 0.22$).
Howe et al. (2021)[92]	New Zealand Pharmacies	Pre–post study 2015–19	Strong	Size: 27 576 Age: not reported Ethnicity Māori: 11 302, 41% Pacific: 1137, 4.1% Asian: 2889, 10.5% Other: 457, 1.7% European: 11791. 42.8%	Tdap	Policy community pharmacy funding. One region received funding for maternal pertussis vaccination	Pre-intervention period: 767/2904 (26%) Post-intervention period: 3545/9342 (38%)	Pre-intervention period: 749/3581 (21%) Post-intervention period: 4112/11748 (35%)	• Intervention group: 67% increase in Tdap uptake in the post- vs pre-intervention period and control group: 44% increase in post- vs pre-intervention period. • Odds of Tdap vaccination increased in the post- vs pre-intervention period with this increase being larger ($P = 0.0014$) in intervention (35 vs 21%, OR = 2.07, 95% CI 1.89–2.27) compared to control regions (38 vs 26%, OR = 1.67, 95% CI 1.52–1.84). (Raw data for intervention: Control: 4112/11 748: 3545/9342) • Coverage was lower for Māori vs non-Māori but increased more for Māori in the intervention vs control regions (117 vs 38% increase). • No significant difference in pertussis vaccine uptake by area-level socioeconomic deprivation
Jina et al. (2019)[102]	USA Hospital Clinic	Pre–post QI 2015–16	Moderate	Size: 708 Age: not reported Ethnicity: not reported	Tdap	Multi-modal components: Educating healthcare professionals and patients, increasing Tdap availability, reminding staff to facilitate vaccination, encouraging obstetricians to offer vaccine and transferring Tdap documents from office to hospital	362/636, 56.9%	457/708, 64.5%	• The intervention resulted in a significant increase in Tdap vaccination amongst clinically eligible pregnant women. The absolute difference was 7.6% (64.5 vs 56.9%, $P < 0.01$), representing a relative increase of 13.4% (64/56.9%). • If this vaccination rate of 64% were applied to over 6500 deliveries annually, it would mean an additional 495 women receiving Tdap during pregnancy in this site

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Jordan et al. (2015)[74]	USA Virtual	RCT 1 week in 2012	Moderate	Size: Planning vaccination at baseline: 1652 not-planning vaccination at baseline: 2253 Age: not reported Ethnicity: not reported	Influenza	Patient Education Free national 'Text4baby' education to improve health knowledge and behaviour by sending three weekly interactive text messages and reminders timed to a woman's due date or her infant's birthday based on cognitive theory, health belief model and transtheoretical model.	Planning vaccination at baseline: 821/1360 (60%) Not planning vaccination at baseline: 267/1228 (22%)	Planning vaccination at baseline: 171/292 (59%) Not planning vaccination at baseline: 219/1025 (21%)	• A reminder increased the odds of vaccination at follow-up amongst mothers (AOR.2.0, 95% CI.1.4, 2.9) and of continued intent to be vaccinated later in the season (pregnant, AOR.2.1, 95% CI.1.4, 3.1; mother, AOR.1.7, 95% CI.1.1, 2.5). • Amongst mothers not planning to be vaccinated because of cost, those who received a tailored message about low-cost vaccination had higher odds of vaccination at follow-up (AOR.1.9, 95% CI.1.1, 3.5). (raw data intervention: control for (a) women planning at baseline to get vaccinated: 171/212: 821/1099; (b) women not planning at baseline to get vaccinated 219/877: 267/1025) • Other tailored messages were not effective.
Klatt et al. (2012)[93]	USA Obstetric Clinic	Pre–post QI 1 month in 2008	Moderate	Size: 1284 Age: not reported Ethnicity: not reported	Influenza	Policy A best-practice alert implemented in an electronic prenatal record to inform healthcare providers if a patient had not received vaccination or expressed a well-informed refusal during prenatal visits.	267/639, 41.8%	393/645, 60.9%	• Post-intervention (2008–09), there was increased vaccination amongst women, increased documented discussions about influenza vaccination (compared to 2007–08) and 68.1% of women accepted vaccination after discussion. • In 2007–08, most unvaccinated women had no documented discussion, whereas in 2008–09, the main reason for not getting vaccinated was an informed refusal.
Krish-naswamy et al. (2018)[90]	Australia Maternity Hospital	Cross-sectional 2015–17	Weak	Size: 916 Age: not reported Ethnicity: not reported	Tdap	Provider different healthcare professional–led immunization services Hospital A: nurse-led immunization Hospital B: standing order for midwife-led vaccination Hospital C: GP-led primary care clinic	Median % uptake: Hospital A 55% Hospital B 39% Hospital C 65%	Median % at 3 and 6 months: Hospital A 65%, 68% Hospital B 48%, 91% Hospital C 74%, 88%	• Uptake improved significantly at all three hospitals over the study period with the most significant change (39–91%, $P < 0.001$) noted at the hospital where standing orders were introduced (midwife-led). • The nurse-led intervention showed improvement in late 2015, with significant progress between periods 1 and 2, improvement was less pronounced between periods 2 and 3. • The GP-led intervention showed steady improvement throughout the study period, increasing from a median of 65% in period 1–88% in period 3.

(*Continued*)

Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Kriss et al. (2017)[71]	USA Obstetric Antenatal Clinic	RCT 4 months in 2013	Moderate	Size: 106 Age: 26.1 Ethnicity: African American: 100%	Tdap	Patient Education Group 1: Video 'Pregnant Pause,' affective messaging. Detailed information on Tdap and influenza vaccines, safety and the current advice (20 min in the waiting room. Group 2: iBook 'Vaccine for Healthy Pregnancy,' cognitive message. Information on antenatal Tdap and influenza vaccination, vaccine safety, the impact of pertussis and influenza on pregnant women and infants and the current advice (20 min in the waiting room)	2/34 (6%)	1: 2/30 (6%) 2: 2/33 (7%)	• Tdap vaccination rates were 18% in the control group, 50% in the iBook group (RR: 2.83; 95% CI: 1.26–6.37), and 29% in the video group (RR: 1.65; 95% CI: 0.66–4.09) • At baseline, average likelihood of getting Tdap during current pregnancy was 3.0 (SD 3.4) on a 0–10 scale; at follow-up, it was 6.3 (SD 3.6). • Main reasons for not receiving Tdap were not receiving a recommendation from a healthcare professional (48%) and not knowing about Tdap (44%)
McAlister et al. (2018)[119]	USA Obstetric Clinic	Cohort 12 weeks	Weak	Size: 75 Age: 19–44 Ethnicity: Hispanic 100%	Tdap	Patient education A handout, a 5-min video and a patient education session (10 min altogether), all available in English and Spanish. Intervention at Clinic A (privately insured or Medicaid) and Clinic B (women with no insurance or vaccine reimbursements).	186/468, 40%	66/75, 81%	• Vaccination rate increased compared with the previous year. Higher vaccinations in private- and Medicaid-insured women (clinic A) than women with no insurance (clinic B). • Participants in Clinic A were more willing to receive Tdap vaccine after discussion before viewing the video. • Language barrier at Clinic B was an obstacle for staff in explaining the importance of Tdap vaccination during pregnancy, but an educational video in Spanish overcame this obstacle. • Factors influencing vaccination rates were video education in native language about Tdap importance and involving family input.
McCarthy et al. (2012)[103]	Australia Tertiary Hospital	Pre–post audit 2 weeks in 2010 and 2011	Moderate	Size: 439 Age: not reported Ethnicity: controls aboriginal or Torres Strait Islander 1.25% Intervention: Not reported	Influenza	Multi-modal Grand round lecture, daily antenatal clinical meetings, an English language patient information brochure, stamped reminder messages and a safety checklist. Increased vaccine supplies and referral to GPs for vaccination.	60/199, 30.2%	96/240, 40%	• Vaccine coverage increased from 30% in 2010 to 40% in 2011 ($P = 0.03$). The reason cited for choosing vaccination was to protect both their babies and themselves. • Following the 2011 educational campaign, fewer women expressed safety concerns for themselves or their babies. • Reasons for not getting vaccinated included concerns about risk to the unborn baby, lack of discussion about vaccination from healthcare professionals and doubts about vaccine efficacy.

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
McCarthy et al. (2015)[104]	Australia Women's Hospital	Pre–post Audit 2010–14	Moderate	Size: 1086 Age: Teenage mothers: 1.2% Over 35: 27.3% Ethnicity Australian-born and indigenous	Influenza	Multi-modal Providing national public health policies promoting influenza vaccination, statement from Royal College of Obstetricians and Gynaecologists, patient information brochures, staff education and increased vaccine supply	59/199, 30%	2011: 95/240, 39.6% 2012: 72/203, 35.5% 2013: 137/253, 54.2% 2014: 98/191, 51.3%	• Influenza vaccination significantly increased by 6% per year (95% CI 4–8%): from 29.6% in 2010 to 51.3% in 2014 ($P < 0.001$). • Lack of discussion from maternity caregivers was a persistent reason for non-vaccination, recalled by 1 in 2 non-vaccinated women. • Women preferred face to face consultations with doctors and midwives, and internet and text messaging as information sources about influenza vaccination. • Messages about vaccine safety in pregnancy and infant benefits are increasingly being heeded. Lower awareness of maternal benefits of influenza vaccination, especially for women with risk factors for severe disease.
Meharry et al. (2013)[122]	USA Antenatal Clinic	RCT 2011–12	Moderate	Size: 133 Age: not reported Ethnicity Asian: 6, 4.5% Black: 36, 27.1% White: 41, 30.8% Hispanic: 50, 37.6%	Influenza	Patient Education Group 1: pamphlet Group 2: pamphlet and verbalized benefit statement	23/49 (47%)	Group 1: 35/48 (73%) Group 2: 31/36 (86%)	• Vaccine uptake significantly improved in both Group 1 ($v2 = 6.81$, df = 1, $P = 0.009$) and Group 2 (v2 = 13.74, df = 1, $P < 0.001$) compared to control. There was no significant difference between Groups 1 and 2. (raw data for vaccination (a) Group 1: 35/48 (b) Group 2: 31/36 (c) Control: 23/49 • Amongst intervention groups, perception of vaccine safety ($F = 4.973$, df = 2, $P < 0.01$) and perception of benefit to mother and infant ($F = 6.690$, df = 2, $P < 0.01$) significantly improved compared to control.
Moniz et al. (2013)[83]	USA Hospital Clinic	RCT 2010–12	Strong	Size: 204 Age: not reported Ethnicity White 56, 28% Black 134, 66% Native American 5, 2% Multi-racial 9, 4%	Influenza	Patient educational and prompting 12 weekly text messages about general preventive health in pregnancy plus the importance of influenza vaccination	31/100 (31%)	34/104 (33%)	• No significant difference in vaccination rate between groups. (raw data for vaccination Intervention: Control: 34/104: 31/100) • Most participants in both groups reported finding texts helpful and wanted to continue receiving texts. • More than 70% of participants felt that receiving text messages about how to stay healthy during pregnancy increased their satisfaction with their prenatal care.

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Morgan et al. (2015)[94]	USA Hospital Clinic	Pre–post QI 2013	Moderate	Size: 20 801 Age: not reported Ethnicity: not reported	Tdap	Policy electronic medical record alert. The best-practice alert was designed to appear starting at 32 weeks of gestation and to reappear at every subsequent encounter until vaccine acceptance was recorded or delivery occurred.	5064/10 600, 48%	9879/10 201, 96.8%	• Implementation of a Tdap vaccine best-practice alert and antepartum administration achieved a 97% vaccination rate, doubling the previous year's rate. • Non-significant decline in pertussis incidence amongst neonates born to mothers receiving prenatal care.
O'Leary et al. (2019)b[105]	USA Obstetric Clinic	RCT 2011–14	Weak	Size Control: 37 085 Intervention: 39 813 Age: Control: 38 ± 12.9 Intervention: 41 ± 14.9 Ethnicity White: 24 477 (31.9%) Black: 1484 (1.9%) Hispanic: 5398 (7%) Other: 2447 (3.2%) Unknown: 43092 (56%)	Influenza Tdap	Multi-modal Assign immunization champions, train staff/providers, assist with vaccine purchasing, identify eligible patients, standing order implementation, chart review/feedback, patient education materials.	Influenza: 775/1900 (41%) Tdap: 1364/2637 (51%)	Influenza: 660/2249 (29%) Tdap: 1161/2280 (51%)	• No significant difference in vaccination rate between groups. • Both intervention and control practices showed improved vaccination of pregnant women; risk ratio = 0.79; 95% CI 0.55, 1.14
O'Leary et al. (2019)a[78]	USA Non-Profit Community Health Clinic	RCT 2013–16	Strong	Size: 462 Age: Flu: 31.3 ± 4.2 Tdap: 32 ± 4.5 Ethnicity Flu: White 255, 88% Tdap: White 148, 84%	Influenza Tdap	Patient Education Group 1: website with vaccine information only Group 2: website with vaccine information, interactive social media including a blog, discussion forum and 'Ask a Question' portal.	Flu: 16/44 (36%) Tdap: 21/31 (68%)	Influenza: 1: 80/140 (57%) 2: 59/105 (56%) Tdap: 1: 57/86 (71%) 2: 43/62 (69%)	• For influenza, women in both Group 2 (OR = 2.19, 95% CI = 1.06, 4.53) and Group 1 (OR = 2.20, 95% CI = 1.03, 4.69) had significantly higher vaccine uptake than controls. (Raw data for (a) Group 1: (59/105) (b) Group 2: 80/140; (c) Control: 16/44) • For Tdap, there were no significant differences in vaccination rate between groups. (Raw data for (a) Group 1: (43/60) (b) Group 2: 57/80; (c) Control: 21/31)

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Omer et al. (2022)[106]	USA Obstetric Clinic	RCT 2017–18	Strong	Size: 2092 Age: not reported Ethnicity White: 1133, 57.1% Black: 284, 14.3% Hispanic: 196, 9.9% American Indian Alaska Native: 24, 1.2% Native Hawaii/Pacific Islander: 11, 0.6% Other: 9, 0.5% Missing: 409, 16.4%	Influenza Tdap	Multi-modal provider: educational CME module, 'VaxChat'. Practice: 'QI program to increase vaccination 'AFIX' Patient: individually tailored app 'MomsTalkShots' Group 1: practice + provider + patient intervention Group 2: practice + provider intervention, patient control Group 3: practice + provider control, patient intervention	Influenza: 320/525, 61% Tdap: 425/525, 81%	Influenza: 1: 347/523 (66%) 2: 327/524 (62%) 3: 323/520 (62%) Tdap 1: 424/523 (88%) 2: 399/524 (76%) 3: 414/520 (80%)	• No significant difference in vaccination rate between groups overall (Raw data for influenza vaccination for (a) Group 1: (347/523) (b) Group 2: 327/524; (c) Group 3: 323/520; Control: 320/525 For dTap (a) Group 1: 424/523; (b) Group 2: 399/524; (c) Group 3: 414/520; Control: 320/525). • Amongst women who had no intention or were unsure about receiving the influenza and Tdap vaccine, those who received patient intervention only were 61% more likely to receive the influenza vaccine than those in control group (RR: 1.61; 95% CI: 1.18–2.21). • Amongst women who intended to receive influenza or Tdap at baseline, vaccination rates during pregnancy were similar.
Orefice et al. (2019)[95]	Australia Women's Hospital	Pre–post audit July 2015, 2017	Moderate	Size: 574 Age: Control: 33.3 ± 5.1 Intervention: 31.5 ± 5 Ethnicity: not reported	Influenza	Policy The electronic health record with a mandatory field that clinicians must complete before closing patient files, requiring them to indicate whether vaccination was performed or not.	96/275, 35%	238/299, 79.8%	• Vaccination rates doubled between audit periods (35.0 vs 79.8%, $P < 0.0001$).
Parsons et al. (2022)[72]	UK Virtual	Cohort 2019–20	Weak	Size: 67 Age: 18+ Ethnicity: not reported	Influenza	Patient education A 4-min online animation on beliefs about flu risk and vaccination efficacy. Emphasizing severity, increased complications and vaccine protection, tackling knowledge gaps and demystifying vaccination with reassurance	43.7% (National statistic, no baseline cohort)	38/67, 56.7%	• Watching the animation led to increased intentions to accept flu vaccination during pregnancy and increased appraisals of likelihood of getting flu and severity of flu during pregnancy. • Of the 67 participants, 38 reported influenza vaccination receipt while pregnant

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	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (n) –age (mean ± SD) –ethnicity (n, %)	Vaccine	Intervention	Control vaccination rate (n, %)	Intervention vaccination rate (n, %)	Findings
Payakachat et al. (2016)[82]	USA Women's Clinic	RCT May–Aug 2014	Moderate	Size: 279 Age: 26.4 ± 5.7 Ethnicity White: 130, 46.6% Black: 126, 45.2% Others: 23, 8.2%	Tdap	Patient education modified version of CDC Tdap information leaflet to 6th-grade literacy levels compared to 10th-grade literacy of standard CDC information leaflet.	68/152 (45%)	68/139 (49%)	• No significant difference in vaccination rate between groups. (Raw data for Intervention: Control: 66/135:65/144) • Overall perception scores significantly increased (3.1–3.4, $P < 0.001$) after intervention, indicating increased knowledge of vaccine.
Pierson et al. (2015)[88]	USA Obstetric Clinic	Pre–post QI 2010–12	Weak	Size: 8019 Age: not reported Ethnicity: not reported	Influenza	Provider Usual care was supplemented with brightly coloured forms attached to clinic notes to prompt healthcare professionals to discuss vaccination status.	101/4590, 2.2%	2/30, 6.67%	• There was a significant difference in vaccination rate between groups from 2.2 to 14.2%. (95% CI: 0.11–0.13; $P < 0.001$).
Ryan et al. (2020)[86]	UK Virtual	Cross-sectional 2017	Weak	Size: 282 Age: 31 ± 5.1 Ethnicity British White 232, 82% Other White 33, 12% Non-White 17, 6%	Tdap	Patient education message framing. Patient assigned to read disease risk, myth busting or control information before answering questions based on the TPB	Intentions: $n = 87$ mean 20.2 (SD 10.7, p-0.56) [vaccination intention]	Intentions: $n = 97$ [a]Disease risk: mean 20.4 (SD 10.7, p-0.56) [a]Myth busting: $n = 98$, mean 22 (SD 9.7, p-0.56) [vaccination intention]	• No significant effects of message framing were found. • Attitudes (Beta = 0.699; $P < 0.001$) and subjective norms (Beta = 0.262, $P < 0.001$) significantly predicted intention to vaccinate but perceived behavioural control did not. • The TPB constructs accounted for 86 and 36% of the variance in vaccine intention and vaccine history, respectively. • Disease risk information did not influence vaccine acceptability.
Schirwani et al. (2022)[85]	Austria Maternity hospital	Cohort 2021	Moderate	Size: 217 Age: 31.5 Ethnicity: not reported	COVID-19	Patient education Arm 1: written briefing recommending vaccine after childbirth. Arm 2: written briefing with 5-min oral counselling by attending physician in the postpartum ward	45/69 (65%) [Vaccination intention]	[a]Arm 1 (group A): 18/68 (26.5%) [a]Arm 2 (group B): 35/80 (43.8%)	• A personal 5-min counselling by a physician increased the willingness to receive the vaccination against COVID-19

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (n) –age (mean ± SD) –ethnicity (n, %)	Vaccine	Intervention	Control vaccination rate (n, %)	Intervention vaccination rate (n, %)	Findings
Sherman et al. (2012)[87]	USA Primary Care Centre	Cohort 3 months in 2003 and 2005	Moderate	Size: 1367 Age: Control: median 24 (range 14–44) Intervention median 24 (range 13–45) Ethnicity: Control Hispanic: 168, 33% White: 162, 32% Black: 127, 25% Asian: 35, 7% Other: 11, 2% Unknown: 1 Intervention Hispanic: 314, 36% White: 288, 33% Black: 192, 22% Asian: 39, 5% Other: 25, 3% Unknown: 5	Influenza	Provider Reminders for staff and providers about vaccination	74/504, 14.7%	445/863, 51.6%	• Vaccination rate improved significantly, $P < 0.0001$ [RD: 37%, 95% CI: 32.5–41.6]. RR = 3.5. • All provider groups demonstrated significant increases in the rates of vaccination with a reminder; however, there were no differences in age, race, education, primary language or insurance.
Spina et al. (2020)[89]	USA Obstetric Clinic	Pre–post QI 2016–18	Weak	Size: 889 Age: Control: 32 ± 5.5 Intervention: 31.5 ± 5 Ethnicity: Controls White 36.6%, Black 7% Hispanic 11% Asian 2.2% Native American 0.2% Other 1.8% Unknown 41.3% Intervention: White 39.3% Black 16.5% Hispanic 9.3% Asian 2.5% Native American 0.2% Other 1.6% Unknown 30.7%	Influenza Tdap	Provider The CDC model: a menu of clearly defined QI strategies, bi-weekly technical assistance meetings with designated immunization champions, incentives for champions/staff and adapted CDC QI tool (AFIX) to aid each practice.	Flu: 250/446, 56% Tdap: 343/447, 77%	Flu: 287/443, 65% Tdap: 372/443, 84%	• Post-intervention, documented influenza vaccination rates increased from 56% at baseline to 65% ($P < 0.01$); and Tdap vaccination rates increased from 77% at baseline to 84% ($P < 0.02$) across all practices. • The intervention improved provider motivation to vaccinate through assessment of current vaccination coverage with feedback, goal setting and incentives.

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Table 1. Continued

	Country and setting	Study design and period	Quality rating	Patient characteristics –sample size (*n*) –age (mean ± SD) –ethnicity (*n*, %)	Vaccine	Intervention	Control vaccination rate (*n*, %)	Intervention vaccination rate (*n*, %)	Findings
Stock-well et al. (2014)[77]	USA Community Clinic	RCT 4 months in 2011	Moderate	Size: 1187 Age: not reported Ethnicity: not reported	Influenza	Patient educational and prompting Five weekly text messages regarding influenza vaccination and two text message appointment reminders. All women included sent introductory text message saying they may receive pregnant health–related messages.	269/577 (47%)	284/576 (49%)	• After adjusting for gestational age and the number of clinic visits, women who received intervention were 30% more likely to be vaccinated (AOR = 1.30; 95% CI = 1.003, 1.69). The majority of vaccinations were given prepartum (84.1% intervention; 82.4% control. (Raw data for vaccination during pregnancy; Intervention: Control: 243/576: 222/577) • Greatest effect was seen amongst women who in early third trimester (28–33 weeks) – where there was up to a 15% absolute difference in vaccination between groups. • Influenza vaccination for the entire cohort remained low, 48%; the small family medicine site had higher coverage 76.9%, obstetric sites ranged 41.5–52.2%.
Wong et al. (2016)[76]	Hong Kong Hospital Antenatal Clinic	RCT 2013–15	Strong	Size: 321 Age: 33.5 ± 4.2 Ethnicity: not reported	Influenza	Patient education leaflet about influenza vaccine in pregnancy with a 10-min one-to-one education session	16/160 (10%)	34/161(21%)	• Brief education was effective in improving vaccination uptake ($P = 0.006$). (Raw data for Intervention: Control: 34/151: 16/154) • More participants in intervention group initiated discussion about influenza vaccination with a healthcare professional (19.9 vs 13.1%; $P = 0.10$), but the difference was not statistically significant.
Yudin et al. (2017)[79]	Canada Hospital Antenatal Clinic	RCT 2013–14	Strong	Size: 317 Age: Control 32.4 Intervention: 32.2 Ethnicity: Caucasian: 50% Other: 50%	Influenza	Patient educational and prompting two text messages weekly for 4 weeks reinforcing that influenza vaccine is recommended and safe	41/152 (27%)	40/129 (31%)	• No significant difference in vaccination rate between groups. (Raw data for intervention: Control: 40/129: 41/152) • Overall vaccination rates low (29%) in the entire cohort. Vaccination more likely if household income (>100 000) or had previously received the vaccine.
Zakrzewski et al. (2014)[91]	USA Community Clinic	Cohort 2010–12	Moderate	Size: 2883 Age: not reported Ethnicity: not reported	Influenza	Provider Nurse-provided and recommended vaccination compared to physician (control)	804/2112, 38.1%	297/771, 38.5%	• A nurse-driven protocol did not improve vaccination rates across varying practice sites • Nurse offering rate 99.7% with 38.2% receiving (vaccination rate 38.1%) and physician offering vaccine 54.5% with 79.7% receiving (vaccination rate 38.5%)

RCT = randomized controlled trial. Tdap = tetanus, diphtheria and pertussis vaccination. QI = quality improvement.
At risk: eligible for influenza vaccine due to pre-existing medical condition, regardless of pregnancy.
[a]Intent to vaccinate.

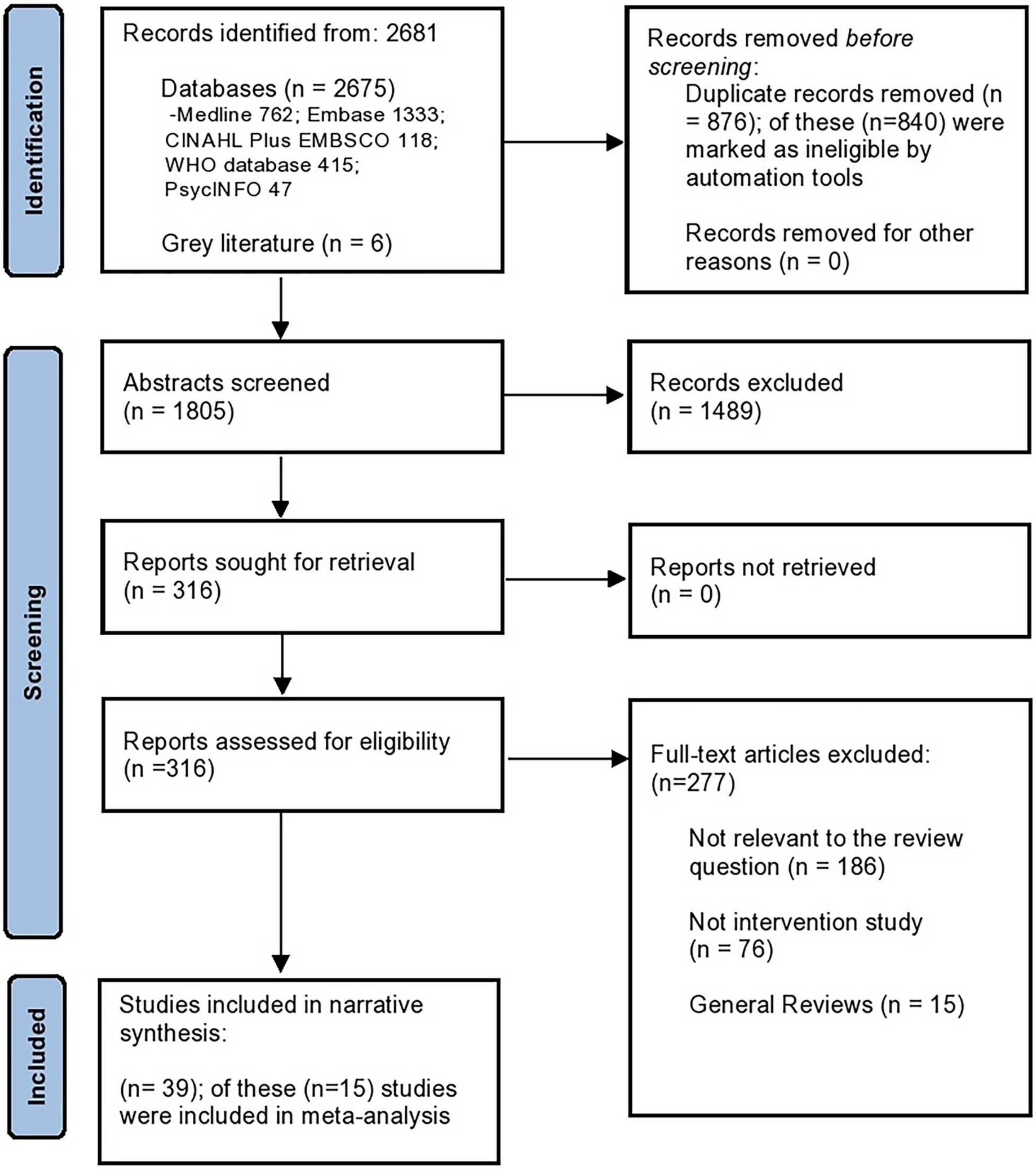

Figure 1. PRISMA flow diagram of included and excluded studies

Four studies were on vaccination intention rather than vaccination receipt. An RCT of a smartphone app providing information and reminders about influenza showed increased vaccination intention.[73] Educational presentations by experts accompanied by handouts decreased hesitancy and improved pregnant women's knowledge of influenza and pertussis vaccinations.[84] Written information and counselling by a physician increased willingness to receive vaccination against COVID-19.[85] However, a cross-sectional study of message framing did not affect vaccine acceptability.[86]

Provider-level interventions (n = 5). Four out of five studies showed increased vaccination rates. A cohort study showed reminders to healthcare staff improved influenza vaccination rates regardless of age, race, education, primary language or insurance.[87] Similarly, supplementing usual care with brightly coloured reminder forms attached to antenatal clinic notes led to an increase in influenza vaccination rates.[88] The CDC's Quality Improvement (QI) Programme in obstetric clinics included twice-weekly technical assistance meetings with designated immunization champions, incentives for champions and staff and adapted CDC QI tools. Post-intervention chart review showed increased influenza and pertussis vaccination rates in all clinics, with feedback, goal setting and incentives improving provider motivation.[89]

Two studies compared two different interventions (rather than comparing them to no intervention). A QI project compared three hospitals' immunization services led by nurses, midwives and general practitioners (GPs). All three interventions resulted in improvements in vaccination rates. The biggest change was observed in the hospital, where standing orders were introduced. These are written protocols authorizing a healthcare professional such as a midwife to administer vaccines without needing physician review or prescription. This led to vaccination rates increasing from 39 to 91%.[90] Finally, a cohort study showed no difference in vaccination rates when vaccination was recommended by nurses vs physicians.[91]

Policy-level interventions (n = 5). Four out of five interventions increased vaccination uptake. A before-and-after study from New Zealand found that community pharmacy funding for administering maternal pertussis vaccination increased pertussis uptake, including in Maori women.[92] A QI project suggested that implementing best-practice alerts in electronic prenatal records increased influenza vaccination rates.[93] Similarly, an electronic medical record alert at 32 weeks of gestation resulted in a higher vaccination rate and a non-significant decline in neonatal pertussis incidence.[94] Another QI project found that a mandatory vaccination field in electronic records doubled influenza vaccination rates between audit cycles.[95] However, a cohort study introducing onsite COVID-19 vaccination at high-risk obstetric clinics, with ~70% of women from Black and minority ethnic groups, found only a (non-significant) increase in COVID-19 vaccination rates from 3 to 10%, but the numbers were small.[96]

Multi-modal interventions (n = 11). Eight out of 11 multi-modal studies reported higher vaccination rates, five of which were significant. An RCT of a practice-, provider- and patient-focused package including talking points on coloured papers, vaccine champions, lapel buttons for staff, provider education, posters, brochures and iPad tutorials for patients and maps to vaccination sites showed a non-significant increase in influenza and pertussis vaccination rates, with provider recommendation being the most influential factor.[97] A community awareness campaign in Stockport, UK, combined with a pharmacy programme and GP financial incentives resulted in higher influenza vaccine coverage in pregnant women in the intervention area. In this study, real-life case stories and staff support played important roles.[98] In the USA, a combination of written information, CDC posters, clinician education and electronic health record prompts both increased influenza vaccination rates and improved documentation.[99] Another intervention combined maternity unit notifications, opportunistic immunization, and after-hours vaccination options, which improved pertussis vaccine uptake. Lack of a vaccination offer by GP was a major reason for non-vaccination.[31] Updated vaccination guidelines and implementation strategies (e.g. medical record reminders, increased stocking of vaccines, feedback on vaccination rates) significantly increased pertussis and influenza vaccine coverage amongst non-Hispanic White women.[100] Implementation of the American College of Gynecologists' guidelines and toolkit also increased pertussis vaccination rates.[101]

A US QI project that included staff education, reminders and increased vaccine availability increased pertussis vaccination rates.[102] Similarly, in Australia, staff education, reminder messages, safety checklists, patient information brochures and increased vaccine supplies improved influenza vaccine coverage and reduced safety concerns, although lack of discussion by healthcare professionals remained a barrier to vaccination.[103] In another study, national policies and professional statements promoting vaccination, patient information brochures, staff education and improved vaccine supply increased influenza vaccination rates.[104] Finally, two multi-modal studies showed no difference in influenza and pertussis vaccination rates.[105,106]

Meta-analyses of RCTs

Overall, 14 RCTs reporting vaccination uptake during pregnancy were meta-analyzed ($n = 86\,424$ participants). One RCT was excluded as it only reported vaccination intention.[73] Most studies (11, 79%) were patient-level educational interventions (79%), and two studies were cluster RCTs. The influenza vaccine uptake meta-analysis comprised 18 effect estimates from 12 studies, while the pertussis vaccine uptake meta-analysis included 10 effect estimates from six studies. We did not identify any trials on COVID-19 vaccinations during pregnancy.

Figure 2 shows pooled results for interventions to increase influenza vaccination uptake amongst pregnant women. The forest plot indicated that the interventions are effective but have a very small effect (risk ratio = 1.07, 95% CI 1.03, 1.13). Pregnant women offered the intervention were more likely to receive the influenza vaccination than pregnant women who were not offered the intervention. The Chi^2 is not significant, and the I^2 is low, suggesting heterogeneity may not be important.

Figure 3 shows pooled results indicating that interventions to increase pertussis vaccination uptake amongst pregnant women were not effective in these studies (risk ratio = 0.98, 95% CI 0.94, 1.03). The $I^2 = 0.01\%$ and the Chi^2 is not significant.

Discussion

Interventions from 12 RCTs promoting influenza vaccination amongst pregnant women significantly increased vaccination rates albeit with a small effect (risk ratio = 1.07, 95% CI 1.03, 1.13). However, our meta-analysis of six RCTs suggests that interventions to increase pertussis vaccination in these studies were not effective. At patient level, clear, consistent, unambiguous recommendations from healthcare professionals backed by text reminders and written information increased vaccine uptake, especially tailored face-to-face interventions, which addressed women's concerns, debunked myths and highlighted the benefits. Provider-level interventions included educating healthcare professionals about vaccines' safety and effectiveness and reminders encouraging them to offer vaccinations routinely. Effective policy-level interventions included financial incentives for providers to vaccinate pregnant women, inserting mandatory vaccination data fields in electronic health records, ensuring

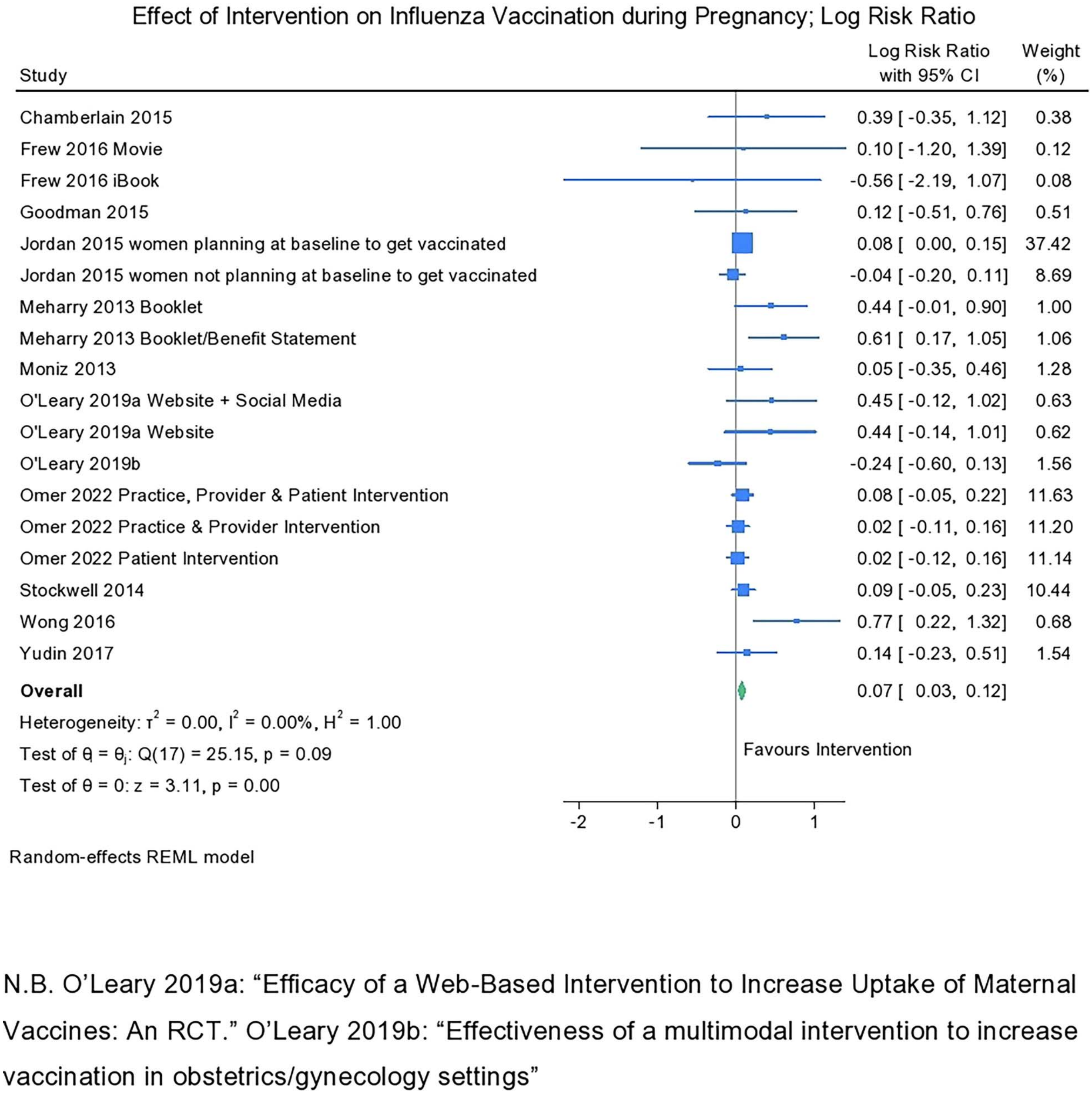

Figure 2. Forest plot of 12 studies (18 effect estimates) of interventions to increase influenza vaccination

easy availability of vaccinations across different healthcare facilities and the use of standing orders enabling midwives to give vaccinations.

A strength of this systematic review is that it is the first to examine all three currently recommended vaccinations in pregnancy. It offers a comprehensive overview of interventions across nine countries and includes studies with large sample sizes. It includes 24 studies that specifically reported on the percentage of participants from ethnic minority groups who often have lower vaccination rates despite being at higher risk.[107] By incorporating both RCTs and observational studies, encompassing patient-level, provider-level, policy-level, and multi-modal strategies, the utility of the findings is enhanced.

However, there are several limitations. Most studies focused on influenza and pertussis vaccination, which limits the applicability of the results to other vaccines, notably COVID-19. Nearly two-thirds of studies were from the USA, potentially limiting generalizability to other countries and healthcare systems. Additionally, the heterogeneity of interventions and outcome measures within multi-modal interventions makes it challenging to compare the effectiveness of different intervention components within and across studies. Only 18% of the studies were of strong quality. The review focused on high-income settings with established vaccination programmes and may not reflect the unique challenges of low- and middle-income contexts. Finally, four studies examined vaccination intentions rather than actual uptake.[73,84–86] According to the theory of planned behaviour, intentions are key determinants of behaviour.[108] While a previous study found intent to be a reliable predictor of influenza vaccination, a recent COVID-19 study

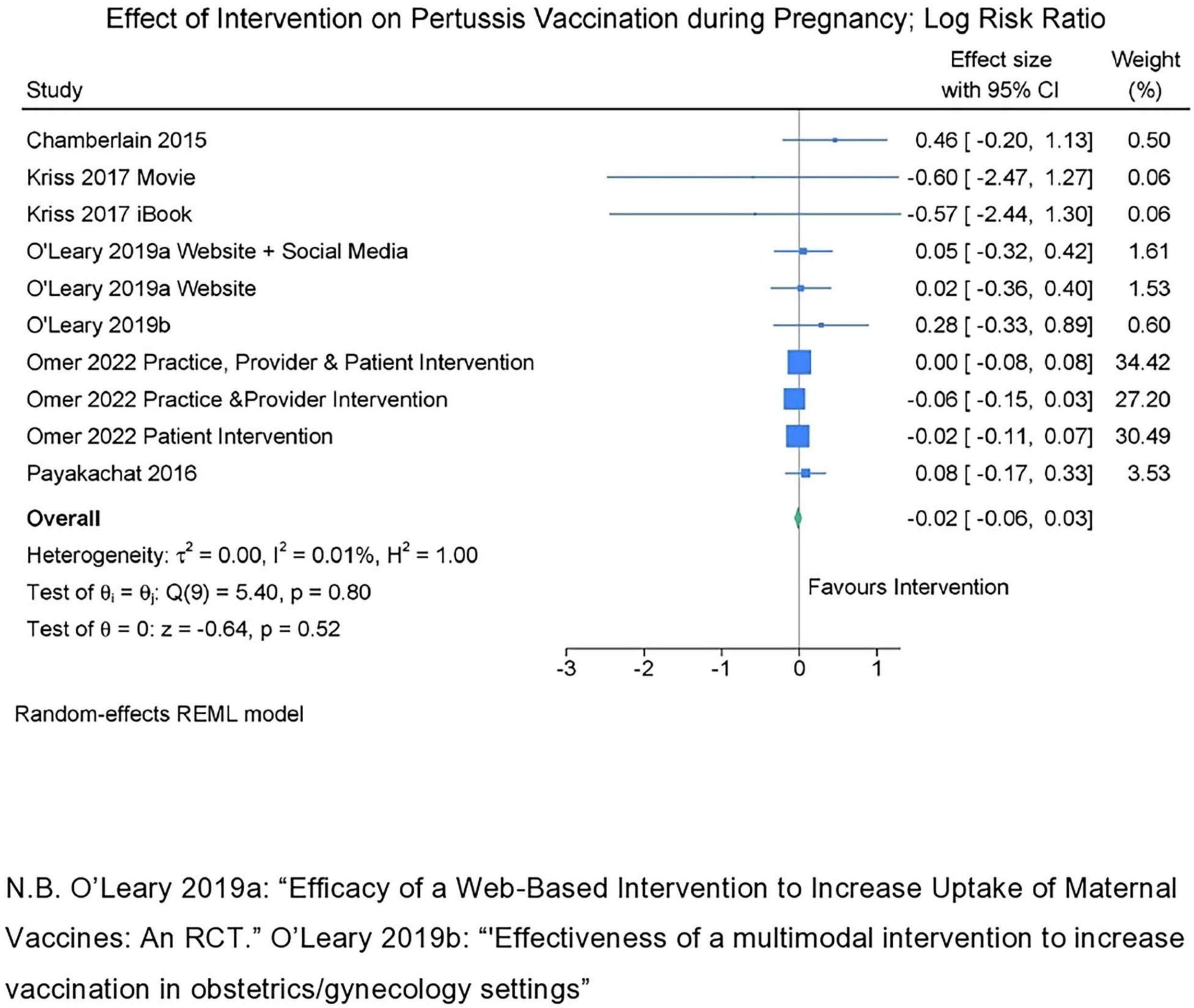

Figure 3. Forest plot of six studies (10 effect estimates) of interventions to increase pertussis vaccination

indicated that stated willingness did not consistently translate to actual vaccination.[109,110]

This study is comparable with previous systematic reviews, but these were smaller, mainly focused on pertussis or influenza and were primarily narrative, excluding meta-analyses.[54,55,111–113] The findings are consistent with existing evidence[45] that it is crucial to increase pregnant women's knowledge about vaccinations and to address concerns about safety and effectiveness.[45] One-way sharing of information[114] may not be as effective as interactive counselling from a healthcare professional.[45,54] It is crucial that healthcare professionals are convinced of the benefits of vaccination (which is not always the case) and have good communication skills and up-to-date knowledge about vaccines.[101,102,115,116] Previous studies suggest that most pregnant women consider healthcare professionals such as GPs and midwives to be reliable sources of information, and this could be effectively leveraged.[107] Moreover, this study highlights policy changes that can facilitate vaccination, such as electronic alerts in healthcare records and incentives for healthcare providers.[117,118]

Several factors might have contributed to the null effects of interventions in the pertussis studies. These include contextual factors such as higher vaccine hesitancy[78,97] and unique challenges within obstetric care settings.[105] Additionally, the absence of baseline equivalence—indicated by varying availability of pertussis vaccines across practices—and uncontrolled confounding factors, such as secular trends in immunization, could have influenced the results.[98,106,107] Moreover, certain study population characteristics not accounted for in the study design (e.g. providing written vaccine information for low-literacy groups) may have influenced the outcomes.[82] Possible contributors to the inefficacy of influenza vaccine interventions were inadequate behavioural change techniques, like single intervention exposure instead of repeated messaging needed for behaviour change,[80,81] non-tailored messages not resonating with the target audience and flawed study procedures like late-season vaccination and lack of message receipt verification.[83,97]

Areas where action could be taken at the patient-, provider- and policy levels to improve maternal vaccination rates are summarized in Figure 4, based on the strength of evidence in each domain. Addressing misconceptions and promoting the benefits of vaccination amongst pregnant women and their families is crucial.[73,98] Tailored approaches, including

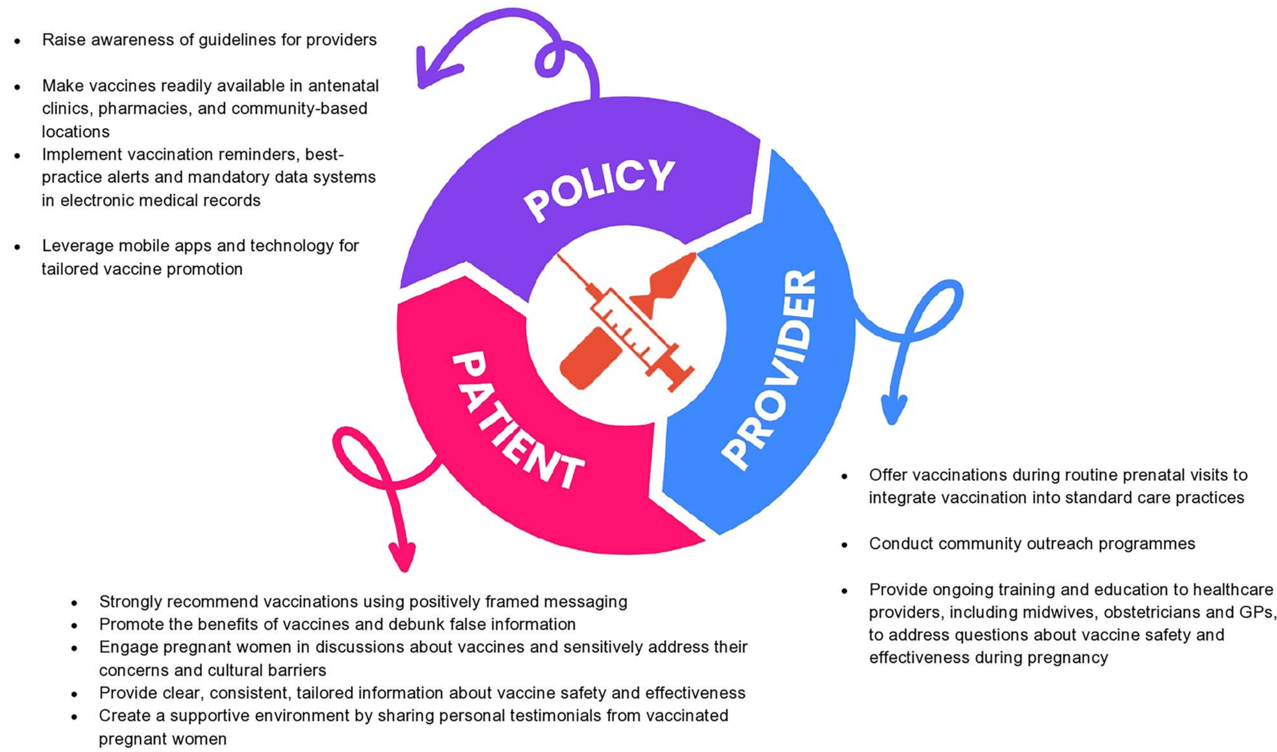

Figure 4. Recommendations for increasing vaccination in pregnancy with the three Ps: patient, provider and policy measures

written material, can enhance understanding and confidence in vaccination.[71,73–75,79,99,106] Community outreach programmes can educate pregnant women and their families about the importance of vaccination, ensuring this information reaches diverse populations.[31,91,100,116,119] Additionally, sharing success stories and personal testimonials from pregnant women who have received vaccines can increase confidence and motivation.[98]

At the provider level, strong vaccination recommendations from healthcare professionals, especially using positively framed messaging, can increase vaccine uptake.[80,81,96–99,104,116,119] Encouraging GPs, midwives and obstetricians to offer vaccinations during routine prenatal visits—with multiple opportunities for counselling—helps integrate vaccination into standard care, increasing accessibility and convenience for pregnant women and providing opportunities for discussions.[76,80,84,88,103] Ongoing training ensures that healthcare providers stay up to date with the latest evidence.[31,80,82,84,87,99–102] Finally, fostering collaboration amongst obstetricians, midwives and other healthcare providers is essential to ensure clear and unambiguous messaging about vaccination during pregnancy.[31]

At the policy level, integrated collaborative healthcare approaches can enhance vaccination coverage and ensure consistent messaging across settings.[31] Making vaccines readily available on-site in antenatal clinics, pharmacies and community-based locations can improve accessibility.[76,80,92,119] Leveraging mobile apps and technology can be an effective tool for vaccine promotion, reaching a wider audience and providing tailoring.[73,78,80,104,106] Collecting data on factors influencing vaccine uptake and evaluating educational initiatives is essential for developing targeted interventions.[83,84,89,99,102,105,106] Implementing vaccination reminders, best-practice alerts and mandatory data field systems can help ensure that pregnant women receive vaccines in a timely manner.[74,77,93–95] By reducing barriers (which may be different for different populations), uptake of maternal vaccines can be increased.[89,120]

Infectious diseases epidemiology and vaccine uptake are multifaceted and continuously shifting[114,121] (e.g. maternal vaccination against Respiratory Syncytial virus has been approved in the USA). It is likely that in future multiple interventions will be needed that must be tailored to individual populations and may need to adapt as new technologies become available.[120] Further research should focus on identifying the most effective components of interventions at the patient-, provider-, and policy levels and explore their long-term sustainability and cost-effectiveness. Continued research and collaboration between researchers and healthcare providers are vital to optimize vaccination rates, ultimately protecting the health of pregnant women and their babies.

Supplementary data

Supplementary data are available at *JTM* online.

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Author contributions

Mohammad S Razai (conceptualisation [lead], writing – study protocol [lead], literature search, data screening, extraction and analysis [lead], writing – original draft, review and editing [lead]). Rania Mansour (data screening, extraction, analysis, quality assessment and revision [supporting]), Lucy Goldsmith (data analysis and revisions [supporting], Pahalavi Ravindran (data screening and extraction [supporting], Samuel Freeman (data screening and extraction [supporting]), Charlotte Mason-Apps (data screening and extraction [supporting]), Pavan Kooner (quality assessment [supporting]), Sima Berendes (writing – review & editing [supporting]), Joan Morris (writing – review & editing [supporting]), Azeem Majeed (writing – review & editing [supporting]), Michael Ussher (writing – review & editing [supporting]), Sally Hargreaves (writing – review & editing [supporting]), and Pippa Oakeshott (conceptualisation [supporting], quality assessment [supporting], writing – review & editing [equal])

Conflict of interest

None declared.

Data availability

data are available upon reasonable request.

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