Systematic Review

Interventions on health care providers to improve seasonal influenza vaccination rates among patients: a systematic review and meta-analysis of the evidence since 2000

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Abstract

Background: Seasonal influenza vaccination (SIV) rates remain suboptimal in many populations, even in those with universal SIV.

Objective: To summarize the evidence on interventions on health care providers (physicians/nurses/pharmacists) to increase SIV rates.

Methods: We systematically searched/selected full-text English publications from January 2000 to July 2019 (PROSPERO-CRD42019147199). Our outcome was the difference in SIV rates between patients in intervention and non-intervention groups. We calculated pooled difference using an inverse variance, random-effects model.

Results: We included 39 studies from 8370 retrieved citations. Compared with no intervention, team-based training/education of physicians significantly increased SIV rates in adult patients: 20.1% [7.5–32.7%; I² = 0%; two randomized controlled trials (RCTs)] and 13.4% [8.6–18.1%; I² = 0%; two non-randomized intervention studies (NRS)]. A smaller increase was observed in paediatric patients: 7% (0.1–14%; I² = 0%; two NRS), and in adult patients with team-based training/education of physicians and nurses together: 0.9% (0.2–1.5%; I² = 30.6%; four NRS). One-off provision of guidelines/information to physicians, and to both physicians and nurses, increased SIV rates: 23.8% [15.7–31.8%; I² = 45.8%; three NRS] and 24% (8.1–39.9%; I² = 0%; two NRS), respectively. Use of reminders (prompts) by physicians and nurses slightly increased SIV rates in paediatric patients: 2.3% (0.5–4.2%; I² = 0%; two RCTs). A larger increase was observed in adult patients: 18.5% (14.8–22.1%; I² = 0%; two NRS). Evidence from both RCTs and NRS showed significant increases in SIV rates with varied combinations of interventions.

Conclusions: Limited evidence suggests various forms of physicians’ and nurses’ education and use of reminders may be effective for increasing SIV rates among patients.

Key words: Health personnel, human influenza, intervention, meta-analysis, systematic review, vaccination
Key messages

- We reviewed 39 studies (7 RCTs and 32 non-randomized intervention studies (NRS)).
- Physicians/nurses’ education/reminders increased vaccination among patients.
- Combinations of education and reminders increased vaccination among patients.
- Education and reminders were both effective among adult and paediatric patients.

Introduction

Vaccination is one of the most successful interventions against vaccine-preventable diseases and is considered to be the most effective and practical strategy for influenza prevention. Advisory bodies such as the World Health Organization (WHO) (1), the European Centre for Disease Prevention and Control (ECDC) (2) and the advisory committees on immunization in the United States of America (USA) (ACIP) (3) and Canada (NACI) (4) recommend annual seasonal influenza vaccination (SIV) for individuals 6 months of age and above, with emphasis on subpopulations that are at increased risk of developing influenza-related complications such as infants, older adults, pregnant women and persons with certain morbidities. Consequently, many countries have annual SIV programmes (5). Despite these programmes, SIV rates remain below national and WHO targets, even in jurisdictions (health regions) with universal (free-for-all) SIV programmes.

Refusal or a delay in acceptance of a vaccine despite its availability and accessibility (vaccine hesitancy) (6) varies across time and place, and may explain the suboptimal SIV rates. This phenomenon is thought to be influenced by an individual's complacency (believing disease is not serious or that vaccination is not necessary), convenience (vaccine availability, accessibility and affordability) and confidence (belief that vaccine works and is safe) in regard to influenza vaccination (6). However, health care providers (physicians, nurses, pharmacists, etc.) have been identified as the most important advocates and the main source of vaccination information for the public, and therefore could facilitate vaccine uptake (7–9).

There have been a few published systematic reviews of interventions focussed on health care providers to increase SIV rates among patients. A Cochrane review focussed only on older community-based patients in high-income countries (10). Other reviews were limited to community-based adult patients (11), or specific patient subpopulations and were mainly narrative without meta-analysis (12,13). These reviews did not assess if any differences existed in the efficacy/effectiveness of interventions across patient populations and study types, and across subtypes of an intervention. To address these gaps in knowledge, we summarized the evidence to determine if the efficacy/effectiveness of the interventions vary by study type, health care provider group, patient population and jurisdiction.

Methods

We conducted a systematic review and meta-analysis of the available evidence, in accordance with the Methodological Expectations of the Cochrane Intervention Reviews (MECIR) guidelines (14), and reported in compliance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (15). We developed and registered a protocol for the review in the International Prospective Register of Systematic Reviews (CRD42019147199) prior to commencement of the review. We included published studies of interventions on health care providers aimed at improving SIV rates. Only studies conducted from the year 2000 onwards, with a full-text publication in English, were included. We excluded mathematical modelling studies and grey literature.

Search strategy and selection criteria

A knowledge synthesis librarian designed a literature search strategy for Medline (Ovid) (Supplementary Table 1). The search strategy was peer-reviewed by a second, independent professional knowledge synthesis librarian using the PRESS checklist (16). The final search strategy was then adapted for EMBASE (Ovid), CINAHL (EBSCO) and Scopus (Web) bibliographic databases, and executed. All literature searches were conducted on 24 July 2019. Identified citations from the executed searches were imported into a specially designed Microsoft Access 2016 database (Microsoft Corporation, Redmond, WA), and screened for eligibility by two independent systematic reviewers using a two-stage sifting approach to review the title/abstract and full-text article. The number of ineligible citations at the title/abstract screening stage was recorded, and both the number and reasons for ineligibility were recorded at the full-text article screening stage. Disagreements during these screening stages were resolved by discussion between the two systematic reviewers, and a third systematic reviewer adjudicated when necessary.

Data extraction

Data extraction was conducted using Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA) by one reviewer after a pilot was conducted on a small selection of the included studies by the reviewer and another independent reviewer. A second reviewer independently checked the extracted data for errors. Disagreements were resolved by discussion between the two reviewers, and a third reviewer adjudicated when necessary. We extracted data such as study first author’s name, duration, publication year, funder, patient population, health care provider information, intervention(s) assessed, and the reported difference in SIV rates between patients in health care provider intervention and control groups or between patients before and after application of a health care provider intervention. The associated 95% confidence interval (CI) of the reported differences was also extracted. In addition, we extracted details relevant to risk of bias or study quality assessment. If a study also administered patient-focussed interventions, it was only included if patients in both the health care provider intervention and control groups (or patients before and during the health care provider intervention) received the same exact patient intervention(s). We did not include studies in which patients in just one of the compared groups (or intervention periods) received patient-focussed intervention(s).

Data synthesis and analysis

We summarized study characteristics and pooled reported differences in SIV rates between intervention and no intervention groups, and associated 95% CIs using an inverse variance, random-effects model implemented in STATA (version 13; StataCorp LP, College Station, TX). Educational interventions were categorized as either one-off provision of guidelines/information or team-based training/
educated sessions. If a study reported differences in SIV rates by population subgroups, we first pooled the differences before pooling the pooled estimate with appropriate differences in SIV rates from other studies. Statistical heterogeneity between pooled differences in SIV rates was assessed and quantified using the I-squared statistic ($I^2$) (17). Where appropriate, publication bias was assessed visually using funnel plots, and statistically using Egger's regression test (18).

We conducted subgroup analyses by study type, intervention, health care provider and patient population (adults versus paediatrics).

**Risk of bias and study quality assessments**

One reviewer assessed risk of bias using the Cochrane risk of bias assessment tool for randomized controlled trials (RCTs) (we also used the tool for a few non-/quasi-RCTs by adding a confounder adjustment domain) (19). The reviewer also assessed study quality of ‘before-and-after intervention studies’ (where outcome assessment is made before and after the introduction of an intervention) using the National Institutes of Health (NIH) quality assessment tool for this study type (20). Another reviewer independently checked the assessments for errors. Disagreements were resolved by discussion between the two reviewers, and a third reviewer adjudicated when necessary.

The Cochrane risk of bias assessment tool considers 6 main domains of potential biases, while the NIH quality assessment tool considers 12 domains of study quality assessment. If there was a high risk of bias in randomization (sequence generation domain assessment), a study was automatically judged to be at a high risk of bias. A study was also judged to be at a high risk of bias if any one of the other domains were judged to be of high risk, and an additional domain judged as having an unclear or high risk of bias. A study was judged as having a low risk of bias if all six domains were judged to be of low risk of bias, or if just one domain (not sequence generation) was judged as having an unclear risk of bias. A study was judged to be of good quality if all 12 domains were judged not to be lacking, or if just one domain (not pre-specified and uniformly measured outcome domain) was judged to be lacking. A moderate quality was assigned if two to four domains were judged to be lacking, while a low quality rating was given if five or more domains were judged to be lacking.

**Results**

Thirty-nine studies met our eligibility criteria, from a total of 8370 identified unique citations (Fig. 1) (21–59). Most of the studies ($n = 28$) were conducted in the USA (Table 1). The rest were conducted mostly in developed countries: two studies each for the UK and Australia, and one study each for UK/Australia, Canada, Denmark, Netherlands, Switzerland, India and Turkey. There were 7 RCTs (3 parallel and 4 cluster randomized) (22,28,47,49,52,56,59) and 32 non-randomized intervention studies (NRS) (2 non-RCTs (33,39), 1 quasi-RCT (54) and 29 before-and-after intervention studies). A total of 20 studies were focussed on physicians, while a smaller number of studies examined interventions targeting nurses (2 studies), pharmacists (1 study), both physicians and nurses (14 studies), both physicians and pharmacists (1 study) and both physicians separately and physicians and nurses together (1 study). Eleven studies examined the use of team-based training/education sessions, and six the use of one-off provision of guidelines/information. Eleven studies examined the use of reminders (nine using electronic prompts, one using paper-based prompt and one using letters), two studies examined the use of incentives (pay-for-performance) whereas nine studies examined the use of multiple interventions. There were five studies each on children/adolescents, pregnant women, adults and older adults, irrespective of health status, and three studies each specifically on chronic obstructive pulmonary disease, and inflammatory bowel disease patients. There were two studies each on adult diabetic and rheumatology patients, and one study each on preterm infants, paediatric asthma, respiratory tract infection, musculoskeletal/neurological patients, coronary heart disease, chronic kidney disease, Hodgkin’s lymphoma patients and patients with a risk of cardiovascular disease. One study was conducted mostly in developed countries: two studies each for the USA and UK/Australia, Canada, one each for UK/Australia, Canada, Denmark, Netherlands, and Switzerland. There were 7 studies each on cardiovascular disease, one study each on adult asthma, adult infants, paediatric asthma, respiratory tract infection, musculoskeletal/neurological patients, coronary heart disease, chronic kidney disease, Hodgkin’s lymphoma patients and patients with a risk of cardiovascular disease. One study was conducted on a mixed patient population. The health care provider sample size among the studies that clearly reported this parameter ranged from 4 to 136 individuals. Six studies were funded by industry (pharmaceutical companies), while non-industry funding was reported by 25 studies. One study was funded by both industry and non-industry sources, and seven studies did not report a funding source. Nearly all RCTs and non-/quasi-RCTs were judged to have a high risk of bias with regard to lack of blinding of participants and study personnel. A majority of the before-and-after intervention studies were deficient with regard to study participants being a good representation of the studied population, having sufficiently large sample size, and blinding of outcome assessors. Overall, the included RCTs and non-/quasi-RCTs were judged to be at a moderate to high risk of bias (Supplementary Table 2), and the before-and-after intervention studies were judged to be of moderate to low quality (Supplementary Table 3).

**Pooled difference in SIV rates for education compared with no intervention**

Two RCTs (56,59) and 15 NRS (23,25,30,32,33,38,39,41,43,45,46,50,54,57,58) contributed to the pooled estimates. Evidence from RCTs showed that team-based training/education of physicians significantly increased SIV rates in adult patients: 20.1% (95% CI 7.5–32.7%; $I^2 = 0$%; two studies) (Fig. 2). Evidence from NRS also showed that team-based training/education of physicians significantly increased SIV rates in adult patients: 21.6% (3.4–39.9%; $I^2 = 97.5$%; three studies) and paediatric patients: 7% (0.1–14%; $I^2 = 0$%; two studies) (Supplementary Fig. 1). The high heterogeneity observed in adult patients was due to higher estimates from Turkey, a country with a dissimilar health system from the other countries (Switzerland and USA). Exclusion of the result from Turkey significantly reduced the high heterogeneity observed in the pooled estimates (13.4%, 8.6–18.1; $I^2 = 0$%). The evidence from NRS also showed that education of physicians and nurses marginally (though significantly) increased SIV rates in adult patients: 0.9% (0.2–1.5%; $I^2 = 30.6$%; four studies) (Supplementary Fig. 1). Similarly, evidence from NRS showed that one-off provision of guidelines/information to physicians, and to both physicians and nurses, significantly increased SIV rates in adult patients: 23.8% (15.7–31.8%; $I^2 = 45.8$%; three studies) and paediatric patients: 24% (8.1–39.9%; $I^2 = 0$%; two studies), respectively (Supplementary Fig. 2). One study focussed on nurses and adult patients, and the study reported no significant benefit.

**Pooled difference in SIV rates for reminders compared with no intervention**

Three RCTs (22,47,49) and seven out of eight NRS (21,29,34,36,42,48,53) contributed to the pooled estimates. One NRS was excluded from the meta-analysis because the authors reported that there was vaccine shortage in the study year compared...
with the preceding year (the comparator), and as a result, many patients who requested vaccination could not be vaccinated (31). Result from this study differed significantly from the rest. Evidence from RCTs showed that use of reminders (prompts) by physicians and nurses significantly increased SIV rates in paediatrics patients by 2.3% (0.5–4.2%; I² = 0%; two studies) (Fig. 3). There was one study on the use of letter reminders among physicians in adult patients, and the study reported no significant benefit. Evidence from NRS showed that physicians and both physicians’ and nurses’ use of reminders (prompts) significantly increased SIV rates in adult patients: 15.3% (7.4–23.2%; I² = 98.1%; three studies) and 18.5% (14.8–22.1%; I² = 0%; two studies), respectively (Supplementary Fig. 3). There were no major differences between the studies among physicians that could explain the high heterogeneity in the pooled estimates. However, all pooled results were in favour of the intervention. There was one study each among nurses alone and physicians and nurses together in paediatric patients and both were in favour of the intervention.

Pooled difference in SIV rates for incentives compared with no intervention
One NRS each examined the impact of physicians’ pay-for-performance (27), and physicians’ practices performance bonus (37) on SIV rates in adult patients, and found significantly increased SIV rate for pay-for-performance: 28.1% (1.3% to 54.9%), and no difference for performance bonus: −0.1% (−42.1% to 42%), respectively.

Pooled difference in SIV rates for combined interventions compared with no intervention
Two RCTs (28,52) and two out of five NRS (40,44) contributed to the pooled estimates. Evidence from RCTs showed that team-based training/education of physicians and nurses, together with use of reminders, significantly increased SIV rates in adult patients: 10.8% (3.3–18.2%; I² = 0%; two studies) (Fig. 4). Evidence from NRS showed that one-off provision of guidelines/information to physicians together with and use of reminders significantly increased SIV rates in adult patients: 19.5% (14.9–24.1%; I² = 0%; two studies) (Supplementary Fig. 4). One study among physicians and nurses in adult patients was also in favour of the interventions combination (Supplementary Fig. 4) (35). One study each reported on team-based training/education of physicians and of pharmacists together with the use of reminders in adult patients and both studies reported no difference: 10.9% (−3.2% to 26.5%) and 24% (−0.0% to 48%), respectively. One study each also reported on physician pay-for-performance together with reminders (26), and team-based training/
Table 1. Summary of study characteristics

| Study (Country) | Funder | Study type | Study unit (Number of participants) | Patients | Provider type (Male %) | Interventions (Types) | Intervention(s) description |
|-----------------|--------|------------|-------------------------------------|----------|------------------------|-----------------------|---------------------------|
| Gill (21) (USA) | Delaware Foundation for Medical Services and DuPont (1997/1998) | Before-and-after intervention study | Health care provider (31) | Elderly (≥65 years) | Physicians (NR) | Reminders (Prompts) | A fully automated office medical record with a computerized physician reminder |
| Chan (22) (USA) | NR (1997/1998) | Parallel RCT | Health care provider (44) and (13) | Musculoskeletal or neurologic issues | Physicians (NR) | Reminders (Letters) | Four separate monthly mailed physician reminders to immunize their patients during the influenza season |
| Gill (23) (USA) | NR (2001/2002) | Before-and-after intervention study | Health care provider (28) | Adult diabetics | Physicians (NR) | Education (One-off provision of guidelines/information) | Provision and explanation of clinical guidelines to doctors |
| Hutt (24) (USA) | Department of Veterans Affairs (2004/2005) | Before-and-after intervention study | Health care provider (40) | Lower respiratory tract infection (veterans) | Physicians (NR) | Education and reminders (Team-based training/education sessions and reminder) | A prototype educational program with case studies, provision of selected materials and reprints to physicians including annotated copy of the guidelines, meetings to help educate physicians, posters and cards |
| Ogburn (25) (USA) | NR (2003/2004) | Before-and-after intervention study | Health care provider (310) | Pregnant women | Physicians and nurses (NR) | Education (Team-based training/education sessions) | Educational sessions for providers and clinic personnel, and a protocol for nurses to screen patients for vaccination |
| Weber (26) (USA) | NR (2005/2007) | Before-and-after intervention study | Health care provider (136) | Adults | Physicians (NR) | Incentives and reminders (Pay-for-performance and prompts) | Electronic health maintenance and best practice alert to draw physician’s attention that an item was needed, and physician bonuses if the practices met a criteria |
| McGovern (27) (UK) | Scottish Executive Health Department, University of Aberdeen (2004/2005) | Before-and-after intervention study | General practice or hospital (310) | Coronary heart disease (adults) | Physicians (NR) | Incentives (Pay-for-performance) | General Medical Services contract |
| Hogg (28) (Canada) | Canadian Institutes of Health Research (CIHR) (NR) | Cluster RCT | General practice or hospital (54) | Adults | Physicians and nurses (NR) | Education and reminders (Team-based training/education sessions and prompts) | A nurse-led preventative educational outreach and training sessions on use of medical office electronic computer systems |
| Ledwich (29) (USA) | NR (2006/2007) | Before-and-after intervention study | General practice or hospital (2) | Adult rheumatology patients taking immunosuppressive drugs | Physicians and nurses (NR) | Reminders (Prompts) | An electronic health record best practice alert clinical reminder |
| Study (Country) | Funder (Study period) | Study type | Study unit (Number of participants) | Patients | Provider type (Male %) | Interventions (Types) | Intervention(s) description |
|----------------|-----------------------|------------|-------------------------------------|----------|------------------------|----------------------|--------------------------|
| Snow (30) (USA) | Pfizer (2006)         | Before-and-after intervention study | Health care provider (54) | Increased risk of cardiovascular disease | Physicians and nurses (NR) | Education (Team-based training/education sessions) | Three training sessions and two conference calls for a team of one physician, one nurse or an allied health professional over a 6-month period |
| Loo (31) (USA)  | Donald W. Reynolds Foundation (2009/2010) | Before-and-after intervention study | Health care provider (17) | Elderly (≥65 years) | Physicians (52.9) | Reminders (Prompts) | A set of electronic medical records and provider's panel list for patients reminders |
| Nace (32) (USA) | NR (2002/2003)         | Before-and-after intervention study | General practice or hospital (3) | Elderly in long-term care (≥65 years) | Nurses (NR) | Education (One-off provision of guidelines/information) | A written educational toolkit and shared information through email and a single half-day collaborative training session |
| Dapp (33) (Switzerland) | EU, Federal Ministry, Bern, Switzerland, Federal Ministry, Berlin, Germany, Max and Ingeburg & Heart Robert Bosch Foundations (NR) | Non-RCT | General practice or hospital (14) | Elderly (≥60 years) | Physicians (NR) | Education (Team-based training/education sessions) | Bimonthly 2-hour training sessions for general practitioners led by an experienced geriatrician using a newly developed evidence-based manual with guidance notes |
| Patwardhan (34) (USA) | NR (2007/2010)         | Before-and-after intervention study | Health care provider (6) | Rheumatic disease (paediatric) | Physicians and nurses (NR) | Reminder (Prompt) | An electronic medical record reminder during inpatient visit and relatively early on in outpatient encounter |
| Sherman (35) (USA) | NR (2003/2005)         | Before-and-after intervention study | Health care provider (NR) | Pregnant women | Physicians and nurses (NR) | Education and reminders (One-off provision of guidelines/information, and reminder) | Education of staff (knowledge base discussions) and reminder (prompts) system containing a simple outline of recommendations for vaccination, answers to common questions and a list of high-risk groups |
| Klatt (36) (USA) | NR (2008/2009)         | Before-and-after intervention study | Health care provider (22) | Pregnant women | Physicians and nurses (NR) | Reminders (Prompts) | An electronic reminder within patient electronic prenatal record |
| Kirschner (37) (Netherlands) | CZ and VGZ Health Insurance Companies (NR) | Before-and-after intervention study | General practice or hospital (60) | High risk and elderly (≥65 years) | Physicians (NR) | Incentives (Pay-for-performance) | Practices received a bonus according to their performance, based on comparing their quality indicator scores of clinical care, practice management and patient experience |
| Satman (38) (Turkey) | Sanofi-Pasteur (2010/2011) | Before-and-after intervention study | Health care provider (44) | Adult diabetics | Physicians (NR) | Education (Team-based training/education sessions) | A physician training program designed in accordance with the immunization recommendations of clinical practice guidelines on diabetes and its complications |
| Study (Country) | Funder (Study period) | Study type | Study unit (Number of participants) | Patients | Provider type (Male %) | Interventions (Types) | Intervention(s) description |
|----------------|-----------------------|------------|-------------------------------------|----------|------------------------|----------------------|-------------------------------------------------|
| Ulrik (39) (Denmark) | GlaxoSmithKline (GSK) (2008, 2009, 2010) | Non-RCT | General practice or hospital (202) | Adults COPD (≥40 years) | Physicians and nurses (NR) | Education (Team-based training/education sessions) | Three-hour teaching lesson to GPs conducted by a specialist in respiratory medicine. Five training visits by a GSK representative. Written educational material to GPs and their staff |
| Walsh (40) (Australia and UK) | NHS, MRC, National Institute of Clinical Studies, GSA (2010) | Before-and-after intervention study | Health care provider (30) | Adult IBD patients | Physicians (NR) | Education and reminders (One-off provision of guidelines/information, and reminder) | A copy of clinical practice guidelines was sent to physicians. Reminder emails were also sent to them on a regular basis |
| McCready (41) (USA) | NR (2011/2012) | Before-and-after intervention study | Health care provider (11) | Asthmatics (paediatric) | Physicians and nurses (NR) | Education (One-off provision of guidelines/information) | Educational session during a free lunch in which a 30-minute lecture with slide presentation was offered |
| Pollack (42) (USA) | National Institutes of Health (NIH) (2003/2012) | Before-and-after intervention study | Health care provider (NR) | Children | Nurses (NR) | Reminders (Prompts) | An electronic device for screening of patients at the time of admission or transfer and automatically placing order for vaccination without requiring direct intervention from a physician |
| Hull (43) (UK) | Tower Hamlets Primary Care Trust, UK (2010/2013) | Before-and-after intervention study | General practice or hospital (8) | Adult COPD | Physicians and nurses (NR) | Education (Team-based training/education sessions) | Training and multidisciplinary team meetings |
| Mendu (44) (USA) | NR (2012/2013) | Non-RCT | Health care provider (4) | Chronic kidney disease | Physicians (0) | Education and reminders (One-off provision of guidelines/information, and reminder) | Education materials provided to physicians and a 30-minute lecture and email reminders |
| Vernacchio (45) (USA) | Paediatric Physicians' Organization (2009/2010) | Before-and-after intervention study | Health care provider (15), (24) and (17) | Children and adolescents | Physicians (46.7), (37.5) and (29.4) | Education (Team-based training/education sessions) | Two-hour face-to-face meetings using Institute for Healthcare Improvement's learning collaborative model, a longitudinal learning curriculum and monthly communication via email or telephone |
| Crawford (46) (Australia) | NR (2007–11) | Before-and-after intervention study | Health care provider (NR) | Preterm infants | Physicians and nurses (NR) | Education (One-off provision of guidelines/information) | Education of health care professionals regarding immunization of preterm infants and the scientific evidence behind the current clinical guidelines |
| Szilagyi (47) (USA) | CDC (2011/2013) | Parallel RCT | General practice or hospital (10) and (12) | Adolescents | Physicians and nurses (NR) | Reminders (Prompts) | Educational sessions and one or two 1-hour training sessions on use of electronic health records prompts |
| Study (Country) | Funder (Study period) | Study type | Study unit (Number of participants) | Patients | Provider type (Male %) | Interventions (Types) | Intervention(s) description |
|----------------|-----------------------|------------|-------------------------------------|----------|------------------------|----------------------|--------------------------|
| Pierson (48) (USA) | Indiana University CPTRM and NIH-NIGMS (2011/2012) | Before-and-after intervention study | Health care provider (NR) | Pregnant women (underserved and needy) | Physicians (NR) | Reminders (Prompts) | A simple paper-based prompt attached to the front of a patient's chart during the check-in process to record whether patient had been previously vaccinated or not, and patient desire for vaccination. |
| Stockwell (49) (USA) | Agency for Healthcare Research and Quality (2011/2012) | Cluster RCT | General practice or hospital (4) | Children and adolescents | Physicians and nurses (NR) | Reminders (Prompts) | A short in-person in-service as well as visual aids training on an automatic electronic reminder display. |
| Sapir (50) (USA) | AbbVie Inc. and Takeda Pharmaceuticals USA Inc. (2013/2013) | Before-and-after intervention study | Health care provider (20) | Adult with ulcerative colitis | Physicians (70) | Education (Team-based training/education sessions) | A private audit feedback session through web conferencing, a total of five webinars, series of 30- to 60-minute interactive videos online/mobile toolkit that included accredited CME activities. |
| Luder (51) (USA) | Community Pharmacy Foundation (2013/2014) | Before-and-after intervention study | Health care provider (12) | Adult diabetic or hypertensive or dyslipidaemia or three or more chronic conditions | Physicians and pharmacists (NR) | Education and incentives (Team-based training/education sessions, and fee-for-service) | Education and capitated payment per patient per month for a predetermined number of 1000 high-risk patients. |
| Zwar (52) (Australia) | Australian National Health and MRC | Cluster RCT | General practice or hospital (36) | Middle age to elderly adult smokers with risk factors for COPD | Physicians and nurses (NR) | Education and reminders (Team-based training/education sessions and prompts) | Computer-based distance learning for physicians, a 3-hour combined workshop for physicians and nurses, provision of copy of national guidelines and computerized clinical record and care planning systems. |
| Patel (53) (USA) | University of Pennsylvania Leonard Davis Institute of Health Economics and NIA (2010/2013) | Before-and-after intervention study | General practice or hospital (3) | Adults with risk factors for COPD | Physicians (NR) | Reminders (Prompts) | An automated electronic health records alert at the time of patient check-in to medical assistants who could pend orders for the physician to review and potentially sign. Regardless, physicians also received the alert when first opening a patient's chart. |
| Real (54) (USA) | Health Resources and Services Admin. (2015/2016) | Quasi-RCT | Health care provider (45) | <5 years old | Physicians (28.89) | Education (Team-based training/education sessions) | Three immersive virtual reality simulations to teach communication skills when discussing influenza vaccine hesitancy. |
| Lin (55) (USA) | None (2016) | Before-and-after intervention study | Health care provider (19) | Adults | Pharmacists (NR) | Education and reminders (Team-based training/education sessions and reminder) | An in-person 2-hour training session, and discussions, and an electronic platform reminder. |
### Table 1. Continued

| Study (Country) | Funder | Study type | Study unit (Number of participants) | Patients | Provider type (Male %) | Interventions (Types) | Intervention(s) description |
|----------------|--------|------------|-------------------------------------|----------|------------------------|----------------------|---------------------------|
| Parker (56) (USA) | National Cancer Institute and National Institutes of Health (2011/2019) [study on-going] | Cluster RCT | General practice or hospital (4) | Hodgkin’s lymphoma or diffuse large B cell lymphoma in remission Adults | Physicians (67) | Education (Team-based training/education sessions) | Five hours of in-person communication skills training, which included role playing, and discussions |
| Whitaker (57) (USA) | Pfizer (2014/2015) | Before-and-after intervention study | Health care provider (47)a and (52)b | Physicians (63) | Education (One-off provision of guidelines/information) | Power-Point presentation focussed on Advisory Committee on Immunization Practices (ACIP) guidelines for influenza immunizations administered over 60 minutes |
| Feuerstein (58) (USA) | The Hellenic Group for the Study of Inflammatory Bowel Disease (NR) | Before-and-after intervention study | Health care provider (30)a and (16)b | Adult IBD patients | Physicians (NR)a Physicians and nurses (NR)b | Education (One-off provision of guidelines/information) | Emailed copy of quality measures, and handout of quality measures placed in clinic room |
| Giduthuri (59) (India) | WHO, CDC, Swiss Government Excellence Fellowship (2015/2016) | Parallel RCT | Health care provider (19)a and (18)b | Pregnant women (third trimester) | Physicians (7.14)a and (43.75)b | Education (Team-based training/education sessions) | Discussions with physicians of WHO recommendations on vaccination, a review article and a policy report of an expert panel |

a,b,c Represent different cohorts (study participants) in the studies.

EU, European Union; GSA, Gastroenterological Society of Australia; IBD, inflammatory bowel disease; MRC, Medical Research Council; NHS, National Health Service; NR, not reported.
education together with fee-for-service for physicians and for pharmacists and physicians (51), all in adult patients. All three were in favour of the intervention combinations: 15.9% (7.9–23.8%), 15% (5.6–24%) and 3.7% (2.2–5.2%), respectively.

**Discussion**

This review indicates that team-based training/education and one-off provision of guidelines/information to physicians and nurses may
Health care provider-focussed interventions to increase influenza vaccination

be effective in increasing SIV rates in adult and paediatric patient populations. The review also indicates that use of reminder prompts by physicians and nurses may be effective in increasing SIV rates in adult and patient populations, and that various combinations of educational and reminder interventions may also be effective in increasing SIV rates. The evidence supporting these findings are, however, limited and are of moderate to low quality.

While patient population types varied considerably across the included studies, almost all belonged to the high-risk groups for whom SIV is highly recommended. Physician specialty also varied slightly across studies. All but one study were conducted in developed countries with similar health system characteristics, although there would have been potentially differing public health practices across the countries with respect to influenza vaccination programs. There were substantial variabilities in the number of studied health care providers and patient, and the forms, methods of delivery and durations of an intervention. Furthermore, a majority of the studies were conducted in the USA; thus, our findings may not be generalizable and may be more applicable to the USA. That said, our findings are substantial contributions to the evidence base and will help in the development and evaluation of health care provider-focussed interventions to increase seasonal influenza vaccine uptake and, potentially, uptake of other vaccines across important patient populations.

SIV is proven to be a safe, effective and cost-effective preventive measure against influenza, but annual rates remain sub-optimal in many countries even among the most at-risk populations. Vaccination behaviour is influenced by so many factors including perceptions of vaccines and vaccination, and intrinsic factors such as an individual’s knowledge, perceptions and attitudes which are often shaped by many external factors. Despite immense influence and importance of the media, health care professionals have been identified as the most important advocates and the main source of vaccination information for the public (7). The summit of independent European vaccination experts in 2007 concluded that it is of utmost importance that health care providers are offered adequate education on vaccinology and an unhindered access to up-to-date information on vaccines (7). The experts also concluded that it is important that vaccine information systems are set up for health care providers, to facilitate promotion of vaccination.

Education can play an important role in prompting positive change in behaviour (60,61). Increases in knowledge and awareness have been found to lead to changes in attitudes (62). Education of health care providers on specific health issues is therefore expected to help increase their knowledge and awareness and, ultimately, promote a positive change in behaviours. This may explain our finding that one-off provision of guidelines/information or team-based training/education of physicians and physicians together with nurses are effective in increasing SIV rates in both adult and paediatric patient populations. Contrary to our findings, a Cochrane review (Thomas and Lorenzetti) found that physician education was ineffective (10). The review included only RCTs focussing on SIV among community-based patients (≥60 years) in high-income countries, unlike our review which considered all available evidence irrespective of provider type, patient population and country of study. In addition, Thomas and Lorenzetti considered all educational interventions the same, whereas we appropriately categorized the interventions, considering that types and methods of education differ. An older systematic review (Lau) also found physician education to be ineffective (11). This review also focussed on community-based adults and, although the review considered both RCTs and non-RCTs, educational interventions were examined as one group without categorization. It was also not clear which studies contributed to the pooled analysis.

Reminder systems serve as alerting tools. In clinical settings, they alert a health care provider to the key procedures and necessary preventive care that a patient may need; thus, informing of the importance of a needed care (63). The Centers for Disease Control and Prevention (CDC) stress that a reminder system helps to reduce missed opportunities for recommending and providing influenza vaccine to eligible patients when vaccine is available (63). Therefore, implementing a SIV reminder system for health care providers is expected to increase the vaccine recommendation and, consequently, vaccination rates as our review suggests. Implementing a reminder system for both physicians and nurses provides more than one level of quality assurance check, and decreases the risk of failing to provide an important recommendation to an eligible patient. This has been demonstrated by studies which have found that a reminder system for both physicians and nurses leads to increased vaccination uptake (64,65). Our findings are in line with those of some clinical studies that have shown that computerized reminders increase the use of preventive care in outpatient settings (66,67). However, some studies in inpatient settings using standard orders and computerized reminders failed to demonstrate the effectiveness of this intervention (67,68), probably due to a focus on treatment of the cause of hospitalization rather than the provision of preventive care. That said, as a study suggested, it is worth noting that reminder systems for physicians are effective only when applied to all eligible patients (69,70).

Our decision to include only English publications may have limited the number of potentially relevant studies for inclusion. Limiting to studies since 2000 may also have limited the inclusion of studies, but this allowed us to focus on studies conducted during the period in which SIV became publicly funded in many jurisdictions. We were unable to determine if SIV was offered free-of-charge to patients or whether some of the patients had to pay for the vaccine out-of-pocket. As such, we could not examine the impact of free vaccination on the efficacy/effectiveness of the assessed interventions. Furthermore, nearly all reported SIV rates from the NRS of quality assurance check, and decreases the risk of failing to promote of vaccination.

Conclusions

Limited low- to moderate-quality evidence suggests that various forms of education for physicians and nurses, and use of reminder prompts by physicians and nurses, may be effective for increasing SIV rates in both adult and paediatric patient populations. High-quality studies are needed for a stronger evidence base to better inform and understand the efficacy/effectiveness of various interventions focussed on health care providers to increase SIV.
Supplementary material
Supplementary material is available at Family Practice online.

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Data availability
The data underlying this article are available in the article and in its online supplementary material.

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