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Educational Interventions to improve prescribing competency: A systematic review

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Objective: To review the literature on educational interventions to improve prescribing and identify educational methods which improve prescribing competency in both medical and non-medical prescribers.

Design: Systematic review

Data sources: The databases Medline, International Pharmaceutical Abstracts (IPA), EMBASE and CINAHL were searched for articles in English published between 1990 and 2011.

Study selection: A total of 40 studies were reviewed. Eligible studies evaluated the effect of educational interventions on at least one outcome measure of prescribing competency demonstrated through prescribing examinations, changes in prescribing habits or adherence to guidelines.

Results: Studies were categorized by their method of assessment, with 15 studies assessing prescribing competence (knows how) and 25 assessing prescribing performance (shows how). A wide variety of educational interventions were employed, with different outcome measures and methods of assessments. In particular, six studies demonstrated that specific prescribing training using the World Health Organization (WHO) *Guide to Good Prescribing* increased prescribing competency in a wide variety of settings. Continuing medical education in the form of academic detailing and personalized prescriber feedback also yielded positive results. Only four studies evaluated educational interventions targeted at non-medical prescribers, highlighting that further research is needed in this area.

Conclusion: A broad range of educational interventions have been conducted to improve prescribing competency. The WHO *Guide to Good Prescribing* has the largest body of evidence to support its use and is a promising model for the design of targeted prescribing

courses. There is a need for further development and evaluation of educational methods for non-medical prescribers.

Article summary

Article Focus

1. Prescribing rights are expanding to non-medical healthcare professions globally

2. Prescribing competencies that cover both medical and non-medical prescribers have been developed internationally

3. This review examines the literature on educational interventions designed to develop and improve patient-focused prescribing competency in both medical and non-medical prescribers.

Key Messages

1. The World Health Organization (WHO) *Guide to Good Prescribing* has the largest body of evidence supporting its use to improve prescribing competencies internationally.

2. Few studies have focused on educational interventions for non-medical prescribers.

3. There is a need for further development and evaluation of educational methods for non-medical prescribers.

Strengths and Limitations

1. This is the first literature review that focuses on both medical and non-medical prescribing interventions.

2. The lack of high quality studies and the range of heterogeneous study designs and outcome measures limits the validity and generalizability of their conclusions.

3. This review highlighted a lack of educational interventions targeted at non-medical prescribers.

Introduction

Prescribing, a complex process involving the initiation, monitoring, continuation and modification of medication therapy,[1] demands a thorough understanding of clinical pharmacology as well as the judgment and ability to prescribe rationally for the benefit of patients.[2] The rational prescribing of medicines as defined by the World Health Organization (WHO) is *the situation in which patients receive medications appropriate to their clinical needs, in doses that meet their own individual requirements for a sufficient length of time, with the lowest cost to them and their community*.[3] Equipping prescribers with skills for rational prescribing is essential.

The diversity of skills required for good prescribing present a major challenge for the development of educational programs. Adding to this complexity is the extension of prescribing rights to non-medical healthcare professionals such as optometrists, nurses and pharmacists. Potential benefits of non-medical prescribing have been argued to include improved continuity of care and access to medicines, better allocation of human resources, increased patient convenience and less fragmentation of care,[1] however the process of prescribing is considered high-risk and error-prone.[2] Hence competent prescribing is paramount to patient safety. Poor prescribing can be illustrated by prescription errors, under or overprescribing, or inappropriate and irrational prescribing.[2 4] Junior prescribers appear most prone to prescribing errors, yet are expected to perform a significant prescribing role.[5-8] Studies have shown that the prescribing performance of interns and medical students is poor, partly because of inadequate training.[9 10] Little is known however about non-medical prescribing practices and rates of prescription errors. Research into non-medical prescribing has mainly been confined to self-report measures such as questionnaire and interview surveys.[11] Although one UK study indicated that nurses' prescribing decisions were generally

clinically appropriate, a large proportion did not display some prescribing competencies, e.g. taking patients' medicines history and allergy status.[12]

Traditionally assessment of education was based upon knowledge tests, however it is recognised today that knowledge alone is insufficient to predict performance in practice.[13] This has led to the introduction of competency-based education, focusing on developing knowledge, judgment and skills.[13 14] Miller proposed a four-staged competency assessment model beginning with assimilation of pure knowledge, progressing to development of real performance in practice (Figure 1).[13] Such developments have led the National Prescribing Centre in the UK and the NPS MedicineWise (Quality Use of Medicines service agency for Australia's National Medicines Policy) to produce a core competency framework for all prescribing, both medical and non-medical.[15 16] Although a number of recommendations for prescribing education to ensure competency have been introduced, there is little detail as to how these competencies could actually be achieved.[17] Two systematic reviews of interventions to improve prescribing were published in 2009.[18 19] One focused on medical students and junior doctors,[19] while the other was an update of two previous reviews investigating the effectiveness of different types of interventions on improving prescribing.[18] The Cochrane collaboration has also comprehensively evaluated the use of audit and feedback to improve prescribing.[20 21] The focus of this review is on prescribing competencies and its assessment, based on the higher stages of Miller's model (competency and performance). This comprises practical aspects of prescription-writing as well as therapeutic decision-making, ensuring rational, evidenced-based therapy-selection is made based on patients' requirements and evaluation of their capacity to comply with a prescribed medicine).

This review aimed to examine the literature on educational interventions designed to develop and improve patient-focused prescribing competency in both medical and non-medical prescribers.

Method

Search strategy

Medline, International Pharmaceutical Abstracts (IPA), EMBASE and CINAHL; were searched using the key words: ('prescription$' OR 'prescriber$' OR 'prescribing') AND ('education' OR 'curriculum' OR 'course$' OR 'training' OR 'intervention$') AND ('drug$' OR 'medication$' or 'medication therapy management') AND ('clinical competence' OR 'competency' OR 'competency assessment'). The search terms were mapped onto Medical Subject Headings (MeSH) in Medline and EMBASE and carried through other database as key search terms. The search was limited to articles published in English from 1990-2011 (Appendix 1-4).

Study selection:

Citations generated by the search strategy were screened by all authors for relevance and eligibility. The full texts of potentially relevant articles were reviewed to determine satisfaction of inclusion criteria. The screening process was conducted according to PRISMA guidelines[22] (Figure 2).

The target population was medical or non-medical prescribers. All study designs were considered for this review. Studies were included if they were original research articles, had an educational intervention, and at least one outcome measure of prescribing competency demonstrated through prescribing examinations which evaluated the application of knowledge to patient cases or scenarios, changes in prescribing habits or adherence to guidelines. Studies were excluded if they only measured theoretical knowledge of

pharmacology and therapeutics or studied an intervention involving drug utilization evaluation (DUE), as this intervention is often primarily targeted towards cost-effectiveness and contains a large body of literature that has been previously reviewed by the Cochrane collaboration.[20 21] Systematic reviews, letters, meeting reports and opinion pieces were also excluded. The review was not restricted to any country.

One author (GK) reviewed the titles and abstracts of the articles retrieved in the search to assess relevance. Discussions were conducted between the four authors to exclude studies which did not meet the inclusion criteria, and this continued until consensus was achieved regarding study selection.

Data extraction and analysis:

Study location, design, characteristics of the study population, description of the education intervention, outcomes measured and results were extracted.

Results:

Number of studies

The search strategy generated 515 articles in Medline, 183 in EMBASE, 14 in IPA and 68 in CINAHL. Further refinement using the exclusion and inclusion criteria and duplicate exclusion resulted in 38 studies identified and reviewed (Table 1).

Study designs

Of the 38 reviewed studies, there were eighteen randomized controlled trials (RCT),[17 23-39] three non-randomized controlled trials,[40-42] nine non-randomized comparative trials[43-51] and eight before-after studies.[52-59]

Setting and participant characterization

Ten educational interventions were targeted at general practitioners,[23 27 28 30-32 38 40 42 56] eight were conducted in hospitals ,[39 41 48 52 54 55 58 59] four were implemented at primary health care clinics/facilities,[34-36 53] fifteen interventions were incorporated within a medical education curriculum at universities[17 24-26 29 37 43-47 49-51 57] and one intervention was carried out in pharmacies.[33] These studies were conducted in numerous countries around the world (Table 1).

Types of educational interventions and prescribing outcomes

A wide variety of educational methods and outcome measures were used. Interventions were summarized into two categories using Miller's competency model:

i) Prescribing competence ('knows how')

ii) Prescribing performance ('shows how')

Prescribing competence

Fifteen studies included interventions targeting particular tasks involved in prescribing, from taking accurate medication history, to choosing a rational treatment and writing the prescription.[17 23-27 29 37 43-47 50 57] Six of these studies used a method of rational pharmacotherapy education based on the World Health Organization (WHO) *Guide to Good Prescribing*.[23 25 29 43 50 57] DeVries *et al*. conducted a multicentre randomized controlled trial with 583 medical students from eight countries.[25] The trial reported a significant increase in mean scores of the intervention group following the WHO *Guide to Good Prescribing* intervention.

Other studies found evidence of a retention effect, where improvement in rational prescribing was maintained several months after the intervention[23] and a transfer effect, where students

were able to apply acquired rational prescribing skills in new situations.[23 50] The main limitation of the trials was that assessments were based primarily on written scenarios with a limited number of disease topics.

Three studies examined the effect of structured prescribing tutorials and programs on prescribing skills of medical students and GPs.[27 37 46] All three, specifically covered high-risk medicines and reported significant improvements in prescribing skills . Prescribing outcomes were assessed using written case scenarios[27 46] and a nine-station OSCE.[37] .

Two studies assessed prescription writing skills of medical students following a prescribing program at university.[44 47] Al Khaja *et al*. evaluated a prescribing program incorporated into a problem-based learning (PBL) curriculum,.[44 60] Students acquired limited prescribing competency during the PBL program. Only 50.2% correctly selected appropriate medicine(s), strength and dosage-form in the written examination.[44] Franson *et al*.[47] examined the effect of implementing a structured format called Individualized Therapy Evaluation and Plan (ITEP) in the curriculum. This format allowed students to provide a rationale-based treatment plan for an individual patient. The study found that ITEP improved students' ability to solve therapeutic problems and select appropriate medications .[47] However, both of these studies were non-randomized cohort studies comparing results between cohorts of different years. Hence it is difficult to attribute their findings to the impact of interventions alone.

Three studies measured the incidence of prescribing errors in written scenario-based examinations.[17 24 45] Specific prescribing tutorials/teaching modules significantly reduced prescription errors.[17 24] However obligatory medical clerkships, where students are assumed to acquire prescribing skills by spending up to 16 weeks with a general practitioner or in a hospital setting, did not to have a significant effect on the rate of prescription errors.[45]

One study examining an online interactive teaching module found a significant improvement in students' ability to calculate correct volumes of lignocaine and adrenaline in an OSCE setting.[26]

Prescribing performance

Twenty- three studies used educational interventions which aimed to improve management of particular conditions and increase the appropriateness of prescribing.[28 30-36 38-42 48 49 51-56 58 59]

In eight of these studies, interventions were implemented to specifically promote prescribing first-line therapy or reduce inappropriate prescribing.[28 30-34 55 56] Academic detailing approaches[28] and educational outreach visits,[32-34 56] were found to show positive results in improving prescribing adherence to guidelines. Mailed personalised prescribing feedback[30 31] was also found to be effective. An intervention in the form of a lecture was found to be ineffective unless reinforced with another intervention, e.g. individual feedback.[31] An in-house training program was found to reduce the inappropriate prescribing of non- steroidal anti-inflammatory drugs (NSAIDs) but results were not statistically significant.[55]

Nine studies used educational interventions to improve overall treatment practices of various conditions, with appropriate and rational pharmacological therapy assessed.[35 36 38 40 42 49 51-53] The methods which reported improvements included educational outreach visits,[35 36] in-service training,[52] and a multipronged approach involving training sessions and some reorganization of management systems.[53]. Two studies assessed the effectiveness of curriculum changes at university on medical graduates' patient-care performance.[49 51] Both a problem-based learning curriculum[51] and a continuity of care clinic (CCC) curriculum[49] increased prescribing performance indicators. However, outcome measures differed, with one study assessing prescribing rates in ambulatory patients aged >65 years[51] and the other focusing specifically on cardiovascular risk management.[49]

Mixed results were found in two studies which evaluated asthma management following an educational intervention.[38 42] An intensive small-group education session and peer review program did not show a significant influence on adherence to guidelines for general pharmacological treatment and management of exacerbations.[38] Another study found a positive change in medication prescribing following an asthma education program, however both the intervention and control groups showed this change in practice.[42]

McCall *et al*. examined the impact of a distance-learning graduate course in general practice psychiatry on managing mental illness.[40] Although the intervention had a positive impact on GP knowledge, there was no significant effect on overall prescribing habits.

Six studies evaluated the impact of educational interventions on the rate of prescribing errors using an audit of medication charts before and after the intervention.[39 41 48 54 58 59] Multidisciplinary interventions using interrelated educational and behavioral modification strategies significantly reduced prescribing errors.[58 59] Academic detailing reduced the number of incorrect prescriptions written for addictive medicines,[41] however prescription errors were defined only on the basis of local state laws in Australia and no assessment of the appropriateness of the choice of medicines was made. Webbe *et al*.[39] reported a reduction in prescribing errors following pharmacist accompaniment on prescribing rounds and a clinical teaching pharmacist program. However, the small sample meant that statistical significance was not reached. Two studies assessed the effect of a prescribing tutorial on the incidence of pediatric prescribing errors.[48 54] Both tutorials focused on prescribing in the pediatric population; however the studies reported mixed results. Kozer *et al*.[48] found no difference in prescribing errors whereas Davey *et al*.[54] reported significant differences.

Discussion:

Although a considerable amount of research has been conducted into improving prescribing competency through educational interventions, the range of heterogeneous study designs and outcome measures limits the validity and generalizability of their conclusions.

According to Miller's framework of competency assessment, tests of knowledge alone are insufficient to properly assess educational interventions. Hence, the assessment of prescribing skills included in these studies mainly focused on Miller's pyramid base 'knows how' and 'shows how'. The translation of knowledge and skills into a rational diagnostic or management plan is defined as competency (knowing how), which was measured using written examinations, patient management or OSCEs. This in turn predicts performance (showing how) and action (does) which was evaluated in daily life circumstances through audits to detect prescription errors or direct observations of prescribers' performance using standardized checklists. However, prescribing performance is difficult to measure as it can be influenced by many factors such as physicians' clinical experience, socio-cultural factors, histopathology of disease, pharmaceutical industry representatives, and the ever-increasing pressure from patients.[23]

Although studies differed considerably in their methods and assessment procedures, a number of key findings were highlighted. Firstly, specific prescribing teaching can lead to improvements in prescribing competency. This was reported in studies which used tutorials and educational programs to guide participants in the process of rational prescribing.[23 25 27 29 37 43 44 46 47 50 57] Of these studies, only the WHO *Guide to Good Prescribing* has been evaluated for both medical students and GPs across a range of countries.[23 25 29 43 50 57] The WHO model provides a six-step guide to choose, prescribe and monitor a suitable medicine for an individual patient and presents a good foundation for the development of therapeutic reasoning in a prescribing curriculum. This model is in line with the prescribing competency framework developed by the National Prescribing Centre[15] and NPS MedicineWise.[16] It also

provides important guidance in the development of educational interventions for medical and non-medical prescribers. The WHO method also encourages prescribers to verify standard treatment for each patient (recognizing issues such as aging or cognition impairment) and to alter treatment if necessary,[23] which is an essential skill to acquire particularly with the aging community.

Incorporating a prescribing component into a structured problem-based curriculum also improved students' ability to prescribe correctly.[24 25 29 37 44 50] Although targeted prescribing-teaching is mainly implemented at the undergraduate level, studies have found that GPs and non-medical prescribers often do not apply rational prescribing principles in daily practice and would benefit from these interventions.[23 33 35 36]

Many studies attempted to influence prescribing behavior through the promotion of rational medication use based on published practice guidelines. These guidelines have been promoted in face-to-face interactions and training through educational outreach visits, academic detailing, and through institutional audits and feedback. All of these methods have positively affected health professionals' behavior.[28 32 56] Although effective, these methods could be labor intensive and may be prohibitively expensive. Findings suggest that personalized feedback letters could be just as effective while blunting costs.[30 31] There is scope to explore why these interventions work and determine which interventions are suitable for different types of prescribers and settings.

Prescribing practices can also be improved through enhanced communication between doctors, pharmacists, nurses, other health professionals, as well as patients and carers. Several studies highlight the interactive role of medical, pharmacy and nursing staff in ensuring safe and effective use of medicines.[17 33 37 39 46 52 54] This is not surprising, as many prescribing errors cannot be attributed to knowledge deficits alone.[17] Hence improving

prescribing practices may require interventions aimed at multiple operant factors, such as developing a safety-oriented attitude through improving environment conditions, direct staff supervision and adopting a zero-tolerance policy for incomplete or incorrect prescriptions.[59] Indeed positive results were reported following multifaceted interventions where education was incorporated into a system-based approach to influence prescribing behavior.[58 59]

Finally, this review has highlighted a lack of educational interventions targeted at non-medical prescribers. Four studies assessed the effectiveness of training programs: two were for nurses,[36 53] one for pharmacists[33] and one for primary health care workers (community health officers, nurses and community health extension workers).[35] All four studies had relatively small sample sizes and differed greatly in prescribing outcome measures. This suggests that further description and evaluation of educational methods are needed for non-medical prescribers.

Overall the conclusions that can be drawn are limited by the quality of the studies reviewed. The number of participants included ranged from thirteen in a randomized controlled trial[39] to 751 in a cohort study.[51] Randomised controlled trials are considered the gold standard; however the smaller studies may have been underpowered and hence could not produce statistically significant results. Nevertheless large-sample randomisation and effective blinding are often not appropriate or possible in prescribing intervention studies. The different methods of assessments were often used with no discussion about their validity and reliability, and marking schemes were inconsistent across the different studies. For example, the definitions of 'prescription error' differed slightly between studies and one study defined errors based on local state laws instead of on appropriateness of medication choices.[41] The correlation between the duration of interventions and the impact on prescribing was also difficult to determine as the interventions ranged from a 30-minute tutorial[48] to a prescribing program implemented for up to three years.[47 49 51]

As our search strategy excluded DUE as an intervention to improve prescribing, we were unable to report important educational strategies that may exist in this area. However, these interventions have already been shown to decrease costs and may subsequently improve prescribing appropriateness.[20 21] Furthermore, the comprehensiveness of our review may have been limited by only including databases that we perceived would contain the bulk of the prescribing competency literature, using the key word 'competency' and following PRISMA guidelines[22] which do not stipulate hand searches. Overall the studies retrieved provided a broad overview of a range of prescribing interventions and may be useful in identifying strategies that can be explored further in more robust, longer-term trials in the future.

Conclusion

A wide range of educational interventions has been conducted to develop and maintain prescribing competency. However few studies have sought to evaluate the educational models used to develop non-medical prescribers' prescribing competency and there is a need for further development in the assessment of teaching for non-medical prescribers as expansions of prescribing powers continue to be implemented. The development of competency frameworks for prescribing has highlighted the need to design interventions which target each prescribing competency domain. In particular, the WHO *Guide to Good Prescribing* is a promising model for the design of targeted prescribing programs and has been shown to be effective in a wide variety of settings.

Figures and tables:

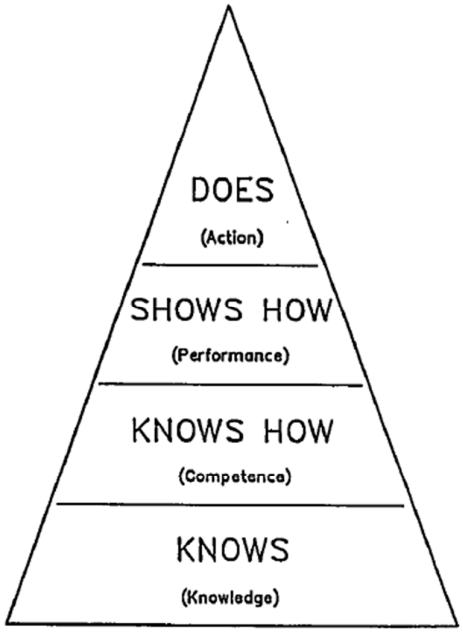

Figure 1: Miller's framework for clinical assessment [14]

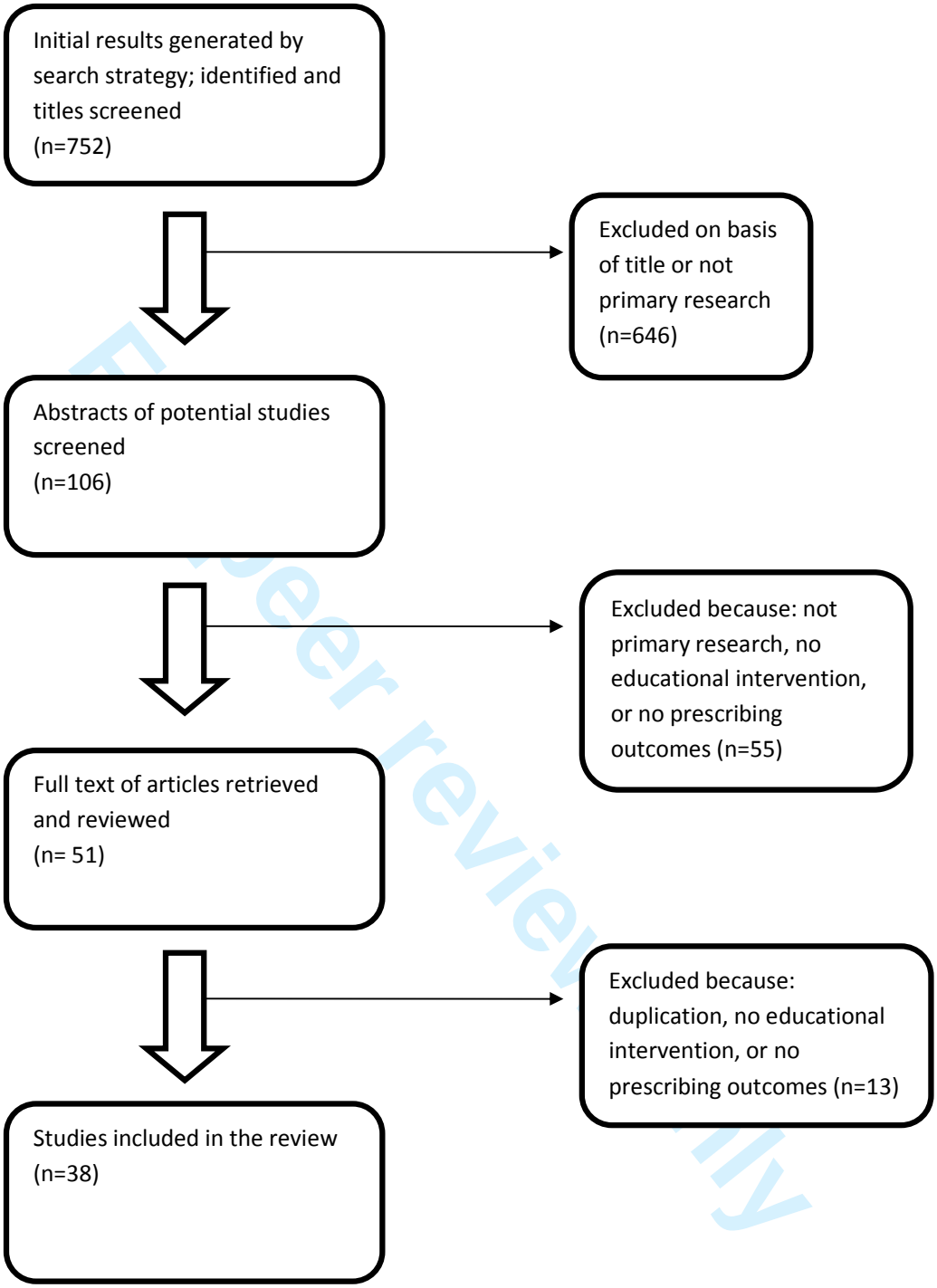

Figure 2: Flowchart of search strategy and study selection based on PRISMA guidelines[22]

Table 1: Summary of educational intervention studies for prescribing

Authors. Year	Setting	Study Design	No of participants	Intervention	Prescribing outcome measures	Results	Potential for bias
De Vries et al. 2008[25]	Eight countries in Asia & Europe	Randomized controlled trial	194 medical students in personal formulary (PF) group; 198 in existing formulary (EF) group; 191 in control group	The PF and EF groups were given teaching sessions based on the WHO Guide to Good Prescribing model (PF group = whole manual; EF group =manual minus p-drugs), with and without use of personal formulary.	Written exam using 16 patient cases based on four topics: hypertension, osteoarthritis, acute bronchitis, gastroenteritis.	A significant increase in mean scores of the intervention group compared to the control group ($p<0.05$). The increase in the PF group was significantly higher than in the EF group. However, this effect was only visible in the universities in Yemen, the Russian Federation, and Indonesia. No significant differences between PF and EF scores were found in the universities in the Netherlands, Slovakia, Spain, India or South Africa.	Funded by the VU University Medical Center and by the Department of Essential Drugs and Medicines Policy of the World Health Organisation.
Hassan et al. 2000[29]	Yemen	Randomized controlled trial	56 medical students in intervention group; 44 students in control group	A prescribing course based on WHO's Guide to Good Prescribing, the Yemen Essential Drug List and Yemen Standard Treatment Guidelines	Written exam based on eight patient problems where a complete treatment plan form must be completed.	Students from the study group performed significantly better than those from control in all problems presented and also when compared with the results of the pre-test ($P < 0.05$).	None declared
Akici et al. 2003[23]	Turkey	Randomized controlled trial	12 GPs in intervention group; 13 GPs in control group	Short rational pharmacotherapy course based on the 'problem-based Groningen/WHO	Written exam with open and structured questions based on hypertensive cases as well as a question	Significant improvement in the mean test scores post-training of the intervention group ($p < 0.05$) for both questions, showing a transfer	None declared

				model'	on osteoarthritis (unexposed indication).	effect. The improvement was maintained for at least 4 months after training.	
Esmaily et al.2009[27]	Iran	Randomized controlled trial	58 GPs in intervention group; 54 GPs in control group	Education with an outcome-based approach utilizing active-learning principles.	Multiple choice and short answer questions, with two case scenarios and three 'irrational' prescriptions.	There was an overall improvement of 26 percentage units in the prescribing knowledge and skills of GPs in the intervention group. No such improvements were seen in the control group.	Additional funding from the National Public Health Management Centre in Tabriz and the Ministry of Health and Medical Education of Iran
Sandilands et al.2010[17]	UK	Randomized controlled trial	50 medical students in the intervention group; 28 students in control group.	Focused doctor- and pharmacist-led practical prescribing teaching.	Written prescribing exam consisting of six scenario-based questions.	Teaching improved the assessment score of the intervention group: mean assessment 2 *vs.* 1, 70% *vs*. 62%, *P* = 0.007; allergy documentation: 98% *vs.* 74%, *P* = 0.0001; and confidence. However, 30% of prescriptions continued to include prescribing errors.	None declared
Celebi et al 2009[24]	Germany	Randomized controlled trial	36 medical students in early intervention group; 38 medical students in late intervention	A 1-week prescribing training module which comprised a seminar on common prescription errors, a prescribing	Students were asked to make prescriptions for two virtual cases on a standard patient chart. These prescription charts were subsequently	Prior to training, students committed a mean of 69 ± 12% of the potential prescription errors. This decreased to 29 ± 15% after prescribing training (P < 0.001).	None declared

			group.	exercise with a standardized paper case patient, drafting of inoperative prescription charts for real patients and discussions with a lecturer.	analyzed by two independent raters using a checklist for common prescription errors.		
Rothman et al. 2000[36]	South Africa	Randomized controlled trial	35 primary health care nurses in the intervention group; 31 in the control group.	A competency-based primary care drug therapy (PCDT) training program in the treatment of acute minor ailments.	Written examination with eight case studies including scenarios on acute gout, congestive heart failure, acute tonsillitis and infectious arthritis.	Post-test results of the intervention group indicated significant improvement towards correct diagnosis and management of the conditions (P<0.05)	Funded by Boehringer Ingelheim (Pty) Ltd (Self-Medication Division)
Scobie et al. 2003[37]	UK	Randomized controlled trial.	16 medical students in intervention group; 16 students in control group.	Practical structured teaching sessions led by a pharmacist.	Nine station OSCE exam covering topics such as anticoagulation, IV administration, discharge prescription and medication history.	The intervention group achieved higher scores in eight OSCE stations. Four of these were statistically significant (P <= 0.005).	None declared
Webbe et al.2007[39]	UK	Randomized controlled trial	13 pre-registration house officers (PRHOs)	A clinical teaching pharmacist program to improve prescribing skills	Number of prescribing errors.	A 37.5% reduction (P=0.14) in prescribing errors after pharmacist intervention	None declared
Degnan et al.2006[26]	UK	Randomized controlled trial	9 medical students in intervention	An online teaching module consisting of an interactive	OSCE station requiring administration of	The teaching module significantly improved the students' ability to calculate	Funded by the Association of Anaesthetists

			group; 35 in the control group.	tutorial of 12 multiple-choice questions and three case studies covering pharmacokinetics, adverse drug reactions and drug doses calculations.	lidocaine and adrenaline for a patient with laceration and anaphylaxis.	the correct volume of lidocaine (p=0.005) and adrenaline (0=0.0002).	of Great Britain and Ireland
Hux et al.1999[30]	Canada	Randomized controlled trial	135 GPs in intervention group; 116 GPs in control group.	Mailed packages of prescribing feedback and guidelines-based educational materials.	Median antibiotic cost and proportion of episodes of care in which a pre-specified first-line antibiotic was used first.	The median prescription cost remained constant in the feedback group but rose in the control group ($p < 0.002$). First-line drug use increased in the feedback group but decreased in the control group ($p < 0.01$).	Author receives salary support from the Institute for Clinical Evaluative Sciences in Ontario.
Kahan et al.2009[31]	Israel	Randomized controlled trial	32 physicians exposed to both interventions; 130 physicians who only received personalized letter; 29 physicians who only attended the lecture; 107 in the control group.	Interventions were in the form of a lecture at a conference and a letter with personalized feedback to improve physicians' rates of prescribing in the treatment of acute uncomplicated cystitis in adult women.	Outcome was the rate of adherence to the guidelines for appropriate treatment using nitrofurantoin or second-line therapy of ofloxacin for three days.	The letter intervention significantly influenced physicians' prescribing patterns. The lecture intervention was only effective in the short run, indicating that the effect of this technique does not last unless reinforced.	Partially funded through a research grant from The Israel National Institute for Health Policy and Health Services Research and through an educational grant from Schering Plough Israel.

Fender et al. 1999[28]	UK	Randomized controlled trial	54 GPs in intervention group; 46 GPs in control group	An educational package based on principles of "academic detailing".	The appropriate prescribing of tranexamic acid, non-steroidal anti-inflammatory drugs, and norethisterone.	A proportionately higher level of appropriate prescribing was found in the intervention group. An increase of 63% in the prescription of tranexamic acid, the most effective first line treatment for menorrhagia, was observed in the intervention group.	None declared
Midlöv at al. 2006[32]	Sweden	Randomized controlled trial	23 GPs in the intervention group; 31 GPs in the control group.	Educational outreach visits	Number of prescriptions of benzodiazepines (BDP) and antipsychotics to the elderly	One year after the educational outreach visits there was a significant decrease in prescribing of medium- and long-acting BDP and total BDP in the active group compared with the control group ($P<0.05$). For antipsychotics there were no significant differences between active and control group.	Funded by the Department of Primary Care Research and Development in the county of Skåne, Apoteket AB and the Faculty of Medicine, Lund University
Nsimba 2007[33]	Tanzania	Randomized controlled trial	20 pharmacists in intervention facilities; 20 in control facilities.	Posters, individual information and one-to-one training sessions.	Simulated clients assessed the drug seller/pharmacist's knowledge and prescribing choices. A short examination was also conducted to assess participants'	85% of simulated clients who went to the intervention facilities were sold the first line drug sulfadoxine/pyrimethamine (SP) compared to 55% at control facilities ($p<0.01$). The intervention group also performed significantly better	Funded by COSTECH-Tanzania

					knowledge of appropriate treatments for common childhood conditions.	on the knowledge exam (p<0.01).	
Smeele et al. 1999[38]	The Netherlands	Randomized controlled trial	17 GPs in the intervention group; 17 GPs in control group	Four sessions (lasting 2 hours each) of interactive group education and peer review program aimed at implementing national guidelines.	Data on prescription of inhaled and anti-inflammatory medications were collected through self-recording by GPs and recording of repeat prescriptions for patients.	No significant difference was found in the pharmacological treatment between intervention and control groups (P>0.05).	None declared
Ochoa 1996[34]	Cuba	Randomized controlled trial	4 groups of 10 physicians (A,B,C,D) with A receiving community education program and refresher training, B receiving refresher training, C receiving community education, D was the control group.	Refresher training based on teaching sessions and periodic advisory visits. Community education involved group discussions and distribution of educational materials.	Rate of over-prescription of antibiotics for mild acute respiratory infections (ARI) cases.	Following the interventions, antibiotic over-prescription rates declined by 26% and 63% in groups A and B, while increasing by 2% and 48% in groups C and D.	None declared
Odusanya	Lagos state,	Randomized	Number of	4-week training	Prescriptions were	At the 2-week evaluation, the	None declared

& Oyediran 2004[35]	Nigeria	controlled trial	participants not specified. Primary health care workers (no doctors) in Mushin were in the intervention group; health workers in Ikeja were in the control group.	program on rational drug use.	evaluated according to compliance to 'standing orders', which are a set of treatment modules. Drug use indicators were also compared.	intervention group achieved a significant reduction in the average number of medicines prescribed compared to the control group. There was also a significant increase in the percentage of patients rationally managed from 18% to 30% (p=0.0005) in the intervention group. Improvements were not sustained at the 3-month evaluation.	
Akici et al. 2004[43]	Turkey	Non randomized comparative control	50 medical students (interns) in intervention group; 54 interns in control group; 53 GPs	Problem-based rational pharmacotherapy education (RPE) via the WHO/Groningen model.	A written examination with open and structured questions based on case scenarios of tonsillitis and mild-to-moderate essential hypertension patients.	Mean scores of the interns in the intervention group were higher than GPs, which were in turn higher than those of interns in the control group for all cases.	Funded by a grant from Marmara University Scientific Research Projects Commission.
Volovitz et al. 2003[42]	Israel	Non randomized controlled trial	83 physicians attended the education program. Four groups of patients were included. The study group had patients whose	Asthma education program involving lectures on pathophysiology, asthma management and prevention. Physicians were also asked to invite patients for three	Changes in asthma medicine use was analyzed before and after the intervention. Data was derived from the central database of Maccabi, Israel.	In all four patient groups, a smaller proportion of reliever medicines (SABA) and a greater proportion of controller medicines (ICS & LABA) were used in the follow up period compared to before the intervention. Patients in the study group were twice more likely to	None declared

			physicians attended the education program and completed two follow up physician visits. Three control groups of patients were also included.	visits to reinforce the principles highlighted in the education program.		decrease their use of SABA than patients from the control group (p = 0.042).	
McCall et al. 2004[40]	Australia	Non randomized controlled trial	14 GPs in intervention group; 14 in control group.	Completion of a Graduate Certificate in General Practice Psychiatry conducted primarily via distance education program.	A clinical audit assessed GPs' recognition, drug management, non-drug management of patients with depression and anxiety.	No effect on the intervention GPs prescribing habits (P>0.05).	None declared
Shaw et al.2003[41]	Australia	Non randomized controlled trial	The number of junior doctors in intervention and control hospitals was not specified.	Academic detailing including the provision of a bookmark containing the requirements for addictive medicines.	Prescription error rates of addictive medicines were assessed. Errors were defined according to legal requirements for prescription of addictive medicines.	At the intervention hospital, there was a significant decrease in error rate (from 41% to 24%, P<0.0001).The control hospital did not show a significant change in error rate over the same study period (P=0.66).	Partially funded by the Postgraduate Medical Council of NSW.
Richir et al. 2008[50]	The Netherlands	Non randomized comparative control	197 medical students in the intervention group; 33	A context-learning pharmacotherapy program with role-play sessions and	A written exam involving the formulation of a treatment plan for	The mean score on the six steps of the World Health Organization (WHO) six-step plan for prescribing increased	None declared

			students in control.	OSCE.	two patients using the WHO six-step guide of rational prescribing.	significantly for students who has received the pharmacotherapy study (P<0.001).	
Coombes et al. 2007[46]	Australia	Non randomized comparative control	99 medical students in intervention group; 134 in control group	Eight interactive problem-based tutorials covering topics such as antibiotics, anticoagulants, IV fluids, analgesics, oral hypoglycaemics and insulin.	A written examination consisting of short answer questions on ADR identification, anticoagulants and analgesics.	A significantly higher score was found in intervention students compared with controls; mean score in intervention group 29.46; control group 26.35 (P<0.05)	None declared
Celebi et al.2010[45]	Germany	Non randomized comparative control	18 medical students who had never completed an internal-medicine clerkship; 38 students who had completed 1-4 weeks of clerkship; 18 students who had completed >5 weeks of clerkship.	Internal medicine clerkship based on one general learning objective of "students are to be familiarized with caring for patients in an outpatient and inpatient setting".	A written test comprising of the completion of prescription charts for two standardized patient paper cases. These were marked using a checklist for common prescription errors.	Students committed 69%±12% of all possible prescription mistakes. There was no significant difference between the group without clerkships in internal medicine (G1) (71±9%), the group with one to four weeks (G2) (67±15%), and the group with more than five weeks of clerkships (G3) (71±10%), p=.76.	None declared
Kozer et al. 2006[48]	Canada	Non randomized comparative control	13 trainees in intervention; 9 trainees in control	30 minute tutorial focusing on appropriate methods for	Main outcome measure was the number of prescribing errors	No significant difference in errors was found between the intervention group (12.4%) and the control group	Funded by the Trainee's Start-up Fund, The Research

				prescribing medications followed by a written test.	on medical charts completed after the tutorial.	(12.7%).	Institution, The Hospital for Sick Children, Toronto Canada.
Al Khaja et al.2005[44]	Bahrain	Non randomized comparative cohort	539 medical students	Problem-based learning curriculum incorporating a prescribing program.	A written examination. Physician-related components of the prescription assessed legality of prescription writing while drug-related components relate to the rational and appropriate use of medicines.	Rate of physician-related components by students (year 2 to 4) was 96.1 (CI 94.1-97.5). However, the rate of various drug-related components was 50.2 (CI 46.0-54.4). No significant difference in overall performance of Year 4 and Year 2 students (p=0.237). However appropriateness of drug-related components were significantly higher in Year 4 than Year 2 (p<0.05).	None declared
Franson et al.2009[47]	The Netherlands	Non randomized comparative cohort	181 medical students in baseline 2003 cohort, 285 students in 2004, 275 students in 2005, 264 students in 2006.	Students were taught to use a structured format called the Individualized Therapy Evaluation and Plan (ITEP) to communicate a therapeutic plan including the writing of a prescription.	Written examination involving two different therapeutic cases; a simple pediatric case and a complex geriatric case.	Students' scores improved significantly in the 3 years after the introduction of the ITEP in the curriculum. The average score of the 2006 cohort was 6.76 compared to 3.83 for the 2003 group (p<0.0001)	None declared
Tamblyn et	Canada	Non	751 doctors	A community	Annual performance	After the intervention,	Funded by the

al.2005[51]		randomized comparative cohort	from four graduation cohorts; 600 from before the intervention and 151 after the intervention.	oriented problem based learning curriculum.	in diagnosis (difference in prescribing rates for specific diseases and relief of symptoms), and management (prescribing rate for contraindicated medicines) assessed using provincial health databases for the first 4-7 years of practice.	graduates showed a significant fourfold increase in disease specific prescribing rates compared with prescribing for symptom relief. No difference in rate of prescribing for contraindicated medicines was observed.	Canadian Institutes of Health Research and Fonds de Recherche en Sante du Quebec
Pandejpong et al.2009[49]	Thailand	Non randomized comparative control	38 continuity of care (CCC) participants; 52 non-CCC participants	Continuity of care (CCC) curriculum.	Medical chart audits were performed and scored with a 12-task checklist of cardiovascular risk management including appropriate prescribing.	There was a significant increase in ability to properly adjust antihypertensive medication and in the prescribing of aspirin as primary prevention for cardiovascular disease in the CCC group ($p<0.05$)	Funded by a Faculty of Medicines Siriraj Hospital Medical Education Research Grant, Mahidol University.
Guney et al.2009[57]	Turkey	Before and after study	101 medical students	Rational pharmacotherapy training based on the Groningen/WHO model.	Prescription audit and OSCE exam based on a simulated patient case with uncomplicated essential hypertension.	A significant improvement in prescription audit scores was observed after the training (p: 0.022).	None declared
Gall et al. 2001[56]	UK	Before and after study	212 GPs; 139 community	Training on the use of guidelines on	Changes in prescribing practice	Education significantly reduced total prescribing by	Funded by South Thames

			nurses (CNs)	prescribing supplements.	of supplements.	15% and reduced the levels of inappropriate prescribing from 77% to 59% due to an improvement in monitoring of patients prescribed supplements.	Health Authorities Clinical Audit Programme.
Bojalil et al. 1999[52]	Tlaxcala, Mexico	Before and after	72 private GPs; 44 public GPs	A training course based on in-service practice. Other materials included the official training manuals for the control of diarrhea and acute respiratory infection (ARI), training videos and wall charts.	Aspects of diarrhea and ARI treatment which were evaluated and scored using a checklist.	Private practitioners showed significant improvements in prescribing practices for children with diarrhea. For ARI management, decisions on antimicrobial therapy and symptomatic drug use improved for both groups but only reached statistical significance for public physicians.	Funded by the Mexican Social Security Institute.
Chopra et al. 2005[53]	Cape Town, South Africa	Before and after	21 nurse prescribers	WHO and UNICEF's Integrated Management of Childhood Illness (IMCI) implementation. Training used the WHO/UNICEF teaching and assessment modules.	A structured observation checklist of the case management of sick children including rational prescribing.	There were significant improvements in the appropriate prescribing of antibiotics, with a significant reduction of inappropriate antibiotic use (62% versus 84 %). However, there was no change in the treatment of anemia or the prescribing of vitamin A to sick children.	None declared
Elkharrat et al. 1998[55]	France	Before and after	27 doctors	Doctors were informed of the Drug Regulatory	The rate of NSAID prescribing errors was analyzed.	Prescribing errors declined from 20% to 14% and when prescriptions were stratified	None declared

				Agency (DRA) prescribing guidelines of NSAIDs. Group sessions were held, posters were displayed and pocket sized, 10-page manuals were distributed.		by cause, the quality of prescribing increased significantly.	
Davey et al. 2008[54]	UK	Before and after	The number of junior doctors included in the study was not specified.	A pediatric junior doctor prescribing tutorial conducted by a pharmacist and a bedside prescribing guideline to encompass the most frequently prescribed medications utilized on the children's unit.	Prescribing errors and preventable adverse drug events.	The introduction of the prescribing tutorial decreased prescribing errors by 46% (p=0.023). The introduction of a bedside prescribing guideline did not decrease prescribing errors.	Author's research position was funded by Airedale NHS Trust.
Leonard et al. 2006[58]	USA	Before and after study	The number of clinical staff (physicians, nurses, pharmacists) included in the study was not specified.	Educational patient safety initiatives using multiple interrelated educational and behavioral modification strategies.	Assessment of medication orders which were then used to calculate the absolute risk reduction from prescribing errors.	The absolute risk reduction achieved after the interventions was 38 per 100 orders written (*t*= 25.735; *P*=.001). This yielded an overall relative risk reduction from prescribing errors of 49% (*P*<.001).	Funded by the New York State Department of Health 2003 Patient Safety Award and by a donation from Lexi-Comp of

							Pediatric Lexi-Drugs limited licenses.
Otero 2008[59]	Argentina	Before and after study	Number of participants not specified. Prescriptions for 95 patients were analysed in 2002 and for 92 patients in 2004.	Educational program developed by the Patient Safety Committee of the Department of Pediatrics including the implementation of the "10 steps to reduce medication errors' checklist.	Prevalence of medication errors detected in written prescription orders during June 2002 (before intervention) and May 2004 (after intervention).	Prevalence of prescription errors was significantly lower in 2004 compared with 2002; 11.4% vs 7.3% (P<0.05)	None declared

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Appendix 1:

Search results from Medline database.

#	Searches	Results
1	exp prescriptions/ or exp drug prescriptions/	21636
2	prescription$.mp.	53900
3	prescribing.mp.	19696
4	prescriber$.mp.	2435
5	1 or 2 or 3 or 4	66094
6	exp Education/	538259
7	Curriculum.mp. or exp Curriculum/	61710
8	course$.mp.	383117
9	training.mp.	202843
10	intervention$.mp. or exp Intervention Studies/	399814
11	6 or 7 or 8 or 9 or 10	1347214
12	drug$.mp. or exp Pharmaceutical Preparations/	2037789
13	medication$.mp. or Medication Therapy Management/	160112
14	12 or 13	2126778
15	clinical competence.mp. or exp Clinical Competence/	52990
16	Competency.mp	16203
17	competency assessment.mp.	255
18	15 or 16 or 17	66195
19	5 and 11 and 14 and 18	595
20	limit 19 to (english language and humans and yr="1990 - 2011")	515
21	from 20 keep 6-7, 13, 17, 32-33, 52, 54...	**66**

Appendix 2:

Search results from Embase

No.	Query	Results
#1	prescription$ AND [embase]/lim	88,272
#2	'drug'/exp AND prescription$ AND [embase]/lim	16,129
#3	prescriber$ AND [embase]/lim	2,373
#4	prescribing AND [embase]/lim	21,411
#5	#1 OR #2 OR #3 OR #4	97,629

#6	'education'/exp AND [embase]/lim	380,484
#7	'curriculum'/exp AND [embase]/lim	14,850
#8	course$ AND [embase]/lim	1,380,158
#9	'training'/exp AND [embase]/lim	51,959
#10	intervention$ AND [embase]/lim	273,519
#11	intervention AND studies AND [embase]/lim	48,611
#12	#6 OR #7 OR #8 OR #9 OR #10 OR #11	1,951,619
#13	drug$ AND [embase]/lim	6,043,011
#14	pharmaceutical AND preparation$ AND [embase]/lim	59,600
#15	'pharmaceutics'/exp AND [embase]/lim	631,723
#16	medication$ AND [embase]/lim	116,159
#17	'medication'/exp AND 'therapy'/exp AND 'management'/exp AND [embase]/lim	37,847
#18	#13 OR #14 OR #15 OR # 16 OR #17	6,067,273
#19	clinical AND 'competence'/exp AND [embase]/lim OR 'competency' AND [embase]/lim	14,791
#20	competency AND assessment$ AND [embase]/lim	1,717
#21	#19 OR #20	15,903
#22	#5 AND #12 AND #18 AND #21	258
#23	#5 AND #12 AND #18 AND #21 AND 'human'/de	183
#24	From #23 keep 5, 19, 20, 54, 55, 57, 71, 73, 81, 84...	**15**

Appendix 3:

Search results from IPA

No	Search terms	Results
1	prescription$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	16697
2	drug prescription$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	255
3	prescriber$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	1834
4	prescribing.mp. [mp=title, subject heading word, registry word, abstract, trade	9795

	name/generic name]	
5	1 or 2 or 3 or 4	23896
6	education.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	21856
7	curriculum.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	4353
8	course$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	12406
9	training.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	5774
10	intervention$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	26345
11	intervention studies.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	61
12	6 or 7 or 8 or 9 or 10 or 11	54610
13	drug$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	233543
14	pharmaceutical preparation$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	1387
15	medication$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	40605
16	medication therapy management.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	194
17	13 or 14 or 15 or 16	246579
18	clinical competence.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	21
19	competency.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	896
20	competency assessment$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	138
21	18 or 19 or 20	912
22	5 and 12 and 17 and 20	45
23	limit 22 to (english language and human and yr="1990 - 2011")	**14**
24	From #22 keep 2, 6, 20, 34, 36	**5**

Appendix 4:

Search results from CINAHL

No	Search terms	Results
1	(MH "Drugs, Prescription") OR "prescription$"	16384
2	"prescriber$"	479
3	"prescribing" OR (MH "Medication Prescribing (Iowa NIC)")	7557
4	S1 or S2 or S3	22779
5	(MH "Education+") OR "education"	421003
6	(MH "Curriculum+") OR "curriculum"	20234
7	"course$"	30657
8	"training"	64700
9	(MH "Intervention Trials") OR "intervention$"	73013
10	"intervention studies"	1100
11	S5 or S6 or S7 or S8 or S9 or S10	511987
12	(MH "Drugs+") OR "drug$"	280866

13	"pharmaceutical preparation$"	9
14	"medication$"	31847
15	(MH "Medication Managements (Iowa NIC) (Non-Cinahl)+") OR "medication therapy management"	79
16	S12 or S13 or S14 or S15	294650
17	(MH "Clinical Competence+") OR "clinical competence" OR (MH "Competency Assessment") OR "Competency"	20832
18	S4 and S11 and S16 and S17	124
19	Limit #18 - Published Date from: 1990-2011; English Language; Human	68
20	From #19 keep 2, 4, 8, 10, 11, 12, 16, 20-21, 37...	**20**

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4-7
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	7
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	Appendices
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7-8
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Appendix
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	7 and figure 2
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	NA
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NA
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	Table 1
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	8
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Figure 2 8
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1 Page8-9
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Table 1 Page 9
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Table 1 Page8-12
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Table 1 Page8-12
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Table 1 Page8-12
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Table 1 Page8-12
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	15-16
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	13-16
FUNDING			

PRISMA 2009 Checklist

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

Appendix 1:

Search results from Medline database.

#	Searches	Results
1	exp prescriptions/ or exp drug prescriptions/	21636
2	prescription$.mp.	53900
3	prescribing.mp.	19696
4	prescriber$.mp.	2435
5	1 or 2 or 3 or 4	66094
6	exp Education/	538259
7	Curriculum.mp. or exp Curriculum/	61710
8	course$.mp.	383117
9	training.mp.	202843
10	intervention$.mp. or exp Intervention Studies/	399814
11	6 or 7 or 8 or 9 or 10	1347214
12	drug$.mp. or exp Pharmaceutical Preparations/	2037789
13	medication$.mp. or Medication Therapy Management/	160112
14	12 or 13	2126778
15	clinical competence.mp. or exp Clinical Competence/	52990
16	Competency.mp	16203
16	competency assessment.mp.	255
17	15 or 16 or 17	66195
18	5 and 11 and 14 and 17	595
19	limit 18 to (english language and humans and yr="1990 - 2011")	515
20	from 19 keep 6-7, 13, 17, 32-33, 52, 54...	**66**

Appendix 2:

Search results from Embase

No.	Query	Results
#1	prescription$ AND [embase]/lim	88,272
#2	'drug'/exp AND prescription$ AND [embase]/lim	16,129
#3	prescriber$ AND [embase]/lim	2,373
#4	prescribing AND [embase]/lim	21,411
#5	#1 OR #2 OR #3 OR #4	97,629
#6	'education'/exp AND [embase]/lim	380,484
#7	'curriculum'/exp AND [embase]/lim	14,850
#8	course$ AND [embase]/lim	1,380,158
#9	'training'/exp AND [embase]/lim	51,959
#10	intervention$ AND [embase]/lim	273,519
#11	intervention AND studies AND [embase]/lim	48,611
#12	#6 OR #7 OR #8 OR #9 OR #10 OR #11	1,951,619
#13	drug$ AND [embase]/lim	6,043,011
#14	pharmaceutical AND preparation$ AND [embase]/lim	59,600
#15	'pharmaceutics'/exp AND [embase]/lim	631,723
#16	medication$ AND [embase]/lim	116,159
#17	'medication'/exp AND 'therapy'/exp AND 'management'/exp AND [embase]/lim	37,847
#18	#13 OR #14 OR #15 OR # 16 OR #17	6,067,273
#19	clinical AND 'competence'/exp AND [embase]/lim OR ‘competency’ AND [embase]/lim	14,791
#20	competency AND assessment$ AND [embase]/lim	1,717
#21	#19 OR #20	15,903
#22	#5 AND #12 AND #18 AND #21	258
#23	#5 AND #12 AND #18 AND #21 AND 'human'/de	183
#24	From #23 keep 5, 19, 20, 54, 55, 57, 71, 73, 81, 84...	**15**

Appendix 3:

Search results from IPA

No	Search terms	Results
1	prescription$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	16697
2	drug prescription$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	255
3	prescriber$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	1834
4	prescribing.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	9795
5	1 or 2 or 3 or 4	23896
6	education.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	21856
7	curriculum.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	4353
8	course$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	12406
9	training.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	5774
10	intervention$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	26345
11	intervention studies.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	61
12	6 or 7 or 8 or 9 or 10 or 11	54610
13	drug$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	233543
14	pharmaceutical preparation$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	1387
15	medication$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	40605
16	medication therapy management.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	194
17	13 or 14 or 15 or 16	246579
18	clinical competence.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	21
19	competency.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	896
20	competency assessment$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	138
21	18 or 19 or 20	912
22	5 and 12 and 17 and 20	45
23	limit 22 to (english language and human and yr="1990 - 2011")	**14**
23	From #22 keep 2, 6, 20, 34, 36	**5**

Appendix 4:

Search results from ***Cinahl***

No	Search terms	Results
1	(MH "Drugs, Prescription") OR "prescription$"	16384
2	"prescriber$"	479
3	"prescribing" OR (MH "Medication Prescribing (Iowa NIC)")	7557
4	S1 or S2 or S3	22779
5	(MH "Education+") OR "education"	421003
6	(MH "Curriculum+") OR "curriculum"	20234
7	"course$"	30657
8	"training"	64700
9	(MH "Intervention Trials") OR "intervention$"	73013
10	"intervention studies"	1100
11	S5 or S6 or S7 or S8 or S9 or S10	511987
12	(MH "Drugs+") OR "drug$"	280866
13	"pharmaceutical preparation$"	9
14	"medication$"	31847
15	(MH "Medication Managements (Iowa NIC) (Non-Cinahl)+") OR "medication therapy management"	79
16	S12 or S13 or S14 or S15	294650
17	(MH "Clinical Competence+") OR "clinical competence" OR (MH "Competency Assessment") OR "Competency"	20832
18	S4 and S11 and S16 and S17	124
19	Limit #18 - Published Date from: 1990-2011; English Language; Human	68
19	From #19 keep 2, 4, 8, 10, 11, 12, 16, 20-21, 37...	**20**

Table 1: Summary of educational intervention studies for prescribing

Authors. Year	Setting	Study Design	No of participants	Intervention	Prescribing outcome measures	Results	Potential for bias
De Vries et al. 2008[25]	Eight countries in Asia & Europe	Randomized controlled trial	194 medical students in personal formulary (PF) group; 198 in existing formulary (EF) group; 191 in control group	The PF and EF groups were given teaching sessions based on the WHO Guide to Good Prescribing model (PF group = whole manual; EF group =manual minus p-drugs), with and without use of personal formulary.	Written exam using 16 patient cases based on four topics: hypertension, osteoarthritis, acute bronchitis, gastroenteritis.	A significant increase in mean scores of the intervention group compared to the control group ($p<0.05$). The increase in the PF group was significantly higher than in the EF group. However, this effect was only visible in the universities in Yemen, the Russian Federation, and Indonesia. No significant differences between PF and EF scores were found in the universities in the Netherlands, Slovakia, Spain, India or South Africa.	Funded by the VU University Medical Center and by the Department of Essential Drugs and Medicines Policy of the World Health Organisation.
Hassan et al. 2000[29]	Yemen	Randomized controlled trial	56 medical students in intervention group; 44 students in control group	A prescribing course based on WHO's Guide to Good Prescribing, the Yemen Essential Drug List and Yemen Standard Treatment Guidelines	Written exam based on eight patient problems where a complete treatment plan form must be completed.	Students from the study group performed significantly better than those from control in all problems presented and also when compared with the results of the pre-test ($P < 0.05$).	None declared
Akici et al. 2003[23]	Turkey	Randomized controlled trial	12 GPs in intervention group; 13 GPs in control group	Short rational pharmacotherapy course based on the 'problem-based Groningen/WHO	Written exam with open and structured questions based on hypertensive cases as well as a question	Significant improvement in the mean test scores post-training of the intervention group ($p < 0.05$) for both questions, showing a transfer	None declared

				model'	on osteoarthritis (unexposed indication).	effect. The improvement was maintained for at least 4 months after training.	
Esmaily et al.2009[27]	Iran	Randomized controlled trial	58 GPs in intervention group; 54 GPs in control group	Education with an outcome-based approach utilizing active-learning principles.	Multiple choice and short answer questions, with two case scenarios and three 'irrational' prescriptions.	There was an overall improvement of 26 percentage units in the prescribing knowledge and skills of GPs in the intervention group. No such improvements were seen in the control group.	Additional funding from the National Public Health Management Centre in Tabriz and the Ministry of Health and Medical Education of Iran
Sandilands et al.2010[17]	UK	Randomized controlled trial	50 medical students in the intervention group; 28 students in control group.	Focused doctor- and pharmacist-led practical prescribing teaching.	Written prescribing exam consisting of six scenario-based questions.	Teaching improved the assessment score of the intervention group: mean assessment 2 *vs.* 1, 70% *vs*. 62%, *P* = 0.007; allergy documentation: 98% *vs.* 74%, *P* = 0.0001; and confidence. However, 30% of prescriptions continued to include prescribing errors.	None declared
Celebi et al 2009[24]	Germany	Randomized controlled trial	36 medical students in early intervention group; 38 medical students in late intervention	A 1-week prescribing training module which comprised a seminar on common prescription errors, a prescribing	Students were asked to make prescriptions for two virtual cases on a standard patient chart. These prescription charts were subsequently	Prior to training, students committed a mean of 69 ± 12% of the potential prescription errors. This decreased to 29 ± 15% after prescribing training (P < 0.001).	None declared

			group.	exercise with a standardized paper case patient, drafting of inoperative prescription charts for real patients and discussions with a lecturer.	analyzed by two independent raters using a checklist for common prescription errors.		
Rothman et al. 2000[36]	South Africa	Randomized controlled trial	35 primary health care nurses in the intervention group; 31 in the control group.	A competency-based primary care drug therapy (PCDT) training program in the treatment of acute minor ailments.	Written examination with eight case studies including scenarios on acute gout, congestive heart failure, acute tonsillitis and infectious arthritis.	Post-test results of the intervention group indicated significant improvement towards correct diagnosis and management of the conditions (P<0.05)	Funded by Boehringer Ingelheim (Pty) Ltd (Self-Medication Division)
Scobie et al. 2003[37]	UK	Randomized controlled trial.	16 medical students in intervention group; 16 students in control group.	Practical structured teaching sessions led by a pharmacist.	Nine station OSCE exam covering topics such as anticoagulation, IV administration, discharge prescription and medication history.	The intervention group achieved higher scores in eight OSCE stations. Four of these were statistically significant (P <= 0.005).	None declared
Webbe et al.2007[39]	UK	Randomized controlled trial	13 pre-registration house officers (PRHOs)	A clinical teaching pharmacist program to improve prescribing skills	Number of prescribing errors.	A 37.5% reduction (P=0.14) in prescribing errors after pharmacist intervention	None declared
Degnan et al.2006[26]	UK	Randomized controlled trial	9 medical students in intervention	An online teaching module consisting of an interactive	OSCE station requiring administration of	The teaching module significantly improved the students' ability to calculate	Funded by the Association of Anaesthetists

			group; 35 in the control group.	tutorial of 12 multiple-choice questions and three case studies covering pharmacokinetics, adverse drug reactions and drug doses calculations.	lidocaine and adrenaline for a patient with laceration and anaphylaxis.	the correct volume of lidocaine (p=0.005) and adrenaline (0=0.0002).	of Great Britain and Ireland
Hux et al.1999[30]	Canada	Randomized controlled trial	135 GPs in intervention group; 116 GPs in control group.	Mailed packages of prescribing feedback and guidelines-based educational materials.	Median antibiotic cost and proportion of episodes of care in which a pre-specified first-line antibiotic was used first.	The median prescription cost remained constant in the feedback group but rose in the control group ($p < 0.002$). First-line drug use increased in the feedback group but decreased in the control group ($p < 0.01$).	Author receives salary support from the Institute for Clinical Evaluative Sciences in Ontario.
Kahan et al.2009[31]	Israel	Randomized controlled trial	32 physicians exposed to both interventions; 130 physicians who only received personalized letter; 29 physicians who only attended the lecture; 107 in the control group.	Interventions were in the form of a lecture at a conference and a letter with personalized feedback to improve physicians' rates of prescribing in the treatment of acute uncomplicated cystitis in adult women.	Outcome was the rate of adherence to the guidelines for appropriate treatment using nitrofurantoin or second-line therapy of ofloxacin for three days.	The letter intervention significantly influenced physicians' prescribing patterns. The lecture intervention was only effective in the short run, indicating that the effect of this technique does not last unless reinforced.	Partially funded through a research grant from The Israel National Institute for Health Policy and Health Services Research and through an educational grant from Schering Plough Israel.

Fender et al. 1999[28]	UK	Randomized controlled trial	54 GPs in intervention group; 46 GPs in control group	An educational package based on principles of "academic detailing".	The appropriate prescribing of tranexamic acid, non-steroidal anti-inflammatory drugs, and norethisterone.	A proportionately higher level of appropriate prescribing was found in the intervention group. An increase of 63% in the prescription of tranexamic acid, the most effective first line treatment for menorrhagia, was observed in the intervention group.	None declared
Midlöv at al. 2006[32]	Sweden	Randomized controlled trial	23 GPs in the intervention group; 31 GPs in the control group.	Educational outreach visits	Number of prescriptions of benzodiazepines (BDP) and antipsychotics to the elderly	One year after the educational outreach visits there was a significant decrease in prescribing of medium- and long-acting BDP and total BDP in the active group compared with the control group ($P<0.05$). For antipsychotics there were no significant differences between active and control group.	Funded by the Department of Primary Care Research and Development in the county of Skåne, Apoteket AB and the Faculty of Medicine, Lund University
Nsimba 2007[33]	Tanzania	Randomized controlled trial	20 pharmacists in intervention facilities; 20 in control facilities.	Posters, individual information and one-to-one training sessions.	Simulated clients assessed the drug seller/pharmacist's knowledge and prescribing choices. A short examination was also conducted to assess participants'	85% of simulated clients who went to the intervention facilities were sold the first line drug sulfadoxine/pyrimethamine (SP) compared to 55% at control facilities ($p<0.01$). The intervention group also performed significantly better	Funded by COSTECH-Tanzania

					knowledge of appropriate treatments for common childhood conditions.	on the knowledge exam (p<0.01).	
Smeele et al. 1999[38]	The Netherlands	Randomized controlled trial	17 GPs in the intervention group; 17 GPs in control group	Four sessions (lasting 2 hours each) of interactive group education and peer review program aimed at implementing national guidelines.	Data on prescription of inhaled and anti-inflammatory medications were collected through self-recording by GPs and recording of repeat prescriptions for patients.	No significant difference was found in the pharmacological treatment between intervention and control groups (P>0.05).	None declared
Ochoa 1996[34]	Cuba	Randomized controlled trial	4 groups of 10 physicians (A,B,C,D) with A receiving community education program and refresher training, B receiving refresher training, C receiving community education, D was the control group.	Refresher training based on teaching sessions and periodic advisory visits. Community education involved group discussions and distribution of educational materials.	Rate of over-prescription of antibiotics for mild acute respiratory infections (ARI) cases.	Following the interventions, antibiotic over-prescription rates declined by 26% and 63% in groups A and B, while increasing by 2% and 48% in groups C and D.	None declared
Odusanya	Lagos state,	Randomized	Number of	4-week training	Prescriptions were	At the 2-week evaluation, the	None declared

& Oyediran 2004[35]	Nigeria	controlled trial	participants not specified. Primary health care workers (no doctors) in Mushin were in the intervention group; health workers in Ikeja were in the control group.	program on rational drug use.	evaluated according to compliance to 'standing orders', which are a set of treatment modules. Drug use indicators were also compared.	intervention group achieved a significant reduction in the average number of medicines prescribed compared to the control group. There was also a significant increase in the percentage of patients rationally managed from 18% to 30% (p=0.0005) in the intervention group. Improvements were not sustained at the 3-month evaluation.	
Akici et al. 2004[43]	Turkey	Non randomized comparative control	50 medical students (interns) in intervention group; 54 interns in control group; 53 GPs	Problem-based rational pharmacotherapy education (RPE) via the WHO/Groningen model.	A written examination with open and structured questions based on case scenarios of tonsillitis and mild-to-moderate essential hypertension patients.	Mean scores of the interns in the intervention group were higher than GPs, which were in turn higher than those of interns in the control group for all cases.	Funded by a grant from Marmara University Scientific Research Projects Commission.
Volovitz et al. 2003[42]	Israel	Non randomized controlled trial	83 physicians attended the education program. Four groups of patients were included. The study group had patients whose	Asthma education program involving lectures on pathophysiology, asthma management and prevention. Physicians were also asked to invite patients for three	Changes in asthma medicine use was analyzed before and after the intervention. Data was derived from the central database of Maccabi, Israel.	In all four patient groups, a smaller proportion of reliever medicines (SABA) and a greater proportion of controller medicines (ICS & LABA) were used in the follow up period compared to before the intervention. Patients in the study group were twice more likely to	None declared

			physicians attended the education program and completed two follow up physician visits. Three control groups of patients were also included.	visits to reinforce the principles highlighted in the education program.		decrease their use of SABA than patients from the control group (p = 0.042).	
McCall et al. 2004[40]	Australia	Non randomized controlled trial	14 GPs in intervention group; 14 in control group.	Completion of a Graduate Certificate in General Practice Psychiatry conducted primarily via distance education program.	A clinical audit assessed GPs' recognition, drug management, non-drug management of patients with depression and anxiety.	No effect on the intervention GPs prescribing habits (P>0.05).	None declared
Shaw et al.2003[41]	Australia	Non randomized controlled trial	The number of junior doctors in intervention and control hospitals was not specified.	Academic detailing including the provision of a bookmark containing the requirements for addictive medicines.	Prescription error rates of addictive medicines were assessed. Errors were defined according to legal requirements for prescription of addictive medicines.	At the intervention hospital, there was a significant decrease in error rate (from 41% to 24%, P<0.0001).The control hospital did not show a significant change in error rate over the same study period (P=0.66).	Partially funded by the Postgraduate Medical Council of NSW.
Richir et al. 2008[50]	The Netherlands	Non randomized comparative control	197 medical students in the intervention group; 33	A context-learning pharmacotherapy program with role-play sessions and	A written exam involving the formulation of a treatment plan for	The mean score on the six steps of the World Health Organization (WHO) six-step plan for prescribing increased	None declared

			students in control.	OSCE.	two patients using the WHO six-step guide of rational prescribing.	significantly for students who has received the pharmacotherapy study (P<0.001).	
Coombes et al. 2007[46]	Australia	Non randomized comparative control	99 medical students in intervention group; 134 in control group	Eight interactive problem-based tutorials covering topics such as antibiotics, anticoagulants, IV fluids, analgesics, oral hypoglycaemics and insulin.	A written examination consisting of short answer questions on ADR identification, anticoagulants and analgesics.	A significantly higher score was found in intervention students compared with controls; mean score in intervention group 29.46; control group 26.35 (P<0.05)	None declared
Celebi et al.2010[45]	Germany	Non randomized comparative control	18 medical students who had never completed an internal-medicine clerkship; 38 students who had completed 1-4 weeks of clerkship; 18 students who had completed >5 weeks of clerkship.	Internal medicine clerkship based on one general learning objective of "students are to be familiarized with caring for patients in an outpatient and inpatient setting".	A written test comprising of the completion of prescription charts for two standardized patient paper cases. These were marked using a checklist for common prescription errors.	Students committed 69%±12% of all possible prescription mistakes. There was no significant difference between the group without clerkships in internal medicine (G1) (71±9%), the group with one to four weeks (G2) (67±15%), and the group with more than five weeks of clerkships (G3) (71±10%), p=.76.	None declared
Kozer et al. 2006[48]	Canada	Non randomized comparative control	13 trainees in intervention; 9 trainees in control	30 minute tutorial focusing on appropriate methods for	Main outcome measure was the number of prescribing errors	No significant difference in errors was found between the intervention group (12.4%) and the control group	Funded by the Trainee's Start-up Fund, The Research

				prescribing medications followed by a written test.	on medical charts completed after the tutorial.	(12.7%).	Institution, The Hospital for Sick Children, Toronto Canada.
Al Khaja et al.2005[44]	Bahrain	Non randomized comparative cohort	539 medical students	Problem-based learning curriculum incorporating a prescribing program.	A written examination. Physician-related components of the prescription assessed legality of prescription writing while drug-related components relate to the rational and appropriate use of medicines.	Rate of physician-related components by students (year 2 to 4) was 96.1 (CI 94.1-97.5). However, the rate of various drug-related components was 50.2 (CI 46.0-54.4). No significant difference in overall performance of Year 4 and Year 2 students (p=0.237). However appropriateness of drug-related components were significantly higher in Year 4 than Year 2 (p<0.05).	None declared
Franson et al.2009[47]	The Netherlands	Non randomized comparative cohort	181 medical students in baseline 2003 cohort, 285 students in 2004, 275 students in 2005, 264 students in 2006.	Students were taught to use a structured format called the Individualized Therapy Evaluation and Plan (ITEP) to communicate a therapeutic plan including the writing of a prescription.	Written examination involving two different therapeutic cases; a simple pediatric case and a complex geriatric case.	Students' scores improved significantly in the 3 years after the introduction of the ITEP in the curriculum. The average score of the 2006 cohort was 6.76 compared to 3.83 for the 2003 group (p<0.0001)	None declared
Tamblyn et	Canada	Non	751 doctors	A community	Annual performance	After the intervention,	Funded by the

al.2005[51]		randomized comparative cohort	from four graduation cohorts; 600 from before the intervention and 151 after the intervention.	oriented problem based learning curriculum.	in diagnosis (difference in prescribing rates for specific diseases and relief of symptoms), and management (prescribing rate for contraindicated medicines) assessed using provincial health databases for the first 4-7 years of practice.	graduates showed a significant fourfold increase in disease specific prescribing rates compared with prescribing for symptom relief. No difference in rate of prescribing for contraindicated medicines was observed.	Canadian Institutes of Health Research and Fonds de Recherche en Sante du Quebec
Pandejpong et al.2009[49]	Thailand	Non randomized comparative control	38 continuity of care (CCC) participants; 52 non-CCC participants	Continuity of care (CCC) curriculum.	Medical chart audits were performed and scored with a 12-task checklist of cardiovascular risk management including appropriate prescribing.	There was a significant increase in ability to properly adjust antihypertensive medication and in the prescribing of aspirin as primary prevention for cardiovascular disease in the CCC group ($p<0.05$)	Funded by a Faculty of Medicines Siriraj Hospital Medical Education Research Grant, Mahidol University.
Guney et al.2009[57]	Turkey	Before and after study	101 medical students	Rational pharmacotherapy training based on the Groningen/WHO model.	Prescription audit and OSCE exam based on a simulated patient case with uncomplicated essential hypertension.	A significant improvement in prescription audit scores was observed after the training (p: 0.022).	None declared
Gall et al. 2001[56]	UK	Before and after study	212 GPs; 139 community	Training on the use of guidelines on	Changes in prescribing practice	Education significantly reduced total prescribing by	Funded by South Thames

			nurses (CNs)	prescribing supplements.	of supplements.	15% and reduced the levels of inappropriate prescribing from 77% to 59% due to an improvement in monitoring of patients prescribed supplements.	Health Authorities Clinical Audit Programme.
Bojalil et al. 1999[52]	Tlaxcala, Mexico	Before and after	72 private GPs; 44 public GPs	A training course based on in-service practice. Other materials included the official training manuals for the control of diarrhea and acute respiratory infection (ARI), training videos and wall charts.	Aspects of diarrhea and ARI treatment which were evaluated and scored using a checklist.	Private practitioners showed significant improvements in prescribing practices for children with diarrhea. For ARI management, decisions on antimicrobial therapy and symptomatic drug use improved for both groups but only reached statistical significance for public physicians.	Funded by the Mexican Social Security Institute.
Chopra et al. 2005[53]	Cape Town, South Africa	Before and after	21 nurse prescribers	WHO and UNICEF's Integrated Management of Childhood Illness (IMCI) implementation. Training used the WHO/UNICEF teaching and assessment modules.	A structured observation checklist of the case management of sick children including rational prescribing.	There were significant improvements in the appropriate prescribing of antibiotics, with a significant reduction of inappropriate antibiotic use (62% versus 84 %). However, there was no change in the treatment of anemia or the prescribing of vitamin A to sick children.	None declared
Elkharrat et al. 1998[55]	France	Before and after	27 doctors	Doctors were informed of the Drug Regulatory	The rate of NSAID prescribing errors was analyzed.	Prescribing errors declined from 20% to 14% and when prescriptions were stratified	None declared

				Agency (DRA) prescribing guidelines of NSAIDs. Group sessions were held, posters were displayed and pocket sized, 10-page manuals were distributed.		by cause, the quality of prescribing increased significantly.	
Davey et al. 2008[54]	UK	Before and after	The number of junior doctors included in the study was not specified.	A pediatric junior doctor prescribing tutorial conducted by a pharmacist and a bedside prescribing guideline to encompass the most frequently prescribed medications utilized on the children's unit.	Prescribing errors and preventable adverse drug events.	The introduction of the prescribing tutorial decreased prescribing errors by 46% (p=0.023). The introduction of a bedside prescribing guideline did not decrease prescribing errors.	Author's research position was funded by Airedale NHS Trust.
Leonard et al. 2006[58]	USA	Before and after study	The number of clinical staff (physicians, nurses, pharmacists) included in the study was not specified.	Educational patient safety initiatives using multiple interrelated educational and behavioral modification strategies.	Assessment of medication orders which were then used to calculate the absolute risk reduction from prescribing errors.	The absolute risk reduction achieved after the interventions was 38 per 100 orders written (*t*= 25.735; *P*=.001). This yielded an overall relative risk reduction from prescribing errors of 49% (*P*<.001).	Funded by the New York State Department of Health 2003 Patient Safety Award and by a donation from Lexi-Comp of

							Pediatric Lexi-Drugs limited licenses.
Otero 2008[59]	Argentina	Before and after study	Number of participants not specified. Prescriptions for 95 patients were analysed in 2002 and for 92 patients in 2004.	Educational program developed by the Patient Safety Committee of the Department of Pediatrics including the implementation of the "10 steps to reduce medication errors' checklist.	Prevalence of medication errors detected in written prescription orders during June 2002 (before intervention) and May 2004 (after intervention).	Prevalence of prescription errors was significantly lower in 2004 compared with 2002; 11.4% vs 7.3% (P<0.05)	None declared

Educational Interventions to improve prescribing competency: A systematic review

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Educational Interventions to improve prescribing competency: A systematic review

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ABSTRACT

OBJECTIVE: To review the literature on educational interventions to improve prescribing and identify educational methods which improve prescribing competency in both medical and non-medical prescribers.

DESIGN: A systematic review was conducted. The databases Medline, International Pharmaceutical Abstracts (IPA), EMBASE and CINAHL were searched for articles in English published between January 1990 and July 2013.

SETTING: Primary and Secondary care

PARTICIPANTS: Medical and non-medical prescribers

INTERVENTION: Educational-based interventions to aid improve prescribing competency

PRIMARY OUTCOME: Improvements in prescribing competency (knows how) or performance (shows how) as defined by Miller's competency model. This was primarily demonstrated through prescribing examinations, changes in prescribing habits or adherence to guidelines.

RESULTS: A total of 47 studies met the inclusion criteria and were included in the systematic review. Studies were categorized by their method of assessment, with 20 studies assessing prescribing competence and 27 assessing prescribing performance. A wide variety of educational interventions were employed, with different outcome measures and methods of assessments. In particular, six studies demonstrated that specific prescribing training using the World Health Organization (WHO) *Guide to Good Prescribing* increased prescribing competency in a wide variety of settings. Continuing medical education in the form of

academic detailing and personalized prescriber feedback also yielded positive results. Only four studies evaluated educational interventions targeted at non-medical prescribers, highlighting that further research is needed in this area.

CONCLUSION: A broad range of educational interventions have been conducted to improve prescribing competency. The WHO *Guide to Good Prescribing* has the largest body of evidence to support its use and is a promising model for the design of targeted prescribing courses. There is a need for further development and evaluation of educational methods for non-medical prescribers.

ARTICLE SUMMARY

Article focus

- Prescribing competencies that cover both medical and non-medical prescribers have been developed internationally
- A review of the educational interventions designed to improve prescribing competencies will help to ensure evidence-based interventions are used to develop competent medical and non-medical prescribers

Key messages

- The World Health Organization (WHO) *Guide to Good Prescribing* has the largest body of evidence supporting its use to improve prescribing competencies internationally.
- Few studies have focused on educational interventions for non-medical prescribers.
- There is a need for further development and evaluation of educational methods for non-medical prescribers.

Strengths and limitations of this study

- Timely systematic review considering international developments regarding non-medical prescribers.
- Difficult to generalize findings considering different methods of assessments used

- Limited to publications in English only.

INTRODUCTION

Prescribing, a complex process involving the initiation, monitoring, continuation and modification of medication therapy,[1] demands a thorough understanding of clinical pharmacology as well as the judgment and ability to prescribe rationally for the benefit of patients.[2] The rational prescribing of medicines as defined by the World Health Organization (WHO) is *the situation in which patients receive medications appropriate to their clinical needs, in doses that meet their own individual requirements for a sufficient length of time, with the lowest cost to them and their community*.[3] Equipping prescribers with skills for rational prescribing is essential.

The diversity of skills required for good prescribing present a major challenge for the development of educational programs. Adding to this complexity is the extension of prescribing rights to non-medical healthcare professionals such as optometrists, nurses and pharmacists. Potential benefits of non-medical prescribing have been argued to include improved continuity of care and access to medicines, better allocation of human resources, increased patient convenience and less fragmentation of care,[1] however the process of prescribing is considered high-risk and error-prone.[2] Hence competent prescribing is paramount to patient safety. Poor prescribing can be illustrated by prescription errors, under or overprescribing, or inappropriate and irrational prescribing.[2 4] Junior prescribers appear most prone to prescribing errors, yet are expected to perform a significant prescribing role.[5-8] Although many prescribing errors are unintentional, studies have shown that the prescribing performance of interns and medical students is poor, partly because of inadequate training.[9 10] Little is known however about non-medical prescribing practices and rates of prescription errors. Research into non-medical prescribing has mainly been confined to self-report measures such as questionnaire and interview surveys.[11] Although one UK study indicated

that nurses' prescribing decisions were generally clinically appropriate, a large proportion did not display some prescribing competencies, e.g. taking patients' medicines history and allergy status.[12]

Traditionally assessment of education was based upon knowledge tests, however it is recognised today that knowledge alone is insufficient to predict performance in practice.[13] This has led to the introduction of competency-based education, focusing on developing knowledge, judgment and skills.[13 14] Miller proposed a four-staged competency assessment model beginning with assimilation of pure knowledge, progressing to development of real performance in practice (Figure 1).[13] Mucklow et al. provides further examples of assessing prescribing competence based on Miller's model and its importance for the healthcare profession.[15] Such developments have led the National Prescribing Centre in the UK and the NPS MedicineWise (Quality Use of Medicines service agency for Australia's National Medicines Policy) to produce a core competency framework for all prescribing, both medical and non-medical.[16 17] Although a number of recommendations for prescribing education to ensure competency have been introduced,[15] there is little evidence and detail as to how these competencies could actually be achieved.[18]

Three systematic reviews of interventions to improve prescribing were published since 2009.[19-21] One focused on medical students and junior doctors,[20] while another was an update of two previous reviews investigating the effectiveness of different types of interventions on improving prescribing.[19] The most recent review focuses on the hospital setting with an emphasis on new prescribers who were less than 2 years post-graduation.[21] Although all new prescribers were included in this review, little was discussed regarding non-medical prescribers. The Cochrane collaboration has also comprehensively evaluated the use of audit and feedback to improve prescribing.[22 23] The focus of this review is on prescribing competencies and its assessment, based on the higher stages of Miller's model (competency

and performance). This comprises practical aspects of prescription-writing as well as therapeutic decision-making, ensuring that rational, evidence-based therapy-selection is made based on patients' requirements and evaluation of their capacity to comply with a prescribed medicine).

This review aimed to examine the literature on educational interventions designed to develop and improve patient-focused prescribing competency in both medical and non-medical prescribers.

METHOD

Search strategy

Medline, International Pharmaceutical Abstracts (IPA), EMBASE and CINAHL; were searched using the key words: ('prescription$' OR 'prescriber$' OR 'prescribing') AND ('education' OR 'curriculum' OR 'course$' OR 'training' OR 'intervention$') AND ('drug$' OR 'medication$' or 'medication therapy management') AND ('clinical competence' OR 'competency' OR 'competency assessment'). The search terms were mapped onto Medical Subject Headings (MeSH) in Medline and EMBASE and carried through other database as key search terms. The search was limited to articles published in English from January 1990-July 2013 (Appendix 1-4).

Study selection

Citations generated by the search strategy were screened by all authors for relevance and eligibility. The full texts of potentially relevant articles were reviewed to determine satisfaction of inclusion criteria. The screening process was conducted according to PRISMA guidelines[24] (Figure 2).

The target population was medical or non-medical prescribers. All study designs were considered for this review. Studies were included if they were original research articles, had an educational intervention, and at least one outcome measure of prescribing competency demonstrated through prescribing examinations which evaluated the application of knowledge to patient cases or scenarios, changes in prescribing habits or adherence to guidelines. Studies were excluded if they only measured theoretical knowledge of pharmacology and therapeutics or studied an intervention involving drug utilization evaluation (DUE) primarily using audit and feedback without a focus on the educational intervention, as thesewere often targeted towards cost-effectiveness and contains a large body of literature that has been previously reviewed by the Cochrane collaboration.[22 23] Systematic reviews, letters, meeting reports and opinion pieces were also excluded. The review was not restricted to any country.

Two authors (GK and JP) reviewed the titles and abstracts of the articles retrieved in the search to assess relevance. Discussions were conducted between the four authors to exclude studies which did not meet the inclusion criteria, and this continued until consensus was achieved regarding study selection.

Data extraction and analysis

Study location, design, characteristics of the study population, description of the education intervention, outcomes measured and results were extracted by GK and JP.

RESULTS

Number of studies

The search strategy generated 796 articles in Medline, 300 in EMBASE, 20 in IPA and 195 in CINAHL. Further refinement using the exclusion and inclusion criteria and duplicate exclusion resulted in 47 studies identified and reviewed (Table 1).

Study designs

Of the 47 reviewed studies, there were twenty randomized controlled trials (RCT),[18 25-43] fifteen non-randomized comparative trials,[44-58] and twelve before-after studies.[59-68]

Setting and participant characterization

Ten educational interventions were targeted at general practitioners,[25 29 30 32-34 40 44 46 63] ten were conducted in hospitals ,[41 45 52 59 61 62 65-67 69] six were implemented at primary health care clinics/facilities,[36-38 43 60 70] twenty interventions were incorporated within the curriculum at universities[18 26-28 31 39 42 47-51 53-58 64 68] and one intervention was carried out in pharmacies.[35] These studies were conducted in numerous countries around the world (Table 1).

Types of educational interventions and prescribing outcomes

A wide variety of educational methods and outcome measures were used. Interventions were summarized into two categories using Miller's competency model:

i) Prescribing competence ('knows how') - assessing prescriptions written for theoretical cases

ii) Prescribing performance ('shows how') – assessing prescriptions written for real patients

Prescribing competence

Twenty studies included interventions targeting particular tasks involved in prescribing, from taking accurate medication history, to choosing a rational treatment and writing the

prescription.[18 25-29 31 39 42 47-51 54 56-58 64 68] Eight of these studies used a method of rational pharmacotherapy education based on the World Health Organization (WHO) *Guide to Good Prescribing*.[25 27 31 47 54 56 64 68] DeVries *et al*. conducted a multicentre randomized controlled trial with 583 medical students from eight countries.[27] The trial reported a significant increase in mean scores of the intervention group following the WHO *Guide to Good Prescribing* intervention.

Other studies found evidence of a retention effect, where improvement in rational prescribing was maintained several months after the intervention[25 42] and a transfer effect, where students were able to apply acquired rational prescribing skills in new situations.[25 54] The main limitation of the trials was that assessments were based primarily on written scenarios with a limited number of disease topics.

Four studies examined the effect of structured prescribing tutorials and programs on prescribing skills of medical students and GPs.[29 39 42 50] Three, specifically covered high-risk medicines and reported significant improvements in prescribing skills.[29 39 50] Prescribing outcomes were assessed using written case scenarios[29 50] and a nine-station OSCE.[39] .

Five studies assessed prescription writing skills of medical students following a prescribing program at university.[48 51 57 58 68] Al Khaja *et al*.(2005) evaluated a prescribing program incorporated into a problem-based learning (PBL) curriculum.[48] Students acquired limited prescribing competency during the PBL program. Only 50.2% correctly selected appropriate medicine(s), strength and dosage-form in the written examination.[48] Al Khaka *et al.* (2013) later used a 2 hour interactive session on prescription writing skills with formative feedback.[57] This program increased appropriate medicine(s) selection to 83.9%, appropriate strength to 68% and appropriate dosage form to 59.6%.[57] The other three studies used peer assisted learning,[58] team –based learning (TBL) based on WHO's *Guide to Good*

Prescribing[68] and Individualized Therapy Evaluation and Plan (ITEP) in the curriculum.[51] The TBL and ITEP format allowed students to provide a rationale-based treatment plan for an individual patient. Both TBL and ITEP improved students' ability to solve therapeutic problems and select appropriate medications.[51 68] However, all of these studies were non-randomized making it difficult to attribute their findings to the impact of interventions alone.

Three studies measured the incidence of prescribing errors in written scenario-based examinations.[18 26 49] Specific prescribing tutorials/teaching modules significantly reduced prescription errors.[18 26] However obligatory medical clerkships, where students are assumed to acquire prescribing skills by spending up to 16 weeks with a general practitioner or in a hospital setting, did not to have a significant effect on the rate of prescription errors.[49]

One study examining an online interactive teaching module found a significant improvement in students' ability to calculate correct volumes of lignocaine and adrenaline in an OSCE setting.[28]

Prescribing performance

Twenty- seven studies used educational interventions which aimed to improve management of particular conditions and increase the appropriateness of prescribing.[30 32-38 40 41 43-46 52 53 55 59-63 65-67 69 70]

In eleven of these studies, interventions were implemented to specifically promote prescribing first-line therapy or reduce inappropriate prescribing.[30 32-36 43 62 63 69 70] Academic detailing approaches[30] and educational outreach visits,[34-36 63] were found to show positive results in improving prescribing adherence to guidelines. Mailed personalised prescribing feedback[32 33] was also found to be effective. An intervention in the form of a lecture was

found to be ineffective unless reinforced with another intervention, e.g. individual feedback.[33] An in-house training program was found to reduce the inappropriate prescribing of non-steroidal anti-inflammatory drugs (NSAIDs) but results were not statistically significant.[62]

Nine studies used educational interventions to improve overall treatment practices of various conditions, with appropriate and rational pharmacological therapy assessed.[37 38 40 44 46 53 55 59 60] The methods which reported improvements included educational outreach visits,[37 38] in-service training,[59] and a multipronged approach involving training sessions and some reorganization of management systems.[60]. Two studies assessed the effectiveness of curriculum changes at university on medical graduates' patient-care performance.[53 55] Both a problem-based learning curriculum[55] and a continuity of care clinic (CCC) curriculum[53] increased prescribing performance indicators. However, outcome measures differed, with one study assessing prescribing rates in ambulatory patients aged >65 years[55] and the other focusing specifically on cardiovascular risk management.[53]

Mixed results were found in two studies which evaluated asthma management following an educational intervention.[40 46] An intensive small-group education session and peer review program did not show a significant influence on adherence to guidelines for general pharmacological treatment and management of exacerbations.[40] Another study found a positive change in medication prescribing following an asthma education program, however both the intervention and control groups showed this change in practice.[46]

McCall *et al*. examined the impact of a distance-learning graduate course in general practice psychiatry on managing mental illness.[44] Although the intervention had a positive impact on GP knowledge, there was no significant effect on overall prescribing habits.

Seven studies evaluated the impact of educational interventions on the rate of prescribing errors using an audit of medication charts before and after the intervention.[41 45 52 61 65-67]

Multidisciplinary interventions using interrelated educational and behavioral modification strategies significantly reduced prescribing errors.[65 66] Academic detailing reduced the number of incorrect prescriptions written for addictive medicines,[45] however prescription errors were defined only on the basis of local state laws in Australia and no assessment of the appropriateness of the choice of medicines was made. Webbe *et al*.[41] reported a reduction in prescribing errors following pharmacist accompaniment on prescribing rounds and a clinical teaching pharmacist program. However, the small sample meant that statistical significance was not reached. Two studies assessed the effect of a prescribing tutorial on the incidence of pediatric prescribing errors.[52 61] Both tutorials focused on prescribing in the pediatric population; however the studies reported mixed results. Kozer *et al*.[52] found no difference in prescribing errors whereas Davey *et al*.[61] reported significant differences.

DISCUSSION

Although a considerable amount of research has been conducted into improving prescribing competency through educational interventions, the range of heterogeneous study designs and outcome measures limits the validity and generalizability of their conclusions.

According to Miller's framework of competency assessment, tests of knowledge alone are insufficient to properly assess educational interventions. Hence, the assessment of prescribing skills included in these studies mainly focused on Miller's pyramid base 'knows how' and 'shows how'. The translation of knowledge and skills into a rational diagnostic or management plan is defined as competency (knowing how), which was measured using written examinations, patient management or OSCEs. This in turn predicts performance (showing how) and action (does) which was evaluated in daily life circumstances through audits to detect prescription errors or direct observations of prescribers' performance using standardized checklists. However, prescribing performance is difficult to measure as it can be

influenced by many factors such as physicians' clinical experience, socio-cultural factors, histopathology of disease, pharmaceutical industry representatives, and the ever-increasing pressure from patients.[25]

Although studies differed considerably in their methods and assessment procedures, a number of key findings were highlighted. Firstly, specific prescribing teaching can lead to improvements in prescribing competency. This was reported in studies which used tutorials and educational programs to guide participants in the process of rational prescribing.[25 27 29 31 39 47 48 50 51 54 64] Of these studies, only the WHO *Guide to Good Prescribing* has been evaluated for both medical students and GPs across a range of countries.[25 27 31 47 54 64 68] The WHO model provides a six-step guide to choose, prescribe and monitor a suitable medicine for an individual patient and presents a good foundation for the development of therapeutic reasoning in a prescribing curriculum. This model is in line with the prescribing competency framework developed by the National Prescribing Centre[16] and NPS MedicineWise.[17] It also provides important guidance in the development of educational interventions for medical and non-medical prescribers. The WHO method also encourages prescribers to verify standard treatment for each patient (recognizing issues such as aging or cognition impairment) and to alter treatment if necessary,[25] which is an essential skill to acquire particularly with the aging community.

Incorporating a prescribing component into a structured problem-based curriculum also improved students' ability to prescribe correctly.[26 27 31 39 48 54] Although targeted prescribing-teaching is mainly implemented at the undergraduate level, studies have found that GPs and non-medical prescribers often do not apply rational prescribing principles in daily practice and would benefit from these interventions.[25 35 37 38]

Many studies attempted to influence prescribing behavior through the promotion of rational medication use based on published practice guidelines. These guidelines have been promoted in face-to-face interactions and training through educational outreach visits, academic detailing, and through institutional audits and feedback. All of these methods have positively affected health professionals' behavior.[30 34 63] Although effective, these methods could be labor intensive and may be prohibitively expensive. Findings suggest that personalized feedback letters could be just as effective while blunting costs.[32 33] There is scope to explore why these interventions work and determine which interventions are suitable for different types of prescribers and settings.

Prescribing practices can also be improved through enhanced communication between doctors, pharmacists, nurses, other health professionals, as well as patients and carers. Several studies highlight the interactive role of medical, pharmacy and nursing staff in ensuring safe and effective use of medicines.[18 35 39 41 50 59 61] This is not surprising, as many prescribing errors cannot be attributed to knowledge deficits alone.[18] Hence improving prescribing practices may require interventions aimed at multiple operant factors, such as developing a safety-oriented attitude through improving environment conditions, direct staff supervision and adopting a zero-tolerance policy for incomplete or incorrect prescriptions.[66] Indeed positive results were reported following multifaceted interventions where education was incorporated into a system-based approach to influence prescribing behavior.[65 66]

Finally, this review has highlighted a lack of educational interventions targeted at non-medical prescribers. Four studies assessed the effectiveness of training programs: two were for nurses,[38 60] one for pharmacists[35] and one for primary health care workers (community health officers, nurses and community health extension workers).[37] All four studies had relatively small sample sizes and differed greatly in prescribing outcome measures. This

suggests that further description and evaluation of educational methods are needed for non-medical prescribers.

Overall the conclusions that can be drawn are limited by the quality of the studies reviewed. The number of participants included ranged from thirteen in a randomized controlled trial[41] to 751 in a cohort study.[55] Randomised controlled trials are considered the gold standard; however the smaller studies may have been underpowered and hence could not produce statistically significant results. Nevertheless large-sample randomisation and effective blinding are often not appropriate or possible in prescribing intervention studies. The current literature also does not show if the improvements in prescribing persists after the intervention occurs as many studies only assess up to a few months after the intervention. Higher quality studies looking at long-term changes in prescribing habits is required to assess the effectiveness of educational interventions on prescribing.

Lastly, the different methods of assessments were often used with no discussion about their validity and reliability, and marking schemes were inconsistent across the different studies. For example, the definitions of 'prescription error' differed slightly between studies and one study defined errors based on local state laws instead of on appropriateness of medication choices.[45] The correlation between the duration of interventions and the impact on prescribing was also difficult to determine as the interventions ranged from a 30-minute tutorial[52] to a prescribing program implemented for up to three years.[51 53 55] This made assessing the quality of the studies difficult and no criteria appeared appropriate for this purpose.

As our search strategy excluded studies that were not in English, we were unable to report important educational strategies that may exist in this area. However, these interventions have

already been shown to decrease costs and may subsequently improve prescribing appropriateness.[22 23] Furthermore, the comprehensiveness of our review may have been limited by only including databases that we perceived would contain the bulk of the prescribing competency literature, using the key word 'competency' and following PRISMA guidelines[24] which do not stipulate hand searches. Overall the studies retrieved provided a broad overview of a range of prescribing interventions and may be useful in identifying strategies that can be explored further in more robust, longer-term trials in the future.

CONCLUSION

A wide range of educational interventions has been conducted to develop and maintain prescribing competency. However few studies have sought to evaluate the educational models used to develop non-medical prescribers' prescribing competency and there is a need for further development in the assessment of teaching for non-medical prescribers as expansions of prescribing powers continue to be implemented. The development of competency frameworks for prescribing has highlighted the need to design interventions which target each prescribing competency domain. In particular, the WHO *Guide to Good Prescribing* is a promising model for the design of targeted prescribing programs and has been shown to be effective in a wide variety of settings.

FIGURE LEGENDS

Figure 1: Miller's framework for clinical assessment[13]

Figure 2: Flowchart of search strategy and study selection based on PRISMA guidelines[24]

Table 1: Summary of educational intervention studies for prescribing

Authors. Year	Setting	Study Design	No of participants	Intervention	Prescribing outcome measures	Results	Potential for bias
Akici et al. 2003[25]	Turkey	Randomized controlled trial	12 GPs in intervention group; 13 GPs in control group	Short rational pharmacotherapy course based on the 'problem-based Groningen/WHO model'	Written exam with open and structured questions based on hypertensive cases as well as a question on osteoarthritis (unexposed indication).	Significant improvement in the mean test scores post-training of the intervention group ($p < 0.05$) for both questions, showing a transfer effect. The improvement was maintained for at least 4 months after training.	None declared
Butler et al. 2012[43]	UK	Randomized controlled trial	34 medical practices with 139 GPs were in the intervention group; 34 medical practices with 124 GPs in the control group.	The intervention contained 7 parts. Six of these were online and included a reflection on their own practice, evidence and guidelines, novel communication skills and sharing experiences. Last, a face-to-face presentation of resistance trends throughout Wales and actual practices.	Total numbers of oral antibiotic items dispensed for all causes per 1000 practice patients adjusted for the previous year's dispensing.	A significant reduction of total oral antibiotic dispensing for the intervention group was observed compared to the control group (664 vs 681.1, P=0.02).	None declared
Celebi et al	Germany	Randomized	36 medical	A 1-week	Students were	Prior to training, students	None

2009[26]		controlled trial	students in early intervention group; 38 medical students in late intervention group.	prescribing training module which comprised a seminar on common prescription errors, a prescribing exercise with a standardized paper case patient, drafting of inoperative prescription charts for real patients and discussions with a lecturer.	asked to make prescriptions for two virtual cases on a standard patient chart. These prescription charts were subsequently analyzed by two independent raters using a checklist for common prescription errors.	committed a mean of 69 ± 12% of the potential prescription errors. This decreased to 29 ± 15% after prescribing training ($P < 0.001$).	declared
De Vries et al. 2008[27]	Eight countries in Asia & Europe	Randomized controlled trial	194 medical students in personal formulary (PF) group; 198 in existing formulary (EF) group; 191 in control group	The PF and EF groups were given teaching sessions based on the WHO Guide to Good Prescribing model (PF group = whole manual; EF group =manual minus p-drugs), with and without use of personal	Written exam using 16 patient cases based on four topics: hypertension, osteoarthritis, acute bronchitis, gastroenteritis.	A significant increase in mean scores of the intervention group compared to the control group ($p<0.05$). The increase in the PF group was significantly higher than in the EF group. However, this effect was only visible in the universities in Yemen, the Russian Federation, and Indonesia. No significant differences between PF	Funded by the VU University Medical Center and by the Department of Essential Drugs and Medicines Policy of the World Health Organisation.

				formulary.		and EF scores were found in the universities in the Netherlands, Slovakia, Spain, India or South Africa.	
Degnan et al.2006[28]	UK	Randomized controlled trial	9 medical students in intervention group; 35 in the control group.	An online teaching module consisting of an interactive tutorial of 12 multiple-choice questions and three case studies covering pharmacokinetics, adverse drug reactions and drug doses calculations.	OSCE station requiring administration of lidocaine and adrenaline for a patient with laceration and anaphylaxis.	The teaching module significantly improved the students' ability to calculate the correct volume of lidocaine (p=0.005) and adrenaline (0=0.0002).	Funded by the Association of Anaesthetists of Great Britain and Ireland
Esmaily et al.2009[29]	Iran	Randomized controlled trial	58 GPs in intervention group; 54 GPs in control group	Education with an outcome-based approach utilizing active-learning principles.	Multiple choice and short answer questions, with two case scenarios and three 'irrational' prescriptions.	There was an overall improvement of 26 percentage units in the prescribing knowledge and skills of GPs in the intervention group. No such improvements were seen in the control group.	Additional funding from the National Public Health Management Centre in Tabriz and the Ministry of Health and Medical Education of Iran

Fender et al. 1999[30]	UK	Randomized controlled trial	54 GPs in intervention group; 46 GPs in control group	An educational package based on principles of "academic detailing".	The appropriate prescribing of tranexamic acid, non-steroidal anti-inflammatory drugs, and norethisterone.	A proportionately higher level of appropriate prescribing was found in the intervention group. An increase of 63% in the prescription of tranexamic acid, the most effective first line treatment for menorrhagia, was observed in the intervention group.	None declared
Gordon et al. 2011[42]	UK	Randomized controlled trial	76 junior doctors in intervention group; 86 in control group.	An 1-2 hours e-learning course on paediatric prescribing	Total correct responses on each prescribing assessment. Drug selection, prescribing calculations for children, discussing therapies and sources of errors were assessed.	A significant increase in correct responses by the intervention group compared to the control group at both 4 and 12 weeks after the intervention. At 4 weeks: 79% vs 63% (P<0.0001) At 12 weeks: 79% vs 69% (P<0.0001)	None declared
Hassan et al. 2000[31]	Yemen	Randomized controlled trial	56 medical students in intervention group; 44 students in control group	A prescribing course based on WHO's Guide to Good Prescribing, the Yemen Essential Drug List and Yemen Standard Treatment	Written exam based on eight patient problems where a complete treatment plan form must be completed.	Students from the study group performed significantly better than those from control in all problems presented and also when compared with the results of the pre-test (P < 0.05).	None declared

				Guidelines			
Hux et al.1999[32]	Canada	Randomized controlled trial	135 GPs in intervention group; 116 GPs in control group.	Mailed packages of prescribing feedback and guidelines-based educational materials.	Median antibiotic cost and proportion of episodes of care in which a pre-specified first-line antibiotic was used first.	The median prescription cost remained constant in the feedback group but rose in the control group ($p < 0.002$). First-line drug use increased in the feedback group but decreased in the control group ($p < 0.01$).	Author receives salary support from the Institute for Clinical Evaluative Sciences in Ontario.
Kahan et al.2009[33]	Israel	Randomized controlled trial	32 physicians exposed to both interventions; 130 physicians who only received personalized letter; 29 physicians who only attended the lecture; 107 in the control group.	Interventions were in the form of a lecture at a conference and a letter with personalized feedback to improve physicians' rates of prescribing in the treatment of acute uncomplicated cystitis in adult women.	Outcome was the rate of adherence to the guidelines for appropriate treatment using nitrofurantoin or second-line therapy of ofloxacin for three days.	The letter intervention significantly influenced physicians' prescribing patterns. The lecture intervention was only effective in the short run, indicating that the effect of this technique does not last unless reinforced.	Partially funded through a research grant from The Israel National Institute for Health Policy and Health Services Research and through an educational grant from Schering Plough Israel.
Midlöv at al. 2006[34]	Sweden	Randomized controlled trial	23 GPs in the intervention group; 31	Educational outreach visits	Number of prescriptions of benzodiazepines	One year after the educational outreach visits there was a significant	Funded by the Department

			GPs in the control group.		(BDP) and antipsychotics to the elderly	decrease in prescribing of medium- and long-acting BDP and total BDP in the active group compared with the control group (P<0.05). For antipsychotics there were no significant differences between active and control group.	of Primary Care Research and Development in the county of Skåne, Apoteket AB and the Faculty of Medicine, Lund University
Nsimba 2007[35]	Tanzania	Randomized controlled trial	20 pharmacists in intervention facilities; 20 in control facilities.	Posters, individual information and one-to-one training sessions.	Simulated clients assessed the drug seller/pharmacist's knowledge and prescribing choices. A short examination was also conducted to assess participants' knowledge of appropriate treatments for common childhood conditions.	85% of simulated clients who went to the intervention facilities were sold the first line drug sulfadoxine/pyrimethamine (SP) compared to 55% at control facilities (p<0.01). The intervention group also performed significantly better on the knowledge exam (p<0.01).	Funded by COSTECH-Tanzania
Ochoa 1996[36]	Cuba	Randomized controlled trial	4 groups of 10 physicians (A,B,C,D) with A	Refresher training based on teaching sessions and periodic advisory	Rate of over-prescription of antibiotics for mild acute	Following the interventions, antibiotic over-prescription rates declined by 26% and 63%	None declared

			receiving community education program and refresher training, B receiving refresher training, C receiving community education, D was the control group.	visits. Community education involved group discussions and distribution of educational materials.	respiratory infections (ARI) cases.	in groups A and B, while increasing by 2% and 48% in groups C and D.	
Odusanya & Oyediran 2004[37]	Lagos state, Nigeria	Randomized controlled trial	Number of participants not specified. Primary health care workers (no doctors) in Mushin were in the intervention group; health workers in Ikeja were in the control group.	4-week training program on rational drug use.	Prescriptions were evaluated according to compliance to 'standing orders', which are a set of treatment modules. Drug use indicators were also compared.	At the 2-week evaluation, the intervention group achieved a significant reduction in the average number of medicines prescribed compared to the control group. There was also a significant increase in the percentage of patients rationally managed from 18% to 30% (p=0.0005) in the intervention group. Improvements were not sustained at the 3-month evaluation.	None declared
Rothman et	South	Randomized	35 primary	A competency-	Written	Post-test results of the	Funded by

al. 2000[38]	Africa	controlled trial	health care nurses in the intervention group; 31 in the control group.	based primary care drug therapy (PCDT) training program in the treatment of acute minor ailments.	examination with eight case studies including scenarios on acute gout, congestive heart failure, acute tonsillitis and infectious arthritis.	intervention group indicated significant improvement towards correct diagnosis and management of the conditions (P<0.05)	Boehringer Ingelheim (Pty) Ltd (Self-Medication Division)
Sandilands et al.2010[18]	UK	Randomized controlled trial	50 medical students in the intervention group; 28 students in control group.	Focused doctor- and pharmacist-led practical prescribing teaching.	Written prescribing exam consisting of six scenario-based questions.	Teaching improved the assessment score of the intervention group: mean assessment 2 *vs.* 1, 70% *vs*. 62%, *P* = 0.007; allergy documentation: 98% *vs.* 74%, *P* = 0.0001; and confidence. However, 30% of prescriptions continued to include prescribing errors.	None declared
Scobie et al. 2003[39]	UK	Randomized controlled trial.	16 medical students in intervention group; 16 students in control group.	Practical structured teaching sessions led by a pharmacist.	Nine station OSCE exam covering topics such as anticoagulation, IV administration, discharge prescription and medication history.	The intervention group achieved higher scores in eight OSCE stations. Four of these were statistically significant (P <= 0.005).	None declared
Smeele et al. 1999[40]	The Netherlands	Randomized controlled trial	17 GPs in the intervention group; 17	Four sessions (lasting 2 hours each) of	Data on prescription of inhaled and anti-	No significant difference was found in the pharmacological treatment	None declared

			GPs in control group	interactive group education and peer review program aimed at implementing national guidelines.	inflammatory medications were collected through self-recording by GPs and recording of repeat prescriptions for patients.	between intervention and control groups (P>0.05).	
Webbe et al.2007[41]	UK	Randomized controlled trial	13 pre-registration house officers (PRHOs)	A clinical teaching pharmacist program to improve prescribing skills	Number of prescribing errors.	A 37.5% reduction (P=0.14) in prescribing errors after pharmacist intervention	None declared
Akici et al. 2004[47]	Turkey	Non randomized comparative control	50 medical students (interns) in intervention group; 54 interns in control group; 53 GPs	Problem-based rational pharmacotherapy education (RPE) via the WHO/Groningen model.	A written examination with open and structured questions based on case scenarios of tonsillitis and mild-to-moderate essential hypertension patients.	Mean scores of the interns in the intervention group were higher than GPs, which were in turn higher than those of interns in the control group for all cases.	Funded by a grant from Marmara University Scientific Research Projects Commission.
Akram et al. 2012[56]	Malaysia	Non-randomized comparative control	18 final year dental students in the intervention group; 19 in the control	Didactic lecture on how to write a complete prescription	Three case studies including irreversible pulpitis associated with a child, a pregnant woman and periapical	Significant improvement in the intervention group occurred compared to the control group in the following areas; date of issue, Rx symbol present, medicine legible, direction	Funded by the faculty of medicine, Universiti Kebangsaan Malaysia.

			group.		pulpitis for an adult man. Assessed according to WHO's Guide to good prescribing.	to use medicines, refill instructions, prescriber's signature, prescriber's date and prescriber's registration	
Al Khaja et al. 2013[57]	Bahrain	Non-randomized comparative control	460 medical students over different stages of the degree were in the intervention group; 450 in the control group.	A 2 hour interactive session on prescription writing skills is presented followed by 5-6 case scenarios given as homework. Formative feedback on these cases was given to the students.	A written examination. Physician-related components of the prescription assessed legality of prescription writing while drug-related components relate to the rational and appropriate use of medicines.	Significantly higher scores were achieved by those that attended the interactive sessions compared to those that did not. 73.5% vs 59.5% (P<0.0001)	No funding received
Al Khaja et al.2005[48]	Bahrain	Non randomized comparative cohort	539 medical students	Problem-based learning curriculum incorporating a prescribing program.	A written examination. Physician-related components of the prescription assessed legality of prescription writing while drug-related components relate to the rational and appropriate use of	Rate of physician-related components by students (year 2 to 4) was 96.1 (CI 94.1-97.5). However, the rate of various drug-related components was 50.2 (CI 46.0-54.4). No significant difference in overall performance of Year 4 and Year 2 students (p=0.237). However appropriateness of drug-related	None declared

					medicines.	components were significantly higher in Year 4 than Year 2 ($p<0.05$).	
Celebi et al.2010[49]	Germany	Non randomized comparative control	18 medical students who had never completed an internal-medicine clerkship; 38 students who had completed 1-4 weeks of clerkship; 18 students who had completed >5 weeks of clerkship.	Internal medicine clerkship based on one general learning objective of "students are to be familiarized with caring for patients in an outpatient and inpatient setting".	A written test comprising of the completion of prescription charts for two standardized patient paper cases. These were marked using a checklist for common prescription errors.	Students committed 69%±12% of all possible prescription mistakes. There was no significant difference between the group without clerkships in internal medicine (G1) (71±9%), the group with one to four weeks (G2) (67±15%), and the group with more than five weeks of clerkships (G3) (71±10%), p=.76.	None declared
Coombes et al. 2007[50]	Australia	Non randomized comparative control	99 medical students in intervention group; 134 in control group	Eight interactive problem-based tutorials covering topics such as antibiotics, anticoagulants, IV fluids, analgesics, oral hypoglycaemics and insulin.	A written examination consisting of short answer questions on ADR identification, anticoagulants and analgesics.	A significantly higher score was found in intervention students compared with controls; mean score in intervention group 29.46; control group 26.35 ($P<0.05$)	None declared
Franson et	The	Non	181 medical	Students were	Written	Students' scores improved	None

al.2009[51]	Netherlands	randomized comparative cohort	students in baseline 2003 cohort, 285 students in 2004, 275 students in 2005, 264 students in 2006.	taught to use a structured format called the Individualized Therapy Evaluation and Plan (ITEP) to communicate a therapeutic plan including the writing of a prescription.	examination involving two different therapeutic cases; a simple pediatric case and a complex geriatric case.	significantly in the 3 years after the introduction of the ITEP in the curriculum. The average score of the 2006 cohort was 6.76 compared to 3.83 for the 2003 group ($p<0.0001$)	declared
Kozer et al. 2006[52]	Canada	Non randomized comparative control	13 trainees in intervention; 9 trainees in control	30 minute tutorial focusing on appropriate methods for prescribing medications followed by a written test.	Main outcome measure was the number of prescribing errors on medication charts completed after the tutorial.	No significant difference in errors was found between the intervention group (12.4%) and the control group (12.7%).	Funded by the Trainee's Start-up Fund, The Research Institution, The Hospital for Sick Children, Toronto Canada.
McCall et al. 2004[44]	Australia	Non randomized comparative control	14 GPs in intervention group; 14 in control group.	Completion of a Graduate Certificate in General Practice Psychiatry conducted primarily via distance education	A clinical audit assessed GPs' recognition, drug management, non-drug management of patients with depression and anxiety.	No effect on the intervention GPs prescribing habits ($P>0.05$).	None declared

				program.			
Pandejpong et al.2009[53]	Thailand	Non randomized comparative control	38 continuity of care (CCC) participants; 52 non-CCC participants	Continuity of care (CCC) curriculum.	Medical chart audits were performed and scored with a 12-task checklist of cardiovascular risk management including appropriate prescribing.	There was a significant increase in ability to properly adjust antihypertensive medication and in the prescribing of aspirin as primary prevention for cardiovascular disease in the CCC group ($p<0.05$)	Funded by a Faculty of Medicines Siriraj Hospital Medical Education Research Grant, Mahidol University.
Richir et al. 2008[54]	The Netherlands	Non randomized comparative control	197 medical students in the intervention group; 33 students in control.	A context-learning pharmacotherapy program with role-play sessions and OSCE.	A written exam involving the formulation of a treatment plan for two patients using the WHO six-step guide of rational prescribing.	The mean score on the six steps of the World Health Organization (WHO) six-step plan for prescribing increased significantly for students who has received the pharmacotherapy study ($P<0.001$).	None declared
Shaw et al.2003[45]	Australia	Non randomized comparative control	The number of junior doctors in intervention and control hospitals was not specified.	Academic detailing including the provision of a bookmark containing the requirements for addictive medicines.	Prescription error rates of addictive medicines were assessed. Errors were defined according to legal requirements for prescription of addictive medicines.	At the intervention hospital, there was a significant decrease in error rate (from 41% to 24%, $P<0.0001$).The control hospital did not show a significant change in error rate over the same study period ($P=0.66$).	Partially funded by the Postgraduate Medical Council of NSW.
Tamblyn et al.2005[55]	Canada	Non randomized	751 doctors from four	A community oriented problem	Annual performance in	After the intervention, graduates showed a	Funded by the Canadian

		comparative cohort	graduation cohorts; 600 from before the intervention and 151 after the intervention.	based learning curriculum.	diagnosis (difference in prescribing rates for specific diseases and relief of symptoms), and management (prescribing rate for contraindicated medicines) assessed using provincial health databases for the first 4-7 years of practice.	significant fourfold increase in disease specific prescribing rates compared with prescribing for symptom relief. No difference in rate of prescribing for contraindicated medicines was observed.	Institutes of Health Research and Fonds de Recherche en Sante du Quebec
Volovitz et al. 2003[46]	Israel	Non randomized comparative control	83 physicians attended the education program. Four groups of patients were included. The study group had patients whose physicians attended the education program and completed	Asthma education program involving lectures on pathophysiology, asthma management and prevention. Physicians were also asked to invite patients for three visits to reinforce the principles highlighted in the education	Changes in asthma medicine use was analyzed before and after the intervention. Data was derived from the central database of Maccabi, Israel.	In all four patient groups, a smaller proportion of reliever medicines (SABA) and a greater proportion of controller medicines (ICS & LABA) were used in the follow up period compared to before the intervention. Patients in the study group were twice more likely to decrease their use of SABA than patients from the control group (p = 0.042).	None declared

			two follow up physician visits. Three control groups of patients were also included.	program.			
Wallace et al. 2011[58]	UK	Non-randomized comparative control	20 final year medical students in the intervention group; 11 in the control group	8 tutorials on prescribing in acute clinical scenarios using peer assisted learning	Accurate completion of a prescription chart	The intervention group significantly improved after the intervention; median score was 47 before; 66 after (P<0.01). No significant change occured in the control group (P=0.17)	None declared
Aghamirsalim et al. 2012[69]	Iran	Before and after study	72 orthopaedic surgeons	Formal 2 hour lectures once a week for 4 weeks and a 30 minute refresher course was offered at the 4th month. Also, simplified osteoporosis guidelines were distributed	Proportion of patients with fragility factures who received appropriate treatment for osteoporosis.	Significantly more patients were appropriately prescribed calcium and vitamin D supplements on discharge. 10% vs 91% (P<0.05) Significantly more patients were appropriately prescribed a bisphosphonate on discharge. 0.1% vs 73% (P<0.05)	None declared
Bojalil et al. 1999[59]	Tlaxcala, Mexico	Before and after	72 private GPs; 44 public GPs	A training course based on in-service practice. Other materials	Aspects of diarrhea and ARI treatment which were evaluated	Private practitioners showed significant improvements in prescribing practices for	Funded by the Mexican Social Security

				included the official training manuals for the control of diarrhea and acute respiratory infection (ARI), training videos and wall charts.	and scored using a checklist.	children with diarrhea. For ARI management, decisions on antimicrobial therapy and symptomatic drug use improved for both groups but only reached statistical significance for public physicians.	Institute.
Chopra et al. 2005[60]	Cape Town, South Africa	Before and after	21 nurse prescribers	WHO and UNICEF's Integrated Management of Childhood Illness (IMCI) implementation. Training used the WHO/UNICEF teaching and assessment modules.	A structured observation checklist of the case management of sick children including rational prescribing.	There were significant improvements in the appropriate prescribing of antibiotics, with a significant reduction of inappropriate antibiotic use (62% versus 84 %). However, there was no change in the treatment of anemia or the prescribing of vitamin A to sick children.	None declared
Davey et al. 2008[61]	UK	Before and after	The number of junior doctors included in the study was not specified.	A pediatric junior doctor prescribing tutorial conducted by a pharmacist and a bedside prescribing guideline to encompass the most frequently prescribed	Prescribing errors and preventable adverse drug events.	The introduction of the prescribing tutorial decreased prescribing errors by 46% (p=0.023). The introduction of a bedside prescribing guideline did not decrease prescribing errors.	Author's research position was funded by Airedale NHS Trust.

				medications utilized on the children's unit.			
Elkharrat et al. 1998[62]	France	Before and after	27 doctors	Doctors were informed of the Drug Regulatory Agency (DRA) prescribing guidelines of NSAIDs. Group sessions were held, posters were displayed and pocket sized, 10-page manuals were distributed.	The rate of NSAID prescribing errors was analyzed.	Prescribing errors declined from 20% to 14% and when prescriptions were stratified by cause, the quality of prescribing increased significantly.	None declared
Guney et al.2009[64]	Turkey	Before and after study	101 medical students	Rational pharmacotherapy training based on the Groningen/WHO model.	Prescription audit and OSCE exam based on a simulated patient case with uncomplicated essential hypertension.	A significant improvement in prescription audit scores was observed after the training (p: 0.022).	None declared
Gall et al. 2001[63]	UK	Before and after study	212 GPs; 139 community nurses (CNs)	Training on the use of guidelines on prescribing supplements.	Changes in prescribing practice of supplements.	Education significantly reduced total prescribing by 15% and reduced the levels of inappropriate prescribing from 77% to 59% due to an improvement in monitoring of patients	Funded by South Thames Health Authorities Clinical Audit Programme.

						prescribed supplements.	
Leonard et al. 2006[65]	USA	Before and after study	The number of clinical staff (physicians, nurses, pharmacists) included in the study was not specified.	Educational patient safety initiatives using multiple interrelated educational and behavioral modification strategies.	Assessment of medication orders which were then used to calculate the absolute risk reduction from prescribing errors.	The absolute risk reduction achieved after the interventions was 38 per 100 orders written (t= 25.735; P=.001). This yielded an overall relative risk reduction from prescribing errors of 49% (P<.001).	Funded by the New York State Department of Health 2003 Patient Safety Award and by a donation from Lexi-Comp of Pediatric Lexi-Drugs limited licenses.
Minas et al. 2012[70]	Australia	Before and after study	GPs and health care prescribers in Emergency Departments and Sexual Health Clinics. Number included not specified	Treatment guidelines were distributed and informed through professional development sessions, letters and newsletters.	Proportion of patients receiving non-occupational post-exposure prophylaxis (nPEP) according to the relevant treatment guidelines.	Significantly more patients that received nPEP met the eligibility criteria as stated in the relevant treatment guidelines after the educational intervention. 61.2% vs 90% (P<0.001)	None declared
Otero 2008[66]	Argentina	Before and after study	Number of participants not specified.	Educational program developed by the	Prevalence of medication errors detected in written	Prevalence of prescription errors was significantly lower in 2004 compared	None declared

			Prescriptions for 95 patients were analysed in 2002 and for 92 patients in 2004.	Patient Safety Committee of the Department of Pediatrics including the implementation of the "10 steps to reduce medication errors' checklist.	prescription orders during June 2002 (before intervention) and May 2004 (after intervention).	with 2002; 11.4% vs 7.3% (P<0.05)	
Taylor et al. 2012[67]	UK	Before and after study	242 junior doctors	1 hour interactive, case-based educational programme regarding inpatient diabetes care.	Number of insulin prescribing errors on medication charts observed after the tutorial.	Insulin prescription errors were significantly lower after the intervention; 15.4% vs 7.8% (P<0.05)	None declared
Zgheib et al. 2011[68]	Lebanon	Before and after study	127 final year medical students divided into 18 groups of 6-7 students	5 team-based learning (TBL) based on WHO's Guide to Good Prescribing. A lecture on the role of the pharmacist, Pharmacy & Therapeutics committees, formularies and hospital policies were also presented	Group formulary and prescription writing exercises occurred after each TBL session. Rationale for the selection of a drug and the format of the prescription was included in these assessments	Significant improvement in mean group scores for both formulary and prescription-writing exercises occurred over the 5 TBL sessions (P=0.002).	None declared

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Contributors: *These authors contributed equally on this work
GK, JP, BC and RM jointly developed the search strategy and review protocol. Data collection and extraction was carried out by GK and JP. All authors contributed to interpretation of the data, drafting the article and revision of the manuscript and approved the final version for submission.

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Educational Interventions to improve prescribing competency: A systematic review

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OBJECTIVE: To review the literature on educational interventions to improve prescribing and identify educational methods which improve prescribing competency in both medical and non-medical prescribers.

DESIGN: ~~A~~AS ~~S~~systematic review was conducted. The databases Medline, International Pharmaceutical Abstracts (IPA), EMBASE and CINAHL were searched for articles in English published between January 1990 and July 2013.

SETTING: Primary and Secondary care

PARTICIPANTS: Medical and non-medical prescribers

INTERVENTION: Educational-based interventions to aid improve prescribing competency

PRIMARY OUTCOME: Improvements in prescribing competency (knows how) or performance (shows how) as defined by Miller's competency model. This was primarily demonstrated through prescribing examinations, changes in prescribing habits or adherence to guidelines.

~~**DATA SOURCES:** The databases Medline, International Pharmaceutical Abstracts (IPA), EMBASE and CINAHL were searched for articles in English published between 1990 and July 20131.~~

~~**STUDY SELECTION:** A total of 38 47 studies were reviewed. Eligible studies evaluated the effect of educational interventions on at least one outcome measure of prescribing competency demonstrated through prescribing examinations, changes in prescribing habits or adherence to guidelines.~~

RESULTS: A total of 47 studies met the inclusion criteria and were included in the systematic review. Studies were categorized by their method of assessment, with ~~15~~ 20

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studies assessing prescribing competence ~~(knows how)~~ and 27 assessing prescribing performance ~~(shows how)~~. A wide variety of educational interventions were employed, with different outcome measures and methods of assessments. In particular, six studies demonstrated that specific prescribing training using the World Health Organization (WHO) *Guide to Good Prescribing* increased prescribing competency in a wide variety of settings. Continuing medical education in the form of academic detailing and personalized prescriber feedback also yielded positive results. Only four studies evaluated educational interventions targeted at non-medical prescribers, highlighting that further research is needed in this area.

CONCLUSION: A broad range of educational interventions have been conducted to improve prescribing competency. The WHO *Guide to Good Prescribing* has the largest body of evidence to support its use and is a promising model for the design of targeted prescribing courses. There is a need for further development and evaluation of educational methods for non-medical prescribers.

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ARTICLE SUMMARY

Article focus

- Prescribing competencies that cover both medical and non-medical prescribers have been developed internationally
- A review of the educational interventions designed to improve prescribing competencies will help to ensure evidence-based interventions are used to develop competent medical and non-medical prescribers

Key messages

- The World Health Organization (WHO) *Guide to Good Prescribing* has the largest body of evidence supporting its use to improve prescribing competencies internationally.
- Few studies have focused on educational interventions for non-medical prescribers.
- There is a need for further development and evaluation of educational methods for non-medical prescribers.

Strengths and limitations of this study

- Timely systematic review considering international developments regarding non-medical prescribers.
- Difficult to generalize findings considering different methods of assessments used
- Limited to publications in English only.

~~WHAT THIS PAPER ADDS~~

What is already known on this subject

1. Prescribing rights are expanding to non-medical healthcare professions globally

2. Prescribing competencies that cover both medical and non-medical prescribers have been developed internationally

3. Educational interventions including audit and feedback have been reported to be the most common and consistent method of improving prescribing competency

What this study adds

1. The World Health Organization (WHO) *Guide to Good Prescribing* has the largest body of evidence supporting its use to improve prescribing competencies internationally.

2. Few studies have focused on educational interventions for non-medical prescribers.

3. There is a need for further development and evaluation of educational methods for non-medical prescribers.

INTRODUCTION

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Prescribing, a complex process involving the initiation, monitoring, continuation and modification of medication therapy,[1] demands a thorough understanding of clinical pharmacology as well as the judgment and ability to prescribe rationally for the benefit of patients.[2] The rational prescribing of medicines as defined by the World Health Organization (WHO) is *the situation in which patients receive medications appropriate to their clinical needs, in doses that meet their own individual requirements for a sufficient length of time, with the lowest cost to them and their community*.[3] Equipping prescribers with skills for rational prescribing is essential.

The diversity of skills required for good prescribing present a major challenge for the development of educational programs. Adding to this complexity is the extension of prescribing rights to non-medical healthcare professionals such as optometrists, nurses and pharmacists. Potential benefits of non-medical prescribing have been argued to include improved continuity of care and access to medicines, better allocation of human resources, increased patient convenience and less fragmentation of care,[1] however the process of prescribing is considered high-risk and error-prone.[2] Hence competent prescribing is paramount to patient safety. Poor prescribing can be illustrated by prescription errors, under or overprescribing, or inappropriate and irrational prescribing.[2 4] Junior prescribers appear most prone to prescribing errors, yet are expected to perform a significant prescribing role.[5-8] Although many prescribing errors are unintentional, ~~S~~studies have shown that the prescribing performance of interns and medical students is poor, partly because of inadequate training.[9 10] Little is known however about non-medical prescribing practices and rates of prescription errors. Research into non-medical prescribing has mainly been confined to self-report measures such as questionnaire and interview surveys.[11] Although one UK study indicated that nurses' prescribing decisions were generally clinically appropriate, a large proportion did

not display some prescribing competencies, e.g. taking patients' medicines history and allergy status.[12]

Traditionally assessment of education was based upon knowledge tests, however it is recognised today that knowledge alone is insufficient to predict performance in practice.[13] This has led to the introduction of competency-based education, focusing on developing knowledge, judgment and skills.[13 14] Miller proposed a four-staged competency assessment model beginning with assimilation of pure knowledge, progressing to development of real performance in practice (Figure 1).[13] Mucklow et al. provides further examples of assessing prescribing competence based on Miller's model and its importance for the healthcare profession.[15] Such developments have led the National Prescribing Centre in the UK and the NPS MedicineWise (Quality Use of Medicines service agency for Australia's National Medicines Policy) to produce a core competency framework for all prescribing, both medical and non-medical.[16 17] Although a number of recommendations for prescribing education to ensure competency have been introduced,[15] there is little evidence and detail as to how these competencies could actually be achieved.[18] ~~Two~~

Three systematic reviews of interventions to improve prescribing were published ~~in~~ since 2009.[19-21] One focused on medical students and junior doctors,[20] while ~~the other was~~another was an update of two previous reviews investigating the effectiveness of different types of interventions on improving prescribing.[19] The most recent review focuses on the hospital setting with an emphasis on new prescribers who were less than 2 years post-graduation.[21] Although all new prescribers were included in this review, little was discussed regarding non-medical prescribers. The Cochrane collaboration has also comprehensively evaluated the use of audit and feedback to improve prescribing.[22 23] The focus of this review is on prescribing competencies and its assessment, based on the higher stages of Miller's model (competency and performance). This comprises practical aspects of prescription-writing as well as

therapeutic decision-making, ensuring that rational, evidenced-based therapy-selection is made based on patients' requirements and evaluation of their capacity to comply with a prescribed medicine).

This review aimed to examine the literature on educational interventions designed to develop and improve patient-focused prescribing competency in both medical and non-medical prescribers.

METHOD

Search strategy

Medline, International Pharmaceutical Abstracts (IPA), EMBASE and CINAHL; were searched using the key words: ('prescription$' OR 'prescriber$' OR 'prescribing') AND ('education' OR 'curriculum' OR 'course$' OR 'training' OR 'intervention$') AND ('drug$' OR 'medication$' or 'medication therapy management') AND ('clinical competence' OR 'competency' OR 'competency assessment'). The search terms were mapped onto Medical Subject Headings (MeSH) in Medline and EMBASE and carried through other database as key search terms. The search was limited to articles published in English from January 1990-July 2013 (Appendix 1-4).

Study selection

Citations generated by the search strategy were screened by all authors for relevance and eligibility. The full texts of potentially relevant articles were reviewed to determine satisfaction of inclusion criteria. The screening process was conducted according to PRISMA guidelines[24] (Figure 2).

The target population was medical or non-medical prescribers. All study designs were considered for this review. Studies were included if they were original research articles, had

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an educational intervention, and at least one outcome measure of prescribing competency demonstrated through prescribing examinations which evaluated the application of knowledge to patient cases or scenarios, changes in prescribing habits or adherence to guidelines. Studies were excluded if they only measured theoretical knowledge of pharmacology and therapeutics or studied an intervention involving drug utilization evaluation (DUE) primarily using audit and feedback without a focus on the educational intervention, as theseis intervention is were often primarily targeted towards cost-effectiveness and contains a large body of literature that has been previously reviewed by the Cochrane collaboration.[22 23] Systematic reviews, letters, meeting reports and opinion pieces were also excluded. The review was not restricted to any country.

One Two authors (GK and JP) reviewed the titles and abstracts of the articles retrieved in the search to assess relevance. Discussions were conducted between the four authors to exclude studies which did not meet the inclusion criteria, and this continued until consensus was achieved regarding study selection.

Data extraction and analysis:

Study location, design, characteristics of the study population, description of the education intervention, outcomes measured and results were extracted by GK and JP.

RESULTS:

Number of studies

The search strategy generated 515 796 articles in Medline, 183 300 in EMBASE, 14 20 in IPA and 68 195 in CINAHL. Further refinement using the exclusion and inclusion criteria and duplicate exclusion resulted in 38 47 studies identified and reviewed (Table 1).

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Study designs

Of the ~~38~~ 47 reviewed studies, there were ~~eighteen~~ twenty randomized controlled trials (RCT),[18 25-43] ~~three~~ fifteen non-randomized ~~controlled~~comparative trials,[44-58] and ~~eight~~ twelve before-after studies.[59-68]

Setting and participant characterization

Ten educational interventions were targeted at general practitioners,[25 29 30 32-34 40 44 46 63] ~~eight~~ ten were conducted in hospitals ,[41 45 52 59 61 62 65-67 69] ~~four~~ six were implemented at primary health care clinics/facilities,[36-38 43 60 70] ~~fifteen~~ twenty interventions were incorporated within ~~a medical education~~the curriculum at universities[18 26-28 31 39 42 47-51 53-58 64 68] and one intervention was carried out in pharmacies.[35] These studies were conducted in numerous countries around the world (Table 1).

Types of educational interventions and prescribing outcomes

A wide variety of educational methods and outcome measures were used. Interventions were summarized into two categories using Miller's competency model:

i) Prescribing competence ('knows how') - assessing prescriptions written for theoretical cases

ii) Prescribing performance ('shows how') – assessing prescriptions written for real patients

Prescribing competence

~~Fifteen~~ Twenty studies included interventions targeting particular tasks involved in prescribing, from taking accurate medication history, to choosing a rational treatment and writing the prescription.[18 25-29 31 39 42 47-51 54 56-58 64 68] ~~Six~~ Eight of these studies used a method

of rational pharmacotherapy education based on the World Health Organization (WHO) *Guide to Good Prescribing*.[25 27 31 47 54 56 64 68] DeVries *et al*. conducted a multicentre randomized controlled trial with 583 medical students from eight countries.[27] The trial reported a significant increase in mean scores of the intervention group following the WHO *Guide to Good Prescribing* intervention.

Other studies found evidence of a retention effect, where improvement in rational prescribing was maintained several months after the intervention[25 42] and a transfer effect, where students were able to apply acquired rational prescribing skills in new situations.[25 54] The main limitation of the trials was that assessments were based primarily on written scenarios with a limited number of disease topics.

~~Three~~ Four studies examined the effect of structured prescribing tutorials and programs on prescribing skills of medical students and GPs.[29 39 42 50] ~~All t~~Three, specifically covered high-risk medicines and reported significant improvements in prescribing skills-.[29 39 50] Prescribing outcomes were assessed using written case scenarios[29 50] and a nine-station OSCE.[39] .

~~Two~~ Five studies assessed prescription writing skills of medical students following a prescribing program at university.[48 51 57 58 68] Al Khaja *et al*.(2005) evaluated a prescribing program incorporated into a problem-based learning (PBL) curriculum~~,~~.[48] ~~-~~Students acquired limited prescribing competency during the PBL program. Only 50.2% correctly selected appropriate medicine(s), strength and dosage-form in the written examination.[48] Al Khaka *et al.* (2013) later used a 2 hour interactive session on prescription writing skills with formative feedback.[57] This program increased appropriate medicine(s) selection to 83.9%, appropriate strength to 68% and appropriate dosage form to 59.6%.[57] The other three studies used peer assisted learning,[58] team –based learning (TBL) based on WHO's *Guide to Good Prescribing*[68] and ~~Franson *et al.*[51] examined the effect of implementing a structured format~~

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~~called~~ Individualized Therapy Evaluation and Plan (ITEP) in the curriculum.[51] ~~This~~ The TBL and ITEP format allowed students to provide a rationale-based treatment plan for an individual patient. ~~The study found that~~ Both TBL and ITEP improved students' ability to solve therapeutic problems and select appropriate medications~~.~~.[51 68] However, ~~both~~all~~-~~ of these studies were non-randomized ~~cohort studies comparing results between cohorts of different years. Hence it is~~making it difficult to attribute their findings to the impact of interventions alone.

Three studies measured the incidence of prescribing errors in written scenario-based examinations.[18 26 49] Specific prescribing tutorials/teaching modules significantly reduced prescription errors.[18 26] However obligatory medical clerkships, where students are assumed to acquire prescribing skills by spending up to 16 weeks with a general practitioner or in a hospital setting, did not to have a significant effect on the rate of prescription errors.[49]

One study examining an online interactive teaching module ~~-~~found a significant improvement in students' ability to calculate correct volumes of lignocaine and adrenaline in an OSCE setting.[28]

Prescribing performance

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Twenty- ~~three~~ seven studies used educational interventions which aimed to improve management of particular conditions and increase the appropriateness of prescribing.[30 32-38 40 41 43-46 52 53 55 59-63 65-67 69 70]

In ~~eight~~ eleven of these studies, interventions were implemented to specifically promote prescribing first-line therapy or reduce inappropriate prescribing.[30 32-36 43 62 63 69 70] Academic detailing approaches[30] and educational outreach visits,[34-36 63] were found to show positive

results in improving prescribing adherence to guidelines. Mailed personalised prescribing feedback[32 33] was also found to be effective. An intervention in the form of a lecture was found to be ineffective unless reinforced with another intervention, e.g. individual feedback.[33] An in-house training program was found to reduce the inappropriate prescribing of non-steroidal anti-inflammatory drugs (NSAIDs) but results were not statistically significant.[62]

Nine studies used educational interventions to improve overall treatment practices of various conditions, with appropriate and rational pharmacological therapy assessed.[37 38 40 44 46 53 55 59 60] The methods which reported improvements included educational outreach visits,[37 38] in-service training,[59] and a multipronged approach involving training sessions and some reorganization of management systems.[60]. Two studies assessed the effectiveness of curriculum changes at university on medical graduates' patient-care performance.[53 55] Both a problem-based learning curriculum[55] and a continuity of care clinic (CCC) curriculum[53] increased prescribing performance indicators. However, outcome measures differed, with one study assessing prescribing rates in ambulatory patients aged >65 years[55] and the other focusing specifically on cardiovascular risk management.[53]

Mixed results were found in two studies which evaluated asthma management following an educational intervention.[40 46] An intensive small-group education session and peer review program did not show a significant influence on adherence to guidelines for general pharmacological treatment and management of exacerbations.[40] Another study found a positive change in medication prescribing following an asthma education program, however both the intervention and control groups showed this change in practice.[46]

McCall *et al*. examined the impact of a distance-learning graduate course in general practice psychiatry on managing mental illness.[44] Although the intervention had a positive impact on GP knowledge, there was no significant effect on overall prescribing habits.

~~Six~~ Seven studies evaluated the impact of educational interventions on the rate of prescribing errors using an audit of medication charts before and after the intervention.[41 45 52 61 65-67] Multidisciplinary interventions using interrelated educational and behavioral modification strategies significantly reduced prescribing errors.[65 66] Academic detailing reduced the number of incorrect prescriptions written for addictive medicines,[45] however prescription errors were defined only on the basis of local state laws in Australia and no assessment of the appropriateness of the choice of medicines was made. Webbe *et al*.[41] reported a reduction in prescribing errors following pharmacist accompaniment on prescribing rounds and a clinical teaching pharmacist program. However, the small sample meant that statistical significance was not reached. Two studies assessed the effect of a prescribing tutorial on the incidence of pediatric prescribing errors.[52 61] Both tutorials focused on prescribing in the pediatric population; however the studies reported mixed results. Kozer *et al*.[52] found no difference in prescribing errors whereas Davey *et al*.[61] reported significant differences.

DISCUSSION~~:~~

Although a considerable amount of research has been conducted into improving prescribing competency through educational interventions, the range of heterogeneous study designs and outcome measures limits the validity and generalizability of their conclusions.

According to Miller's framework of competency assessment, tests of knowledge alone are insufficient to properly assess educational interventions. Hence, the assessment of prescribing skills included in these studies mainly focused on Miller's pyramid base 'knows how' and 'shows how'. The translation of knowledge and skills into a rational diagnostic or management plan is defined as competency (knowing how), which was measured using written examinations, patient management or OSCEs. This in turn predicts performance (showing how) and action (does) which was evaluated in daily life circumstances through

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audits to detect prescription errors or direct observations of prescribers' performance using standardized checklists. However, prescribing performance is difficult to measure as it can be influenced by many factors such as physicians' clinical experience, socio-cultural factors, histopathology of disease, pharmaceutical industry representatives, and the ever-increasing pressure from patients.[25]

Although studies differed considerably in their methods and assessment procedures, a number of key findings were highlighted. Firstly, specific prescribing teaching can lead to improvements in prescribing competency. This was reported in studies which used tutorials and educational programs to guide participants in the process of rational prescribing.[25 27 29 31 39 47 48 50 51 54 64] Of these studies, only the WHO *Guide to Good Prescribing* has been evaluated for both medical students and GPs across a range of countries.[25 27 31 47 54 64 68] The WHO model provides a six-step guide to choose, prescribe and monitor a suitable medicine for an individual patient and presents a good foundation for the development of therapeutic reasoning in a prescribing curriculum. This model is in line with the prescribing competency framework developed by the National Prescribing Centre[16] and NPS MedicineWise.[17] It also provides important guidance in the development of educational interventions for medical and non-medical prescribers. The WHO method also encourages prescribers to verify standard treatment for each patient (recognizing issues such as aging or cognition impairment) and to alter treatment if necessary,[25] which is an essential skill to acquire particularly with the aging community.

Incorporating a prescribing component into a structured problem-based curriculum also improved students' ability to prescribe correctly.[26 27 31 39 48 54] Although targeted prescribing-teaching is mainly implemented at the undergraduate level, studies have found that GPs and non-medical prescribers often do not apply rational prescribing principles in daily practice and would benefit from these interventions.[25 35 37 38]

Many studies attempted to influence prescribing behavior through the promotion of rational medication use based on published practice guidelines. These guidelines have been promoted in face-to-face interactions and training through educational outreach visits, academic detailing, and through institutional audits and feedback. All of these methods have positively affected health professionals' behavior.[30 34 63] Although effective, these methods could be labor intensive and may be prohibitively expensive. Findings suggest that personalized feedback letters could be just as effective while blunting costs.[32 33] There is scope to explore why these interventions work and determine which interventions are suitable for different types of prescribers and settings.

Prescribing practices can also be improved through enhanced communication between doctors, pharmacists, nurses, other health professionals, as well as patients and carers. Several studies highlight the interactive role of medical, pharmacy and nursing staff in ensuring safe and effective use of medicines.[18 35 39 41 50 59 61] This is not surprising, as many prescribing errors cannot be attributed to knowledge deficits alone.[18] Hence improving prescribing practices may require interventions aimed at multiple operant factors, such as developing a safety-oriented attitude through improving environment conditions, direct staff supervision and adopting a zero-tolerance policy for incomplete or incorrect prescriptions.[66] Indeed positive results were reported following multifaceted interventions where education was incorporated into a system-based approach to influence prescribing behavior.[65 66]

Finally, this review has highlighted a lack of educational interventions targeted at non-medical prescribers. Four studies assessed the effectiveness of training programs: two were for nurses,[38 60] one for pharmacists[35] and one for primary health care workers (community health officers, nurses and community health extension workers).[37] All four studies had relatively small sample sizes and differed greatly in prescribing outcome measures. This

suggests that further description and evaluation of educational methods are needed for non-medical prescribers.

Overall the conclusions that can be drawn are limited by the quality of the studies reviewed. The number of participants included ranged from thirteen in a randomized controlled trial[41] to 751 in a cohort study.[55] Randomised controlled trials are considered the gold standard; however the smaller studies may have been underpowered and hence could not produce statistically significant results. Nevertheless large-sample randomisation and effective blinding are often not appropriate or possible in prescribing intervention studies. The current literature also does not show if the improvements in prescribing persists after the intervention occurs as many studies only assess up to a few months after the intervention. Higher quality studies looking at long-term changes in prescribing habits is required to assess the effectiveness of educational interventions on prescribing.

Lastly, ~~T~~the different methods of assessments were often used with no discussion about their validity and reliability, and marking schemes were inconsistent across the different studies. For example, the definitions of 'prescription error' differed slightly between studies and one study defined errors based on local state laws instead of on appropriateness of medication choices.[45] The correlation between the duration of interventions and the impact on prescribing was also difficult to determine as the interventions ranged from a 30-minute tutorial[52] to a prescribing program implemented for up to three years.[51 53 55] This made assessing the quality of the studies difficult and no criteria appeared appropriate for this purpose.

As our search strategy excluded studies that were not in English, we were unable to report important educational strategies that may exist in this area. However, these interventions have

already been shown to decrease costs and may subsequently improve prescribing appropriateness.[22 23] Furthermore, the comprehensiveness of our review may have been limited by only including databases that we perceived would contain the bulk of the prescribing competency literature, using the key word 'competency' and following PRISMA guidelines[24] which do not stipulate hand searches. Overall the studies retrieved provided a broad overview of a range of prescribing interventions and may be useful in identifying strategies that can be explored further in more robust, longer-term trials in the future.

CONCLUSION

A wide range of educational interventions has been conducted to develop and maintain prescribing competency. However few studies have sought to evaluate the educational models used to develop non-medical prescribers' prescribing competency and there is a need for further development in the assessment of teaching for non-medical prescribers as expansions of prescribing powers continue to be implemented. The development of competency frameworks for prescribing has highlighted the need to design interventions which target each prescribing competency domain. In particular, the WHO *Guide to Good Prescribing* is a promising model for the design of targeted prescribing programs and has been shown to be effective in a wide variety of settings.

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FIGURES AND TABLES

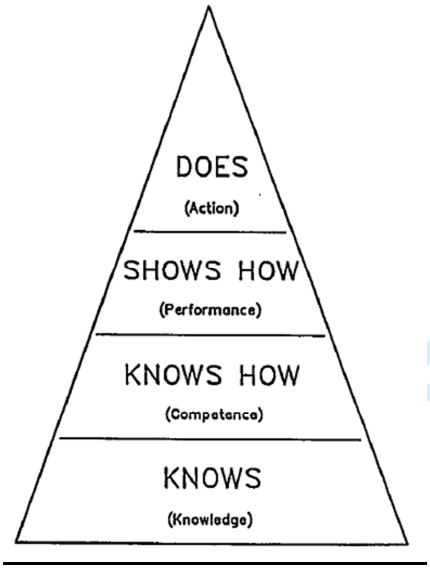

Figure 1: Miller's framework for clinical assessment[1,3,4]

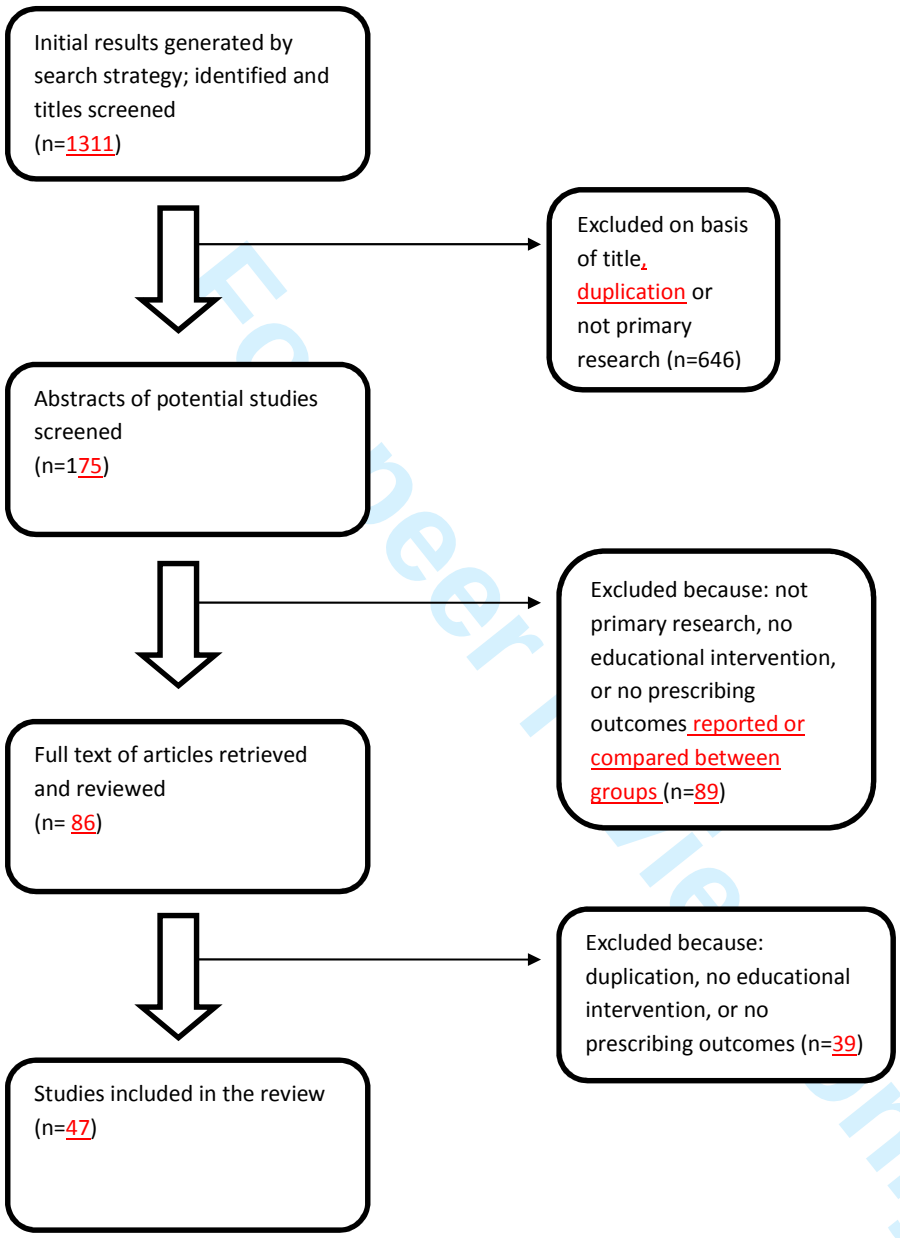

Figure 2: Flowchart of search strategy and study selection based on PRISMA guidelines[24] ~~[22]~~

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Table 1: Summary of educational intervention studies for prescribing

Authors. Year	Setting	Study Design	No of participants	Intervention	Prescribing outcome measures	Results	Potential for bias
Akici et al. 2003[25]	Turkey	Randomized controlled trial	12 GPs in intervention group; 13 GPs in control group	Short rational pharmacotherapy course based on the 'problem-based Groningen/WHO model'	Written exam with open and structured questions based on hypertensive cases as well as a question on osteoarthritis (unexposed indication).	Significant improvement in the mean test scores post-training of the intervention group ($p < 0.05$) for both questions, showing a transfer effect. The improvement was maintained for at least 4 months after training.	None declared
Butler et al. 2012[43]	UK	Randomized controlled trial	34 medical practices with 139 GPs were in the intervention group; 34 medical practices with 124 GPs in the control group.	The intervention contained 7 parts. Six of these were online and included a reflection on their own practice, evidence and guidelines, novel communication skills and sharing experiences. Last, a face-to-face presentation of resistance trends throughout Wales and actual practices.	Total numbers of oral antibiotic items dispensed for all causes per 1000 practice patients adjusted for the previous year's dispensing.	A significant reduction of total oral antibiotic dispensing for the intervention group was observed compared to the control group (664 vs 681.1, P=0.02).	None declared
Celebi et al 2009[26]	Germany	Randomized controlled trial	36 medical students in early intervention	A 1-week prescribing training module which comprised a	Students were asked to make prescriptions for two virtual cases on	Prior to training, students committed a mean of 69 ± 12% of the potential prescription errors. This	None declared

			group; 38 medical students in late intervention group.	seminar on common prescription errors, a prescribing exercise with a standardized paper case patient, drafting of inoperative prescription charts for real patients and discussions with a lecturer.	a standard patient chart. These prescription charts were subsequently analyzed by two independent raters using a checklist for common prescription errors.	decreased to 29 ± 15% after prescribing training (P < 0.001).	
De Vries et al. 2008[27]	Eight countries in Asia & Europe	Randomized controlled trial	194 medical students in personal formulary (PF) group; 198 in existing formulary (EF) group; 191 in control group	The PF and EF groups were given teaching sessions based on the WHO Guide to Good Prescribing model (PF group = whole manual; EF group =manual minus p-drugs), with and without use of personal formulary.	Written exam using 16 patient cases based on four topics: hypertension, osteoarthritis, acute bronchitis, gastroenteritis.	A significant increase in mean scores of the intervention group compared to the control group ($p<0.05$). The increase in the PF group was significantly higher than in the EF group. However, this effect was only visible in the universities in Yemen, the Russian Federation, and Indonesia. No significant differences between PF and EF scores were found in the universities in the Netherlands, Slovakia, Spain, India or South Africa.	Funded by the VU University Medical Center and by the Department of Essential Drugs and Medicines Policy of the World Health Organisation.
Degnan et al.2006[28]	UK	Randomized controlled trial	9 medical students in intervention	An online teaching module consisting of an interactive	OSCE station requiring administration of	The teaching module significantly improved the students' ability to calculate	Funded by the Association of Anaesthetists

			group; 35 in the control group.	tutorial of 12 multiple-choice questions and three case studies covering pharmacokinetics, adverse drug reactions and drug doses calculations.	lidocaine and adrenaline for a patient with laceration and anaphylaxis.	the correct volume of lidocaine (p=0.005) and adrenaline (0=0.0002).	of Great Britain and Ireland
Esmaily et al.2009[29]	Iran	Randomized controlled trial	58 GPs in intervention group; 54 GPs in control group	Education with an outcome-based approach utilizing active-learning principles.	Multiple choice and short answer questions, with two case scenarios and three 'irrational' prescriptions.	There was an overall improvement of 26 percentage units in the prescribing knowledge and skills of GPs in the intervention group. No such improvements were seen in the control group.	Additional funding from the National Public Health Management Centre in Tabriz and the Ministry of Health and Medical Education of Iran
Fender et al. 1999[30]	UK	Randomized controlled trial	54 GPs in intervention group; 46 GPs in control group	An educational package based on principles of "academic detailing".	The appropriate prescribing of tranexamic acid, non-steroidal anti-inflammatory drugs, and norethisterone.	A proportionately higher level of appropriate prescribing was found in the intervention group. An increase of 63% in the prescription of tranexamic acid, the most effective first line treatment for menorrhagia, was observed in the intervention group.	None declared
Gordon et al.	UK	Randomized	76 junior	An 1-2 hours e-	Total correct	A significant increase in	None

2011[42]		controlled trial	doctors in intervention group; 86 in control group.	learning course on paediatric prescribing	responses on each prescribing assessment. Drug selection, prescribing calculations for children, discussing therapies and sources of errors were assessed.	correct responses by the intervention group compared to the control group at both 4 and 12 weeks after the intervention. At 4 weeks: 79% vs 63% (P<0.0001) At 12 weeks: 79% vs 69% (P<0.0001)	declared
Hassan et al. 2000[31]	Yemen	Randomized controlled trial	56 medical students in intervention group; 44 students in control group	A prescribing course based on WHO's Guide to Good Prescribing, the Yemen Essential Drug List and Yemen Standard Treatment Guidelines	Written exam based on eight patient problems where a complete treatment plan form must be completed.	Students from the study group performed significantly better than those from control in all problems presented and also when compared with the results of the pre-test ($P < 0.05$).	None declared
Hux et al.1999[32]	Canada	Randomized controlled trial	135 GPs in intervention group; 116 GPs in control group.	Mailed packages of prescribing feedback and guidelines-based educational materials.	Median antibiotic cost and proportion of episodes of care in which a pre-specified first-line antibiotic was used first.	The median prescription cost remained constant in the feedback group but rose in the control group ($p < 0.002$). First-line drug use increased in the feedback group but decreased in the control group ($p < 0.01$).	Author receives salary support from the Institute for Clinical Evaluative Sciences in Ontario.
Kahan et al.2009[33]	Israel	Randomized controlled trial	32 physicians exposed to both interventions;	Interventions were in the form of a lecture at a conference and a	Outcome was the rate of adherence to the guidelines for appropriate	The letter intervention significantly influenced physicians' prescribing patterns. The lecture	Partially funded through a research grant

			130 physicians who only received personalized letter; 29 physicians who only attended the lecture; 107 in the control group.	letter with personalized feedback to improve physicians' rates of prescribing in the treatment of acute uncomplicated cystitis in adult women.	treatment using nitrofurantoin or second-line therapy of ofloxacin for three days.	intervention was only effective in the short run, indicating that the effect of this technique does not last unless reinforced.	from The Israel National Institute for Health Policy and Health Services Research and through an educational grant from Schering Plough Israel.
Midlöv at al. 2006[34]	Sweden	Randomized controlled trial	23 GPs in the intervention group; 31 GPs in the control group.	Educational outreach visits	Number of prescriptions of benzodiazepines (BDP) and antipsychotics to the elderly	One year after the educational outreach visits there was a significant decrease in prescribing of medium- and long-acting BDP and total BDP in the active group compared with the control group (P<0.05). For antipsychotics there were no significant differences between active and control group.	Funded by the Department of Primary Care Research and Development in the county of Skåne, Apoteket AB and the Faculty of Medicine, Lund University
Nsimba 2007[35]	Tanzania	Randomized controlled trial	20 pharmacists in intervention facilities; 20 in control facilities.	Posters, individual information and one-to-one training sessions.	Simulated clients assessed the drug seller/pharmacist's knowledge and prescribing choices. A short examination was also conducted	85% of simulated clients who went to the intervention facilities were sold the first line drug sulfadoxine/pyrimethamine (SP) compared to 55% at control facilities (p<0.01).	Funded by COSTECH-Tanzania

					to assess participants' knowledge of appropriate treatments for common childhood conditions.	The intervention group also performed significantly better on the knowledge exam ($p<0.01$).	
Ochoa 1996[36]	Cuba	Randomized controlled trial	4 groups of 10 physicians (A,B,C,D) with A receiving community education program and refresher training, B receiving refresher training, C receiving community education, D was the control group.	Refresher training based on teaching sessions and periodic advisory visits. Community education involved group discussions and distribution of educational materials.	Rate of over-prescription of antibiotics for mild acute respiratory infections (ARI) cases.	Following the interventions, antibiotic over-prescription rates declined by 26% and 63% in groups A and B, while increasing by 2% and 48% in groups C and D.	None declared
Odusanya & Oyediran 2004[37]	Lagos state, Nigeria	Randomized controlled trial	Number of participants not specified. Primary health care workers (no doctors) in Mushin were in the intervention	4-week training program on rational drug use.	Prescriptions were evaluated according to compliance to 'standing orders', which are a set of treatment modules. Drug use indicators were also compared.	At the 2-week evaluation, the intervention group achieved a significant reduction in the average number of medicines prescribed compared to the control group. There was also a significant increase in the percentage of patients	None declared

			group; health workers in Ikeja were in the control group.			rationally managed from 18% to 30% (p=0.0005) in the intervention group. Improvements were not sustained at the 3-month evaluation.	
Rothman et al. 2000[38]	South Africa	Randomized controlled trial	35 primary health care nurses in the intervention group; 31 in the control group.	A competency-based primary care drug therapy (PCDT) training program in the treatment of acute minor ailments.	Written examination with eight case studies including scenarios on acute gout, congestive heart failure, acute tonsillitis and infectious arthritis.	Post-test results of the intervention group indicated significant improvement towards correct diagnosis and management of the conditions (P<0.05)	Funded by Boehringer Ingelheim (Pty) Ltd (Self-Medication Division)
Sandilands et al.2010[18]	UK	Randomized controlled trial	50 medical students in the intervention group; 28 students in control group.	Focused doctor- and pharmacist-led practical prescribing teaching.	Written prescribing exam consisting of six scenario-based questions.	Teaching improved the assessment score of the intervention group: mean assessment 2 *vs.* 1, 70% *vs*. 62%, *P* = 0.007; allergy documentation: 98% *vs.* 74%, *P* = 0.0001; and confidence. However, 30% of prescriptions continued to include prescribing errors.	None declared
Scobie et al. 2003[39]	UK	Randomized controlled trial.	16 medical students in intervention group; 16 students in control group.	Practical structured teaching sessions led by a pharmacist.	Nine station OSCE exam covering topics such as anticoagulation, IV administration, discharge prescription and medication history.	The intervention group achieved higher scores in eight OSCE stations. Four of these were statistically significant (P <= 0.005).	None declared

Smeele et al. 1999[40]	The Netherlands	Randomized controlled trial	17 GPs in the intervention group; 17 GPs in control group	Four sessions (lasting 2 hours each) of interactive group education and peer review program aimed at implementing national guidelines.	Data on prescription of inhaled and anti-inflammatory medications were collected through self-recording by GPs and recording of repeat prescriptions for patients.	No significant difference was found in the pharmacological treatment between intervention and control groups (P>0.05).	None declared
Webbe et al.2007[41]	UK	Randomized controlled trial	13 pre-registration house officers (PRHOs)	A clinical teaching pharmacist program to improve prescribing skills	Number of prescribing errors.	A 37.5% reduction (P=0.14) in prescribing errors after pharmacist intervention	None declared
Akici et al. 2004[47]	Turkey	Non randomized comparative control	50 medical students (interns) in intervention group; 54 interns in control group; 53 GPs	Problem-based rational pharmacotherapy education (RPE) via the WHO/Groningen model.	A written examination with open and structured questions based on case scenarios of tonsillitis and mild-to-moderate essential hypertension patients.	Mean scores of the interns in the intervention group were higher than GPs, which were in turn higher than those of interns in the control group for all cases.	Funded by a grant from Marmara University Scientific Research Projects Commission.
Akram et al. 2012[56]	Malaysia	Non-randomized comparative control	18 final year dental students in the intervention group; 19 in the control	Didactic lecture on how to write a complete prescription	Three case studies including irreversible pulpitis associated with a child, a pregnant woman and	Significant improvement in the intervention group occurred compared to the control group in the following areas; date of issue, Rx symbol present,	Funded by the faculty of medicine, Universiti Kebangsaan Malaysia.

			group.		periapical pulpitis for an adult man. Assessed according to WHO's Guide to good prescribing.	medicine legible, direction to use medicines, refill instructions, prescriber's signature, prescriber's date and prescriber's registration	
Al Khaja et al. 2013[57]	Bahrain	Non-randomized comparative control	460 medical students over different stages of the degree were in the intervention group; 450 in the control group.	A 2 hour interactive session on prescription writing skills is presented followed by 5-6 case scenarios given as homework. Formative feedback on these cases was given to the students.	A written examination. Physician-related components of the prescription assessed legality of prescription writing while drug-related components relate to the rational and appropriate use of medicines.	Significantly higher scores were achieved by those that attended the interactive sessions compared to those that did not. 73.5% vs 59.5% (P<0.0001)	No funding received
Al Khaja et al.2005[48]	Bahrain	Non randomized comparative cohort	539 medical students	Problem-based learning curriculum incorporating a prescribing program.	A written examination. Physician-related components of the prescription assessed legality of prescription writing while drug-related components relate to the rational and appropriate use of medicines.	Rate of physician-related components by students (year 2 to 4) was 96.1 (CI 94.1-97.5). However, the rate of various drug-related components was 50.2 (CI 46.0-54.4). No significant difference in overall performance of Year 4 and Year 2 students (p=0.237). However appropriateness of drug-related components were significantly higher in Year 4 than Year 2 (p<0.05).	None declared
Celebi et al.2010[49]	Germany	Non randomized	18 medical students who	Internal medicine clerkship based on	A written test comprising of the	Students committed 69%±12% of all possible	None declared

		comparative control	had never completed an internal-medicine clerkship; 38 students who had completed 1-4 weeks of clerkship; 18 students who had completed >5 weeks of clerkship.	one general learning objective of "students are to be familiarized with caring for patients in an outpatient and inpatient setting".	completion of prescription charts for two standardized patient paper cases. These were marked using a checklist for common prescription errors.	prescription mistakes. There was no significant difference between the group without clerkships in internal medicine (G1) (71±9%), the group with one to four weeks (G2) (67±15%), and the group with more than five weeks of clerkships (G3) (71±10%), p=.76.	
Coombes et al. 2007[50]	Australia	Non randomized comparative control	99 medical students in intervention group; 134 in control group	Eight interactive problem-based tutorials covering topics such as antibiotics, anticoagulants, IV fluids, analgesics, oral hypoglycaemics and insulin.	A written examination consisting of short answer questions on ADR identification, anticoagulants and analgesics.	A significantly higher score was found in intervention students compared with controls; mean score in intervention group 29.46; control group 26.35 (P<0.05)	None declared
Franson et al.2009[51]	The Netherlands	Non randomized comparative cohort	181 medical students in baseline 2003 cohort, 285 students in 2004, 275 students in 2005, 264 students in	Students were taught to use a structured format called the Individualized Therapy Evaluation and Plan (ITEP) to communicate a therapeutic plan	Written examination involving two different therapeutic cases; a simple pediatric case and a complex geriatric case.	Students' scores improved significantly in the 3 years after the introduction of the ITEP in the curriculum. The average score of the 2006 cohort was 6.76 compared to 3.83 for the 2003 group (p<0.0001)	None declared

			2006.	including the writing of a prescription.			
Kozer et al. 2006[52]	Canada	Non randomized comparative control	13 trainees in intervention; 9 trainees in control	30 minute tutorial focusing on appropriate methods for prescribing medications followed by a written test.	Main outcome measure was the number of prescribing errors on medication charts completed after the tutorial.	No significant difference in errors was found between the intervention group (12.4%) and the control group (12.7%).	Funded by the Trainee's Start-up Fund, The Research Institution, The Hospital for Sick Children, Toronto Canada.
McCall et al. 2004[44]	Australia	Non randomized comparative control	14 GPs in intervention group; 14 in control group.	Completion of a Graduate Certificate in General Practice Psychiatry conducted primarily via distance education program.	A clinical audit assessed GPs' recognition, drug management, non-drug management of patients with depression and anxiety.	No effect on the intervention GPs prescribing habits (P>0.05).	None declared
Pandejpong et al.2009[53]	Thailand	Non randomized comparative control	38 continuity of care (CCC) participants; 52 non-CCC participants	Continuity of care (CCC) curriculum.	Medical chart audits were performed and scored with a 12-task checklist of cardiovascular risk management including appropriate prescribing.	There was a significant increase in ability to properly adjust antihypertensive medication and in the prescribing of aspirin as primary prevention for cardiovascular disease in the CCC group (p<0.05)	Funded by a Faculty of Medicines Siriraj Hospital Medical Education Research Grant, Mahidol University.
Richir et al.	The	Non	197 medical	A context-learning	A written exam	The mean score on the six	None

2008[54]	Netherlands	randomized comparative control	students in the intervention group; 33 students in control.	pharmacotherapy program with role-play sessions and OSCE.	involving the formulation of a treatment plan for two patients using the WHO six-step guide of rational prescribing.	steps of the World Health Organization (WHO) six-step plan for prescribing increased significantly for students who has received the pharmacotherapy study (P<0.001).	declared
Shaw et al.2003[45]	Australia	Non randomized comparative control	The number of junior doctors in intervention and control hospitals was not specified.	Academic detailing including the provision of a bookmark containing the requirements for addictive medicines.	Prescription error rates of addictive medicines were assessed. Errors were defined according to legal requirements for prescription of addictive medicines.	At the intervention hospital, there was a significant decrease in error rate (from 41% to 24%, P<0.0001).The control hospital did not show a significant change in error rate over the same study period (P=0.66).	Partially funded by the Postgraduate Medical Council of NSW.
Tamblyn et al.2005[55]	Canada	Non randomized comparative cohort	751 doctors from four graduation cohorts; 600 from before the intervention and 151 after the intervention.	A community oriented problem based learning curriculum.	Annual performance in diagnosis (difference in prescribing rates for specific diseases and relief of symptoms), and management (prescribing rate for contraindicated medicines) assessed using provincial health databases for the first 4-7 years of practice.	After the intervention, graduates showed a significant fourfold increase in disease specific prescribing rates compared with prescribing for symptom relief. No difference in rate of prescribing for contraindicated medicines was observed.	Funded by the Canadian Institutes of Health Research and Fonds de Recherche en Sante du Quebec
Volovitz et al.	Israel	Non	83 physicians	Asthma education	Changes in asthma	In all four patient groups, a	None

2003[46]		randomized comparative control	attended the education program. Four groups of patients were included. The study group had patients whose physicians attended the education program and completed two follow up physician visits. Three control groups of patients were also included.	program involving lectures on pathophysiology, asthma management and prevention. Physicians were also asked to invite patients for three visits to reinforce the principles highlighted in the education program.	medicine use was analyzed before and after the intervention. Data was derived from the central database of Maccabi, Israel.	smaller proportion of reliever medicines (SABA) and a greater proportion of controller medicines (ICS & LABA) were used in the follow up period compared to before the intervention. Patients in the study group were twice more likely to decrease their use of SABA than patients from the control group (p = 0.042).	declared
Wallace et al. 2011[58]	UK	Non-randomized comparative control	20 final year medical students in the intervention group; 11 in the control group	8 tutorials on prescribing in acute clinical scenarios using peer assisted learning	Accurate completion of a prescription chart	The intervention group significantly improved after the intervention; median score was 47 before; 66 after (P<0.01). No significant change occured in the control group (P=0.17)	None declared
Aghamirsalim et al. 2012[69]	Iran	Before and after study	72 orthopaedic surgeons	Formal 2 hour lectures once a week for 4 weeks and a 30 minute	Proportion of patients with fragility factures who received	Significantly more patients were appropriately prescribed calcium and vitamin D supplements on	None declared

				refresher course was offered at the 4th month. Also, simplified osteoporosis guidelines were distributed	appropriate treatment for osteoporosis.	discharge. 10% vs 91% (P<0.05) Significantly more patients were appropriately prescribed a bisphosphonate on discharge. 0.1% vs 73% (P<0.05)	
Bojalil et al. 1999[59]	Tlaxcala, Mexico	Before and after	72 private GPs; 44 public GPs	A training course based on in-service practice. Other materials included the official training manuals for the control of diarrhea and acute respiratory infection (ARI), training videos and wall charts.	Aspects of diarrhea and ARI treatment which were evaluated and scored using a checklist.	Private practitioners showed significant improvements in prescribing practices for children with diarrhea. For ARI management, decisions on antimicrobial therapy and symptomatic drug use improved for both groups but only reached statistical significance for public physicians.	Funded by the Mexican Social Security Institute.
Chopra et al. 2005[60]	Cape Town, South Africa	Before and after	21 nurse prescribers	WHO and UNICEF's Integrated Management of Childhood Illness (IMCI) implementation. Training used the WHO/UNICEF teaching and assessment modules.	A structured observation checklist of the case management of sick children including rational prescribing.	There were significant improvements in the appropriate prescribing of antibiotics, with a significant reduction of inappropriate antibiotic use (62% versus 84 %). However, there was no change in the treatment of anemia or the prescribing of vitamin A to sick children.	None declared
Davey et al. 2008[61]	UK	Before and after	The number of junior doctors	A pediatric junior doctor prescribing	Prescribing errors and preventable	The introduction of the prescribing tutorial	Author's research

			included in the study was not specified.	tutorial conducted by a pharmacist and a bedside prescribing guideline to encompass the most frequently prescribed medications utilized on the children's unit.	adverse drug events.	decreased prescribing errors by 46% (p=0.023). The introduction of a bedside prescribing guideline did not decrease prescribing errors.	position was funded by Airedale NHS Trust.
Elkharrat et al. 1998[62]	France	Before and after	27 doctors	Doctors were informed of the Drug Regulatory Agency (DRA) prescribing guidelines of NSAIDs. Group sessions were held, posters were displayed and pocket sized, 10-page manuals were distributed.	The rate of NSAID prescribing errors was analyzed.	Prescribing errors declined from 20% to 14% and when prescriptions were stratified by cause, the quality of prescribing increased significantly.	None declared
Guney et al.2009[64]	Turkey	Before and after study	101 medical students	Rational pharmacotherapy training based on the Groningen/WHO model.	Prescription audit and OSCE exam based on a simulated patient case with uncomplicated essential hypertension.	A significant improvement in prescription audit scores was observed after the training (p: 0.022).	None declared
Gall et al.	UK	Before and	212 GPs; 139	Training on the use	Changes in	Education significantly	Funded by

2001[63]		after study	community nurses (CNs)	of guidelines on prescribing supplements.	prescribing practice of supplements.	reduced total prescribing by 15% and reduced the levels of inappropriate prescribing from 77% to 59% due to an improvement in monitoring of patients prescribed supplements.	South Thames Health Authorities Clinical Audit Programme.
Leonard et al. 2006[65]	USA	Before and after study	The number of clinical staff (physicians, nurses, pharmacists) included in the study was not specified.	Educational patient safety initiatives using multiple interrelated educational and behavioral modification strategies.	Assessment of medication orders which were then used to calculate the absolute risk reduction from prescribing errors.	The absolute risk reduction achieved after the interventions was 38 per 100 orders written (*t*= 25.735; *P*=.001). This yielded an overall relative risk reduction from prescribing errors of 49% (*P*<.001).	Funded by the New York State Department of Health 2003 Patient Safety Award and by a donation from Lexi-Comp of Pediatric Lexi-Drugs limited licenses.
Minas et al. 2012[70]	Australia	Before and after study	GPs and health care prescribers in Emergency Departments and Sexual Health Clinics. Number included not specified	Treatment guidelines were distributed and informed through professional development sessions, letters and newsletters.	Proportion of patients receiving non-occupational post-exposure prophylaxis (nPEP) according to the relevant treatment guidelines.	Significantly more patients that received nPEP met the eligibility criteria as stated in the relevant treatment guidelines after the educational intervention. 61.2% vs 90% (P<0.001)	None declared
Otero 2008[66]	Argentina	Before and after study	Number of participants not specified.	Educational program developed by the Patient	Prevalence of medication errors detected in written	Prevalence of prescription errors was significantly lower in 2004 compared with 2002;	None declared

			Prescriptions for 95 patients were analysed in 2002 and for 92 patients in 2004.	Safety Committee of the Department of Pediatrics including the implementation of the "10 steps to reduce medication errors' checklist.	prescription orders during June 2002 (before intervention) and May 2004 (after intervention).	11.4% vs 7.3% (P<0.05)	
Taylor et al. 2012[67]	UK	Before and after study	242 junior doctors	1 hour interactive, case-based educational programme regarding inpatient diabetes care.	Number of insulin prescribing errors on medication charts observed after the tutorial.	Insulin prescription errors were significantly lower after the intervention; 15.4% vs 7.8% (P<0.05)	None declared
Zgheib et al. 2011[68]	Lebanon	Before and after study	127 final year medical students divided into 18 groups of 6-7 students	5 team-based learning (TBL) based on WHO's Guide to Good Prescribing. A lecture on the role of the pharmacist, Pharmacy & Therapeutics committees, formularies and hospital policies were also presented	Group formulary and prescription writing exercises occurred after each TBL session. Rationale for the selection of a drug and the format of the prescription was included in these assessments	Significant improvement in mean group scores for both formulary and prescription-writing exercises occurred over the 5 TBL sessions (P=0.002).	None declared

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COMPETING INTERESTS

None

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None.

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Appendix 1:

Search results from Medline database.

#	Searches	Results
1	exp prescriptions/ or exp drug prescriptions/	26232
2	prescription$.mp.	66835
3	prescribing.mp.	24972
4	prescriber$.mp.	3267
5	1 or 2 or 3 or 4	83643
6	exp Education/	608498
7	Curriculum.mp. or exp Curriculum/	71123
8	course$.mp.	438879
9	training.mp.	245044
10	intervention$.mp. or exp Intervention Studies/	523226
11	6 or 7 or 8 or 9 or 10	1598941
12	drug$.mp. or exp Pharmaceutical Preparations/	2412229
13	medication$.mp. or Medication Therapy Management/	773987
14	12 or 13	3028683
15	clinical competence.mp. or exp Clinical Competence/	63650
16	Competency.mp	20362
17	competency assessment.mp.	328
18	15 or 16 or 17	80028
19	5 and 11 and 14 and 18	875
20	limit 19 to (english language and humans)	796

Appendix 2:

Search results from Embase

No.	Query	Results
#1	prescription$ AND [embase]/lim	113844
#2	'drug'/exp AND prescription$ AND [embase]/lim	20608
#3	prescriber$ AND [embase]/lim	3249
#4	prescribing AND [embase]/lim	29192
#5	#1 OR #2 OR #3 OR #4	127141
#6	'education'/exp AND [embase]/lim	509851
#7	'curriculum'/exp AND [embase]/lim	18658
#8	course$ AND [embase]/lim	1797183
#9	'training'/exp AND [embase]/lim	58412
#10	intervention$ AND [embase]/lim	380160
#11	intervention AND studies AND [embase]/lim	70533
#12	#6 OR #7 OR #8 OR #9 OR #10 OR #11	2547830
#13	drug$ AND [embase]/lim	7121492
#14	pharmaceutical AND preparation$ AND [embase]/lim	75122
#15	'pharmaceutics'/exp AND [embase]/lim	750572
#16	medication$ AND [embase]/lim	156785
#17	medicines AND [embase]/lim	39772
#18	'medication'/exp AND 'therapy'/exp AND 'management'/exp AND [embase]/lim	54942
#19	#13 OR #14 OR #15 OR #16 OR #17 OR #18	7156695
#20	clinical AND 'competence'/exp AND [embase]/lim OR ‘competency’ AND [embase]/lim	25119
#21	competency AND assessment$ AND [embase]/lim	2560
#22	#20 OR #21	25119
#23	#5 AND #12 AND #19 AND #22	391
#24	#5 AND #12 AND #19 AND #22 AND 'human'/exp	300

Appendix 3:

Search results from IPA

No	Search terms	Results
1	prescription$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	18048
2	drug prescription$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	293
3	prescriber$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	2050
4	prescribing.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	10397
5	1 or 2 or 3 or 4	25682
6	education.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	23147
7	curriculum.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	4586
8	course$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	13277
9	training.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	6295
10	intervention$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	31795
11	intervention studies.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	72
12	6 or 7 or 8 or 9 or 10 or 11	61319
13	drug$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	252394
14	pharmaceutical preparation$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	1434
15	medication$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	44288
16	medication therapy management.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	292
17	medicines.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	5944
18	13 or 14 or 15 or 16 or 17	268439
19	clinical competence.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	23
20	competency.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	962
21	competency assessment$.mp. [mp=title, subject heading word, registry word, abstract, trade name/generic name]	150
22	19 or 20 or 21	979
23	5 and 12 and 18 and 22	52
24	limit 23 to (english language and human)	20

Appendix 4:

Search results from CINAHL

No	Search terms	Results
1	(MH "Drugs, Prescription") OR "prescription$"	24482
2	"prescriber$"	1531
3	"prescribing" OR (MH "Medication Prescribing (Iowa NIC)")	9429
4	S1 or S2 or S3	31704
5	(MH "Education+") OR "education"	499816
6	(MH "Curriculum+") OR "curriculum"	23807
7	"course$"	43304
8	"training"	78863
9	(MH "Intervention Trials") OR "intervention$"	150883
10	"intervention studies"	1384
11	S5 or S6 or S7 or S8 or S9 or S10	655263
12	(MH "Drugs+") OR "drug$"	354262
13	"pharmaceutical preparation$"	43
14	"medication$"	52649
	"medicines"	4450
15	(MH "Medication Managements (Iowa NIC) (Non-Cinahl)+") OR "medication therapy management"	102
16	S12 or S13 or S14 or S15 or S16	377287
17	(MH "Clinical Competence+") OR "clinical competence" OR (MH "Competency Assessment") OR "Competency"	25079
18	S4 and S11 and S16 and S17	200
19	Limit #18 - Published Date from: 1990-2011; English Language; Human	195

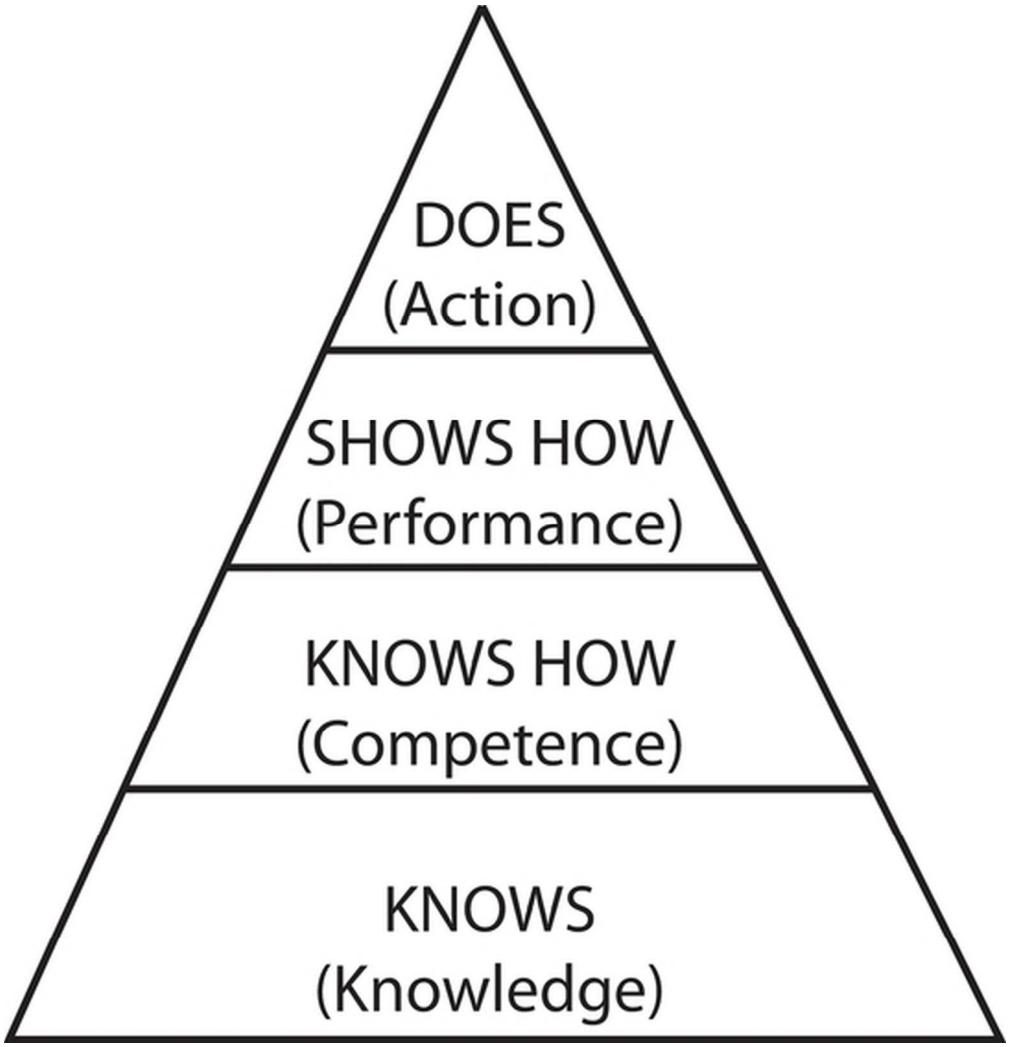

Figure 1: Miller's framework for clinical assessment
191x198mm (300 x 300 DPI)

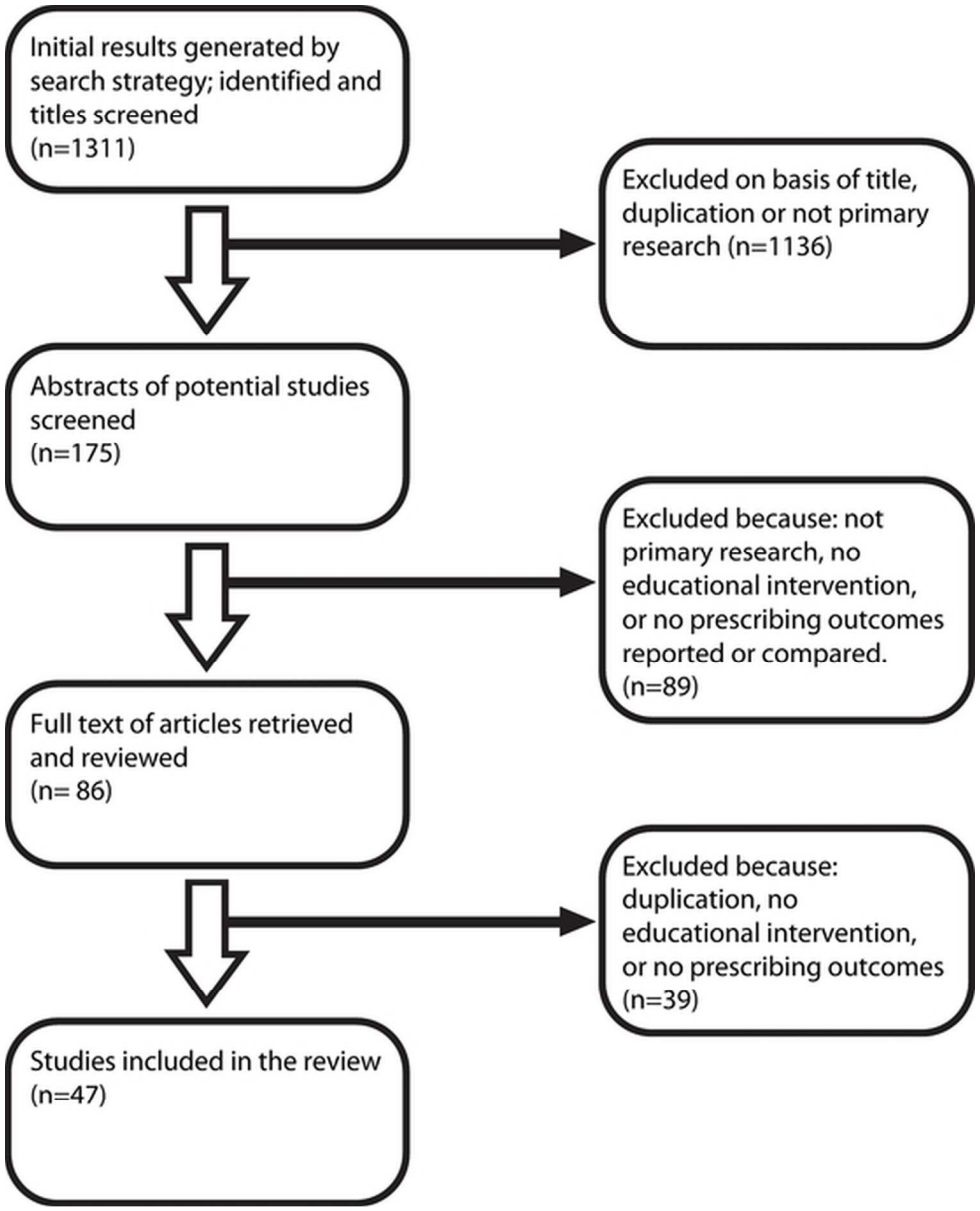

Figure 2: Flowchart of search strategy and study selection based on PRISMA guidelines
195x241mm (300 x 300 DPI)

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19	Limit #18 - Published Date from: 1990-2011; English Language; Human	195

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4-7
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	7
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	Appendices
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7-8
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	7
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Appendix
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	7 and figure 2
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	NA
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	NA
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	Table 1
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	8
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Figure 2 8
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 1 Page8-9
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Table 1 Page 9
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Table 1 Page8-12
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Table 1 Page8-12
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Table 1 Page8-12
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Table 1 Page8-12
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	15-16
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	13-16
FUNDING			

PRISMA 2009 Checklist

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	NA

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

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