Family Practice, 2021, 524–536
doi:10.1093/fampra/cmaa149
Advance Access publication 31 January 2021

OXFORD

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

George N Okoli[a], Viraj K Reddy[a], Otto LT Lam[a], Tiba Abdulwahid[a], Nicole Askin[b], Edward Thommes[c], Ayman Chit[c], Ahmed M Abou-Setta[a,d] and Salaheddin M Mahmud[d,e,*]

[a]George and Fay Yee Centre for Healthcare Innovation and [b]Neil John Maclean Health Sciences Library, University of Manitoba, Winnipeg, Canada, [c]Sanofi Pasteur, Swiftwater, PA, USA and [d]Community Health Sciences, Rady Faculty of Health Sciences and [e]Vaccine and Drug Evaluation Centre, University of Manitoba, Winnipeg, Canada

*Correspondence to Salaheddin M Mahmud, Vaccine and Drug Evaluation Centre, University of Manitoba, 750 McDermot Avenue, Winnipeg R3E 0T5, MB Canada; E-mail: Salah.Mahmud@umanitoba.ca

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%; I^2 = 0%; two randomized controlled trials (RCTs)] and 13.4% [8.6–18.1%; I^2 = 0%; two non-randomized intervention studies (NRS)]. A smaller increase was observed in paediatric patients: 7% (0.1–14%; I^2 = 0%; two NRS), and in adult patients with team-based training/education of physicians and nurses together: 0.9% (0.2–1.5%; I^2 = 30.6%; four NRS). One-off provision of guidelines/information to physicians, and to both physicians and nurses, increased SIV rates in adult patients: 23.8% (15.7–31.8%; I^2 = 45.8%; three NRS) and paediatric patients: 24% (8.1–39.9%; I^2 = 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%; I^2 = 0%; two RCTs). A larger increase was observed in adult patients: 18.5% (14.8–22.1%; I^2 = 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/

education 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 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

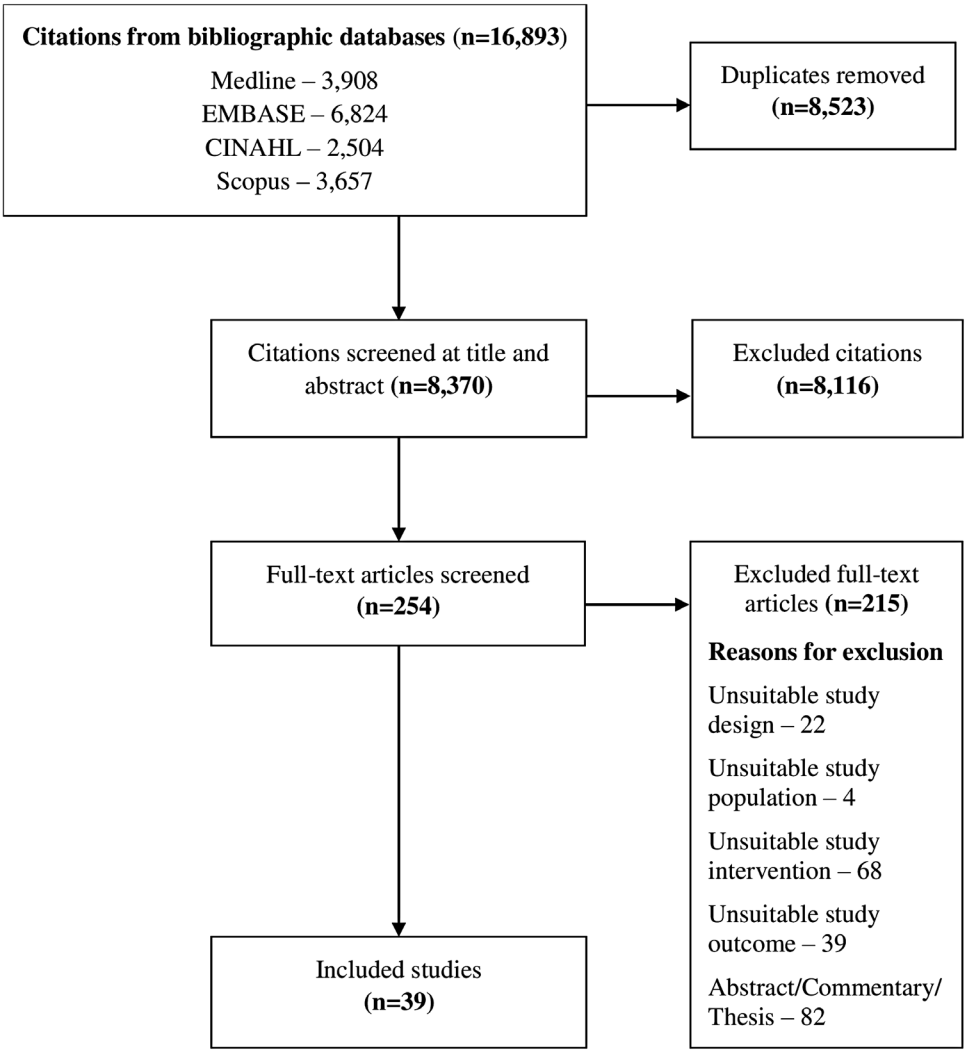

Figure 1. Summary of literature search and screening process (modified PRISMA flow chart).

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%; I^2 = 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%; I^2 = 98.1%; three studies) and 18.5% (14.8–22.1%; I^2 = 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%; I^2 = 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%; I^2 = 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 period)	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)[a] and (13)[b]	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 (NR)	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 (66.8)	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

Table 1. Continued

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

Table 1. Continued

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
McCreary (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 luncheon 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)[a], (24)[b] and (17)[c]	Children and adolescents	Physicians (46.7)[a], (37.5)[b] and (29.4)[c]	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)[a] and (12)[b]	Adolescents	Physicians and nurses (NR)	Reminders (Prompts)	Educational sessions and one or two 1-hour training sessions on use of electronic health records prompts

Table 1. Continued

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	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 period)	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	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]	Adults	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.

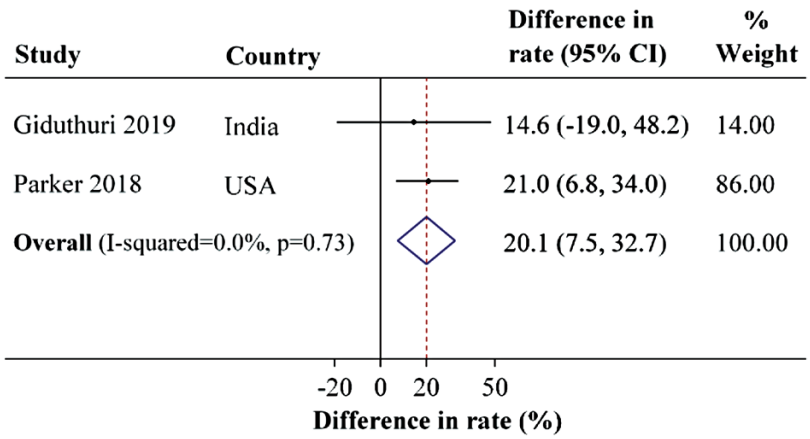

Figure 2. Forest plot of team-based training/education of physicians compared with no intervention, in adult patients (RCTs).

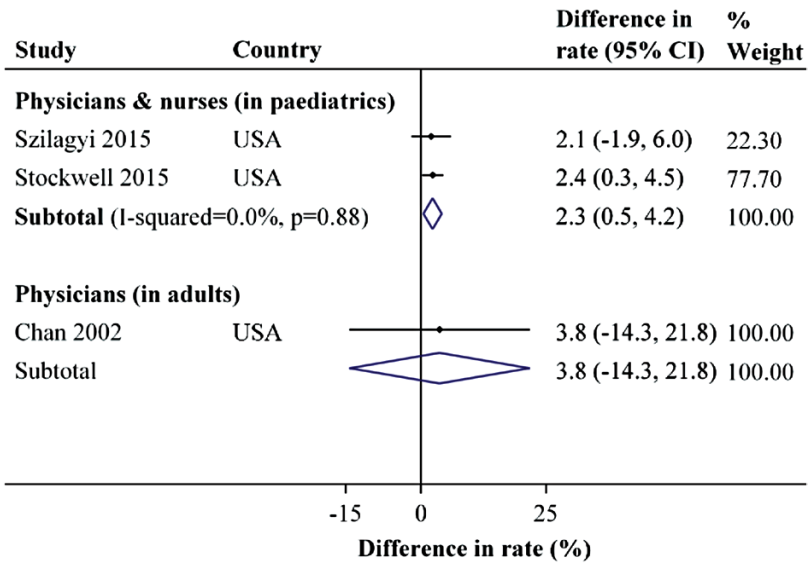

Figure 3. Forest plot of reminders (prompts) compared with no intervention (RCTs).

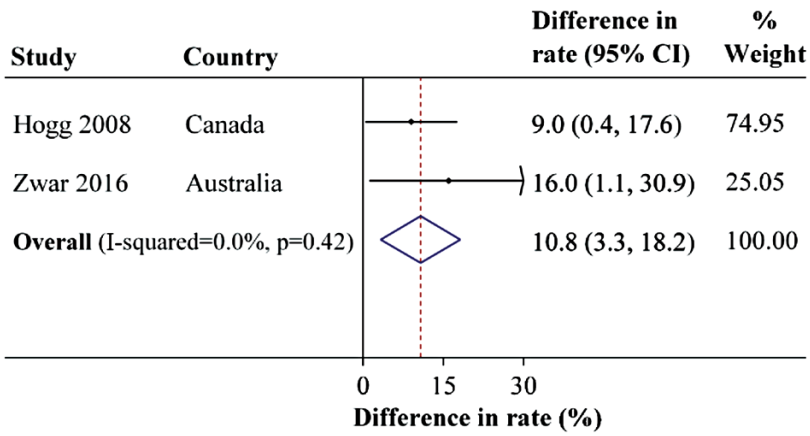

Figure 4. Forest plot of combined team-based training/education of physicians and nurses, and reminders (prompts) compared with no intervention, in adult patients (RCTs).

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

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 patients, 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 suboptimal 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 have also 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 were crude rates. For the before-and-after intervention studies, the populations at baseline were not always exactly the same as those post-intervention.

Nevertheless, this review has many merits, including full compliance with the Cochrane Handbook for Systematic Reviews of Interventions guidelines, utilization of the expertise of knowledge synthesis librarians in developing and peer reviewing a comprehensive search strategy, and searching of appropriate bibliographic databases for literature. Where necessary, we requested additional data from corresponding authors of the included studies, to ensure completeness of the analysed data. We conducted the review to the expected standards and reported in accordance with the PRISMA guidelines.

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.

Acknowledgements

We thank Drs Thomas J Van Hoof, James M Gill, Ulrike Dapp, Louis Vernacchio, William Trick, Ari Pollack, Timothy Loo, David Nace, Valerie Weber, Eric Ruderman and Jan van Lieshout for responding kindly to our request for additional data on their publication(s).

Declaration

Funding: this work was supported by Sanofi Pasteur, USA (grant number not applicable). The funder contributed towards specifying the research questions but had no role in the study design, data collection and analysis.
Ethical approval: not applicable.
Conflict of interest: Salaheddin M Mahmud (SMM) has received unrestricted research grants from GlaxoSmithKline, Merck, Sanofi Pasteur, Pfizer and Roche-Assurex for unrelated studies, and fees as an advisory board member for Sanofi Pasteur. SMM is supported, in part, by funding from the Canada Research Chairs Program. E Thommes and A Chit are employees of Sanofi Pasteur, USA. The other authors have no conflicts of interest to declare.

Data availability

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

References

1. The World Health Organization Strategic Advisory Group of Experts (SAGE) Working Group. *Background Paper on Influenza Vaccines and Immunization*. Geneva, Switzerland: WHO, 2012. https://www.who.int/influenza/vaccines/SAGE_information/en/
2. European Centre for Disease Prevention and Control. *Seasonal Influenza Vaccination and Antiviral Use in EU/EEA Member States: Overview of Vaccine Recommendations for 2017–2018 and Vaccination Coverage Rates for 2015–2016 and 2016–2017 Influenza Seasons*. Stockholm, Sweden: ECDC, 2018.
3. Grohskopf LA, Sokolow LZ, Broder KR *et al*. Prevention and control of seasonal influenza with vaccines: recommendations of the Advisory Committee on Immunization Practices—United States, 2017–18 influenza season. *Morb Mortal Wkly Rep* 2017; **66**(2): 1–20.
4. National Advisory Committee on Immunization (NACI). *Canadian Immunization Guide Chapter on Influenza and Statement on Seasonal Influenza Vaccine for 2017–2018*. Ottawa, Ontario, Canada: Public Health Agency of Canada, 2017.
5. Ortiz JR, Perut M, Dumolard L *et al*. A global review of national influenza immunization policies: analysis of the 2014 WHO/UNICEF Joint Reporting Form on immunization. *Vaccine* 2016; **34**(45): 5400–5.
6. MacDonald NE; SAGE Working Group on Vaccine Hesitancy. Vaccine hesitancy: definition, scope and determinants. *Vaccine* 2015; **33**(34): 4161–4.
7. Schmitt HJ, Booy R, Aston R *et al*. How to optimise the coverage rate of infant and adult immunisations in Europe. *BMC Med* 2007; **5**: 11.
8. Smith PJ, Kennedy AM, Wooten K, Gust DA, Pickering LK. Association between health care providers' influence on parents who have concerns about vaccine safety and vaccination coverage. *Pediatrics* 2006; **118**(5): e1287–92.
9. Vorsters A, Bonanni P, Maltezou HC *et al*. The role of healthcare providers in HPV vaccination programs—a meeting report. *Papillomavirus Res* 2019; **8**: 100183.
10. Thomas RE, Lorenzetti DL. Interventions to increase influenza vaccination rates of those 60 years and older in the community (review). *Cochrane Database Syst Rev* 2018;(5): CD005188.
11. Lau D, Hu J, Majumdar SR *et al*. Interventions to improve influenza and pneumococcal vaccination rates among community-dwelling adults: a systematic review and meta-analysis. *Ann Fam Med* 2012; **10**(6): 538–46.
12. Sanftenberg L, Brombacher F, Schelling J, Klug SJ, Gensichen J. Increasing influenza vaccination rates in people with chronic illness. *Dtsch Arztebl Int* 2019; **116**(39): 645–52.
13. Gosselin Boucher V, Colmegna I, Gemme C *et al*. Interventions to improve vaccine acceptance among rheumatoid arthritis patients: a systematic review. *Clin Rheumatol* 2019; **38**(6): 1537–44.
14. Higgins JPT, Lasserson T, Chandler J, Tovey D, Churchill R. *Methodological Expectations of Cochrane Intervention Reviews (MECIR)*. London, UK: The Cochrane Collaboration, 2016.
15. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg* 2010; **8**(5): 336–41.
16. McGowan J, Sampson M, Salzwedel DM *et al*. PRESS peer review of electronic search strategies: 2015 guideline statement. *J Clin Epidemiol* 2016; **75**: 40–6.
17. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002; **21**(11): 1539–58.
18. Sterne JA, Egger M, Smith GD. Systematic reviews in health care: investigating and dealing with publication and other biases in meta-analysis. *BMJ* 2001; **323**(7304): 101–5.
19. Higgins JPT, Altman DG, Gøtzsche PC *et al*. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011; **343**: d5928.
20. National Hearth L, and Blood Institute. *Quality Assessment Tool for Before-After (Pre-Post) Studies with No Control Group*. National Institutes of Health (NIH). https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools. (accessed on 31 December 2019).
21. Gill JM, Saldarriaga AM. The impact of a computerized physician reminder and a mailed patient reminder on influenza immunizations for older patients. *Del Med J* 2000; **72**(10): 425–30.
22. Chan L, MacLehose RF, Houck PM. Impact of physician reminders on the use of influenza vaccinations: a randomized trial. *Arch Phys Med Rehabil* 2002; **83**(3): 371–5.
23. Gill JM, DiPrinzio MJ. The Medical Society of Delaware's Uniform Clinical Guidelines for diabetes: did they have a positive impact on quality of diabetes care? *Del Med J* 2004; **76**(3): 111–22.
24. Hutt E, Ruscin JM, Corbett K *et al*. A multifaceted intervention to implement guidelines improved treatment of nursing home-acquired pneumonia in a state veterans home. *J Am Geriatr Soc* 2006; **54**(11): 1694–700.
25. Ogburn T, Espey EL, Contreras V, Arroyo P. Impact of clinic interventions on the rate of influenza vaccination in pregnant women. *J Reprod Med* 2007; **52**(9): 753–6.
26. Weber V, Bloom F, Pierdon S, Wood C. Employing the electronic health record to improve diabetes care: a multifaceted intervention in an integrated delivery system. *J Gen Intern Med* 2008; **23**(4): 379–82.
27. McGovern MP, Boroujerdi MA, Taylor MW *et al*. The effect of the UK incentive-based contract on the management of patients with coronary heart disease in primary care. *Fam Pract* 2008; **25**(1): 33–9.
28. Hogg W, Lemelin J, Graham ID *et al*. Improving prevention in primary care: evaluating the effectiveness of outreach facilitation. *Fam Pract* 2008; **25**(1): 40–8.
29. Ledwich LJ, Harrington TM, Ayoub WT, Sartorius JA, Newman ED. Improved influenza and pneumococcal vaccination in rheumatology patients taking immunosuppressants using an electronic health record best practice alert. *Arthritis Rheum* 2009; **61**(11): 1505–10.
30. Snow V, Reynolds CE, Bennett L *et al*. Closing the gap-cardiovascular risk and primary prevention: results from the American College of Physicians quality improvement program. *Am J Med Qual* 2010; **25**(4): 261–7.
31. Loo TS, Davis RB, Lipsitz LA *et al*. Electronic medical record reminders and panel management to improve primary care of elderly patients. *Arch Intern Med* 2011; **171**(17): 1552–8.
32. Nace DA, Perera S, Handler SM, Muder R, Hoffman EL. Increasing influenza and pneumococcal immunization rates in a nursing home network. *J Am Med Dir Assoc* 2011; **12**(9): 678–84.
33. Dapp U, Anders JA, von Renteln-Kruse W *et al*.; PRO-AGE Study Group. A randomized trial of effects of health risk appraisal combined with group

sessions or home visits on preventive behaviors in older adults. *J Gerontol A Biol Sci Med Sci* 2011; **66**(5): 591–8.
34. Patwardhan A, Kelleher K, Cunningham D, Menke J, Spencer C. The use of a mandatory best practice reminder in the electronic record improves influenza vaccination rate in a pediatric rheumatology clinic. *Clin Govern* 2011; **16**(4): 308–19.
35. Sherman MJ, Raker CA, Phipps MG. Improving influenza vaccination rates in pregnant women. *J Reprod Med* 2012; **57**(9–10): 371–6.
36. Klatt TE, Hopp E. Effect of a best-practice alert on the rate of influenza vaccination of pregnant women. *Obstet Gynecol* 2012; **119**(2 Pt 1): 301–5.
37. Kirschner K, Braspenning J, Akkermans RP, Jacobs JE, Grol R. Assessment of a pay-for-performance program in primary care designed by target users. *Fam Pract* 2013; **30**(2): 161–71.
38. Satman I, Akalin S, Cakir B, Altinel S; diaVAX Study Group. The effect of physicians' awareness on influenza and pneumococcal vaccination rates and correlates of vaccination in patients with diabetes in Turkey: an epidemiological Study "diaVAX". *Hum Vaccin Immunother* 2013; **9**(12): 2618–26.
39. Ulrik CS, Sørensen TB, Højmark TB, Olsen KR, Vedsted P. Adherence to COPD guidelines in general practice: impact of an educational programme delivered on location in Danish general practices. *Prim Care Respir J* 2013; **22**(1): 23–8.
40. Walsh AJ, Weltman M, Burger D *et al*. Implementing guidelines on the prevention of opportunistic infections in inflammatory bowel disease. *J Crohns Colitis* 2013; **7**(10): e449–56.
41. McCreary L. Increasing the rate of influenza vaccination in children with asthma using a clinic staff and provider educational intervention. *J Asthma Allergy Educ* 2013; **4**(6): 277–81.
42. Pollack AH, Kronman MP, Zhou C, Zerr DM. Automated screening of hospitalized children for influenza vaccination. *J Pediatr Infect Dis Soc* 2014; **3**(1): 7–14.
43. Hull S, Mathur R, Lloyd-Owen S, Round T, Robson J. Improving outcomes for people with COPD by developing networks of general practices: evaluation of a quality improvement project in east London. *NPJ Prim Care Respir Med* 2014; **24**: 14082.
44. Mendu ML, Schneider LI, Aizer AA *et al*. Implementation of a CKD checklist for primary care providers. *Clin J Am Soc Nephrol* 2014; **9**(9): 1526–35.
45. Vernacchio L, Francis ME, Epstein DM *et al*. Effectiveness of an asthma quality improvement program designed for maintenance of certification. *Pediatrics* 2014; **134**(1): e242–8.
46. Crawford NW, Barfield C, Hunt RW, Pitcher H, Buttery JP. Improving preterm infants' immunisation status: a follow-up audit. *J Paediatr Child Health* 2014; **50**(4): 314–8.
47. Szilagyi PG, Serwint JR, Humiston SG *et al*. Effect of provider prompts on adolescent immunization rates: a randomized trial. *Acad Pediatr* 2015; **15**(2): 149–57.
48. Pierson RC, Malone AM, Haas DM. Increasing influenza vaccination rates in a busy urban clinic. *J Nat Sci* 2015;**1**(3): e57.
49. Stockwell MS, Catallozzi M, Camargo S *et al*. Registry-linked electronic influenza vaccine provider reminders: a cluster-crossover trial. *Pediatrics* 2015; **135**(1): e75–82.
50. Sapir T, Moreo K, Carter JD *et al*. Continuing medical education improves gastroenterologists' compliance with inflammatory bowel disease quality measures. *Dig Dis Sci* 2016; **61**(7): 1862–9.
51. Luder H, Frede S. Community pharmacist collaboration with a patient-centered medical home: establishment of a patient-centered medical neighborhood and payment model. *J Am Pharm Assoc* 2016; **56**(3): e18–9.
52. Zwar NA, Bunker JM, Reddel HK *et al*. Early intervention for chronic obstructive pulmonary disease by practice nurse and GP teams: a cluster randomized trial. *Fam Pract* 2016; **33**(6): 663–70.
53. Patel MS, Volpp KG, Small DS *et al*. Using active choice within the electronic health record to increase influenza vaccination rates. *J Gen Intern Med* 2017; **32**(7): 790–5.
54. Real FJ, DeBlasio D, Beck AF *et al*. A virtual reality curriculum for pediatric residents decreases rates of influenza vaccine refusal. *Acad Pediatr* 2017; **17**(4): 431–5.
55. Lin JL, Bacci JL, Reynolds MJ *et al*. Comparison of two training methods in community pharmacy: project VACCINATE. *J Am Pharm Assoc (2003)* 2018; **58**(4S): S94–100.e3.
56. Parker PA, Banerjee SC, Matasar MJ *et al*. Efficacy of a survivorship-focused consultation versus a time-controlled rehabilitation consultation in patients with lymphoma: a cluster randomized controlled trial. *Cancer* 2018; **124**(23): 4567–76.
57. Whitaker JA, Poland CM, Beckman TJ *et al*. Immunization education for internal medicine residents: a cluster-randomized controlled trial. *Vaccine* 2018; **36**(14): 1823–9.
58. Feuerstein JD, Papamichael K, Popejoy S *et al*. Targeted physician education and standardizing documentation improves documented reporting with inflammatory bowel disease quality measures in a large academic and private practice. *Dig Dis Sci* 2018; **63**(1): 36–45.
59. Giduthuri JG, Purohit V, Maire N *et al*. Influenza vaccination of pregnant women: engaging clinicians to reduce missed opportunities for vaccination. *Vaccine* 2019; **37**(14): 1910–7.
60. Aminrad Z, Zarina S, Sayed B *et al*. Relationship between awareness, knowledge and attitudes towards environmental education among secondary school students in Malaysia. *World Appl Sci* 2013; **22**(9): 1326–33.
61. Ho HJ, Chan YY, Ibrahim MAB *et al*. A formative research-guided educational intervention to improve the knowledge and attitudes of seniors towards influenza and pneumococcal vaccinations. *Vaccine* 2017; **35**(47): 6367–74.
62. Rose KA, Ayad S. Factors associated with changes in knowledge and attitude towards public health concepts among chiropractic college students enrolled in a community health class. *J Chiropr Educ* 2008; **22**(2): 127–37.
63. Centers for Disease Control and Prevention. *Epidemiology and Prevention of Vaccine—Preventable Diseases: Immunization Strategies for Healthcare Practices and Providers*. 13th edn. Washington, DC: Public Health Foundation, 2015.
64. Donato AA, Motz LM, Wilson G, Lloyd BJ. Efficacy of multiple influenza vaccine delivery systems in a single facility. *Infect Control Hosp Epidemiol* 2007; **28**(2): 219–21.
65. Rees S, Stevens L, Drayton J, Engledow N, Sanders J. Improving inpatient pneumococcal and influenza vaccination rates. *J Nurs Care Qual* 2011; **26**(4): 358–63.
66. Coyle CM, Currie BP. Improving the rates of inpatient pneumococcal vaccination: impact of standing orders versus computerized reminders to physicians. *Infect Control Hosp Epidemiol* 2004; **25**(11): 904–7.
67. Shojania KG, Jennings A, Mayhew A *et al*. Effect of point-of-care computer reminders on physician behaviour: a systematic review. *CMAJ* 2010; **182**(5): E216–25.
68. Fiks AG, Hunter KF, Localio AR *et al*. Impact of electronic health record-based alerts on influenza vaccination for children with asthma. *Pediatrics* 2009; **124**(1): 159–69.
69. Chambers CV, Balaban DJ, Carlson BL, Grasberger DM. The effect of microcomputer-generated reminders on influenza vaccination rates in a university-based family practice center. *J Am Board Fam Pract* 1991; **4**(1): 19–26.
70. Tierney WM, Overhage JM, Murray MD *et al*. Can computer-generated evidence-based care suggestions enhance evidence-based management of asthma and chronic obstructive pulmonary disease? A randomized, controlled trial. *Health Serv Res* 2005; **40**(2): 477–97.