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A systematic review of educational interventions to change behaviour of prescribers in hospital settings, with a particular emphasis on new prescribers

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AIMS
Prescribing is a complex task and a high risk area of clinical practice. Poor prescribing occurs across staff grades and settings but new prescribers are attributed much of the blame. New prescribers may not be confident or even competent to prescribe and probably have different support and development needs than their more experienced colleagues. Unfortunately, little is known about what interventions are effective in this group. Previous systematic reviews have not distinguished between different grades of staff, have been narrow in scope and are now out of date. Therefore, to inform the design of educational interventions to change prescribing behaviour, particularly that of new prescibers, we conducted a systematic review of existing hospital-based interventions.

METHODS
Embase, Medline, SIGLE, Cinahl and PsychINFO were searched for relevant studies published 1994–2010. Studies describing interventions to change the behaviour of prescribers in hospital settings were included, with an emphasis on new prescibers. The bibliographies of included papers were also searched for relevant studies. Interventions and effectiveness were classified using existing frameworks and the quality of studies was assessed using a validated instrument.

RESULTS
Sixty-four studies were included in the review. Only 13% of interventions specifically targeted new prescribers. Most interventions (72%) were deemed effective in changing behaviour but no particular type stood out as most effective.

CONCLUSION
Very few studies have tailored educational interventions to meet needs of new prescribers, or distinguished between new and experienced prescribers. Educational development and research will be required to improve this important aspect of early clinical practice.

Introduction

Prescribing is a complex, challenging task and a high risk area of clinical practice [1]. Prescribing errors are common, affecting 7% of medication orders, 2% of patient days and 50% of hospital admissions [2]. Studies have identified a range of factors underpinning poor prescribing at individual, environmental and organizational levels [3]. These include lack of training, low perceived task importance and lack of awareness of errors, as well as increasingly complex polypharmacy and patient factors, lack of standardization and particular care environments [4–6].

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There is evidence of poor prescribing across different grades of staff and in different settings [5] with new prescribers in particular being attributed a lot of the blame [5, 7]. Studies have found that new prescribers may not be confident or even competent when prescribing, both by their own assessment and that of their supervisors [8–10]. Many excellent initiatives have focused on improving prescribing knowledge and technical skills (e.g. Hospital Pharmacy Initiative [11]; Medical Schools Councils Safe Prescribing Working Group [12]). However improving prescribing knowledge and technical skills is not enough. Prescribing is a complex mix of knowledge, skills and behaviours and there is no simple relationship between them [13, 14]. The skills and experience of new prescribers must develop as they work within an environment where any positive gains may be negated by the numerous complex and overwhelming pressures that may influence prescribing behaviour.

The behaviour change literature is large and growing, supported by research funding to explore the theory and practice of behaviour change, and the development and evaluation of behaviour change interventions. The challenges inherent in studying behaviour change are widely recognized. Behaviour change not only involves individual capability, opportunity and motivation but the fact that it takes place in a complex healthcare system adds another layer of complexity to the equation [15]. There is a plethora of behaviour change theories and frameworks, and behaviour change interventions are equally diverse, leading to challenges of nomenclature [16]. A useful way of categorizing types of intervention is offered by Bero *et al*. [17] and this has been adopted in systematic reviews that aimed to determine educational strategies that were effective in changing physician performance and healthcare outcomes (but not necessarily prescribing behaviours) [18, 19]. Davis *et al*. [19] included only randomized controlled trials and found that commonly used educational approaches like didactic presentations had little impact, whereas reminders, patient-mediated interventions, outreach visits, opinion leaders and multifaceted activities were more effective. Bloom [18] reviewed systematic reviews to examine effectiveness of current CME tools and techniques in changing physician clinical practices and improving patient health outcomes and found that interactive techniques such as audit/feedback, academic detailing/outreach and reminders were more effective at changing physician care and patient outcomes than guidelines, opinion leaders, didactic presentations and printed information. Unfortunately, Bloom concluded that '*Even though the cost effective CME techniques have been proven, use of least effective ones predominates*'.

In order to inform the design of educational interventions that can change the behaviours of new prescribers, we conducted a systematic review of existing interventions. There is no similar study to our knowledge. The most similar review was conducted by Gill *et al*. [20] but it had a narrow methodological scope (only randomized controlled trials and non-equivalent group designs), did not distinguish between grades of prescriber and is now out of date (only including studies up until 1994). Our study will update this review by identifying educational interventions that aimed to change the behaviour of new prescribers in hospital settings using a deliberately inclusive approach to definitions of educational interventions and study design.

Methods

Search strategy

The databases used in the systematic review by Gill *et al*. [20] that are still in use were searched (Embase; Medline; SIGLE), in addition to Cinahl and PsychINFO. The searches were carried out on the 8 and 9 November 2010 and searched for relevant items published between 1994 and November 2010.

The databases were searched for the following free text keywords in a variety of combinations 'prescribing or drug administration or drug prescription or drug utilization or drug utilization or drug prescription' and 'medical education or continuing medical education or nursing education or dental education or clinical education' depending on the database. Subject headings relevant to each database were also used for example MeSH and Emtree. See Table 1 for details of the search used in Medline.

The bibliographies of included papers identified by our search of electronic databases were searched for relevant

Table 1

Medline search

1. 'Drug Utilization Review'/or Drug Prescriptions/or Drug Utilization/or drug utilization.mp.
2. prescription drugs.mp. or Drug Prescriptions/or Prescription Drugs/
3. medication errors.mp. or Medication Errors/
4. prescribing.tw.
5. (drug$ adj4 administ$).tw.
6. (drug$ adj4 prescri$).tw.
7. (drug$ adj4 utilisation).tw.
8. (drug$ adj4 utilization).tw.
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. medical education.mp. or Education, Medical/
11. continuing medical education.mp. or Education, Medical, Continuing/
12. nursing education.mp. or Education, Nursing/
13. dental education.mp. or Education, Dental/
14. Education, Professional/or Education, Medical/
15. Education, Medical/or clinical education.mp. [mp = title, original title, abstract, name of substance word, subject heading word, unique identifier]
16. Education, Medical/or Education, Medical, Graduate/or doctor training/or interprofessional education.mp.
17. 10 or 11 or 12 or 13 or 14 or 15 or 16
18. 9 and 17

items by NB & KM. Abstracts were sought for the papers that were considered to be potentially relevant. The inclusion criteria were then applied to these papers. In addition, the title, abstract or keywords needed to contain the word education to keep in line with our search strategy.

Inclusion criteria

For the purposes of this review, prescribing was defined as the act of determining what medication a patient should have and the correct dosage and duration of treatment [21].

The following inclusion criteria were adopted:

- Aspect of prescribing – all studies that focused on developing one or more aspects of prescribing as defined above. Studies focusing only on drug administration were not included.
- Study design – all study designs were included.
- Types of settings – all studies that were conducted in hospital settings. This was the setting we were most interested in as the purpose of the review was to inform the design of educational interventions that develop the behavioural aspects of prescribing in new prescribers, and the vast majority of new prescribers are based in hospital settings. Furthermore we felt that the interventions and reasons underpinning why they might work may be different between hospital and primary care.
- Types of participants – all studies that included doctors, nurses, dentists or other healthcare professionals that prescribe and are in the early stages of their careers i.e. qualified but <2 years post graduation. If the study participants involved all prescribers in a hospital setting (which would include new prescribers) then it was included.
- Types of intervention – interventions or resources that focus on changing or developing the behavioural aspects of prescribing.
- Outcome measures – all prescribing related outcome measures were accepted.
- Language – studies published in the English language.

Data collection and analysis

One review author (NB) assessed the potential relevance of all titles and abstracts identified from the electronic searches. As a reliability measure, the first 10% of the titles and abstracts were assessed independently and then compared by the two review authors (NB and KM). If a difference was found the issue was discussed. The remaining titles and abstracts (90%) were assessed independently by NB. If NB had any doubts about particular studies while assessing them they were resolved by discussion with KM. A categorization system was developed to categorize excluded papers (Figure 1).

Data extraction and quality appraisal

The papers of all eligible studies were obtained and read in full and data were extracted by each review author. Data were extracted independently using a standardized review form. Interventions were categorized using the same classification as the Gill *et al*. study [20] which was based on Bero *et al*. (see Table 2). Where possible the pre and post test scores were extracted but some studies failed to report these and in these cases the numerical or percentage change was reported instead. The effectiveness of interventions was categorized using a modified version of the classification system used in the Gill *et al*.[20] study (see Table 3). It was not possible to use an identical framework to Gill *et al*. because this relied on the statistical significance of change in the outcomes measured and some of our included studies did not conduct this type of analysis. Our modified approach is described in Table 3 and the categorization was applied independently by both NB and KM. Greater than 95% agreement was reached between KM and NB using this method. The few differences that were found were discussed and agreement was reached.

The quality of studies was appraised using the medical education research study quality instrument (MERSQI) (Table 4) [22]. This tool was the most appropriate for this review because the majority of interventions included in the study had an educational, conference or training element to the intervention. Furthermore the majority of studies were observational or experimental and the MERSQI was designed for these study designs. The six items on the MERSQI scale (study design, sampling, type of data, validity of evaluation instrument, data analysis and outcomes) were scored on a scale of 1 to 3 and summed to determine a total MERSQI score. The maximum score for each domain was 3, producing a maximum possible MERSQI score of 18 and potential range of 5 to 18. The total MERSQI score was calculated as the percentage of total achievable points (accounting for 'non applicable' responses) and then adjusted to a standard denominator of 18 to allow for comparison of scores across studies [22]. Both reviewers independently scored the papers using the MERSQI tool and consistent scores were found.

Results

Literature identified

The search identified 5966 potentially relevant articles and, after the exclusions were applied, 53 articles satisfied the inclusion criteria (Figure 1). Checking the references of the 53 included items identified 11 more relevant studies. The 64 studies included in the analysis are listed in Table 5.

Description of studies

Only 13% of interventions specifically focused on new prescribers. The majority of studies were conducted in the USA

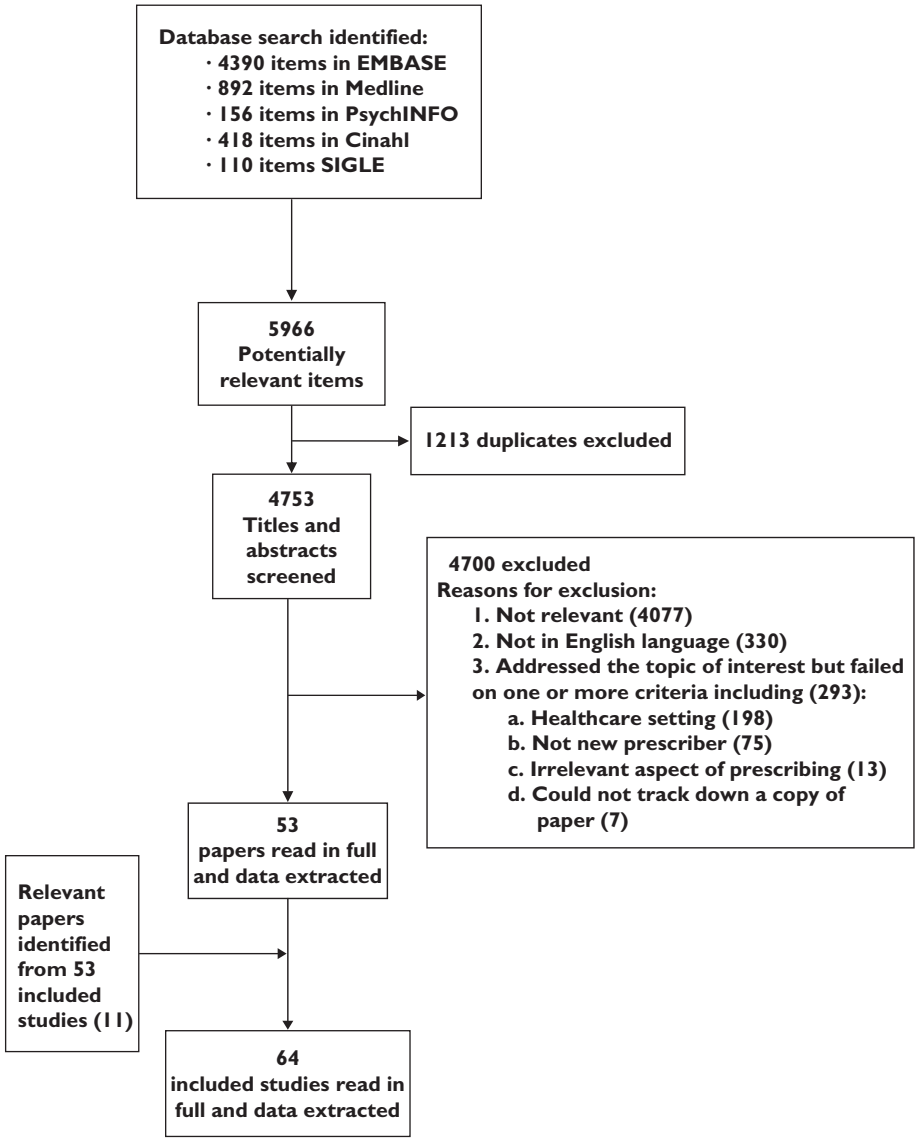

Figure 1
Flow chart of study selection

and Canada (39%) and Europe (33%) (Table 5). In terms of clinical area, 38% were conducted in internal medicine, 27% were carried out in all clinical areas and 13% were carried out in paediatrics. A variety of drug types were involved, with the largest group being antibiotics (32%).

The majority of studies were single group pre-test and post-test (72% n = 46), with the remainder being randomized control trials (9%, n = 6), non-randomized two group (11%, n = 7) and single group cross-sectional or single group post test only (8%, n = 5). Of the six RCTs, three were from the USA and three from the UK. In the USA, Frush *et al*. [56] demonstrated that a web-based education programme was able to reduce significantly the median dosage deviation summary (P = 0.0002) and median dosing time (P = 0.02). Metlay *et al*. [70] found that performance feedback, together with clinician and patient education, was able to reduce unnecessary antibiotic use for adults with acute respiratory tract infections in emergency departments by 10% in intervention sites (95% CI −18%, −2%); and Soloman *et al*. [80] found that academic detailing involving targeted one-on-one education was able to reduce the number of days that unnecessary broad spectrum antibiotics were administered by 37% (P < 0.001). In the UK, Thompson *et al*. [23, 24] found that a multifaceted intervention (involving workbooks, visits and reminder systems) was able to reduce prescribing of antipsychotic polypharmacy significantly (OR 0.43, 95% CI 0.21–0.90, P = 0.028) although the effect size was modest and Webbe *et al*. [25] reported a 37.5% reduction (P = 0.14) in prescribing errors compared with the baseline after implementing

Table 2

Classification and types of intervention [20]

Type of intervention	Number of interventions	%
Educational materials: **Distribution of published or printed recommendations for clinical care, including clinical practice guidelines, audiovisual materials and electronic publications**	44	28
Conferences and training: **Participation of health care providers in conferences, lectures, workshops or traineeships outside their practice settings. Practice settings are defined as on the ward or in their office. But could be taking place in a room on the hospital site.**	36	23
Audit and feedback: **Any summary of clinical performance of health care over a specified period, with or without recommendations for clinical action. The information can have been obtained from medical records, computerised databases or patients or by observation including a knowledge test.**	27	17
Outreach visits: **Use of a trained person who meets with providers in their practice settings to provide information. The information given may include feedback on the providers performance. Practice settings are defined as on the ward or in their office. But could be taking place in a room on the hospital site.**	15	10
Reminders: **Any intervention (manual or computerised) that prompts the health care provider to perform a clinical action. Examples include concurrent or inter-visit reminders to professionals about desired actions such as screening or other preventative services, enhanced laboratory reports or administrative support (e.g. follow-up appointment systems or stickers on charts, order forms or physician order entry systems).**	24	15
Marketing: **Use of personal interviewing, group discussion (focus groups) or a survey of targeted providers to identify barriers to change and the subsequent design of an intervention and refinement.**	9	6
Patient-mediated interventions: **Any intervention aimed at changing the performance of health care providers for which information was sought from or given directly to patients by others (e.g. direct mailings to patients, patient counselling delivered by others or clinical information collected directly from patients and given to the provider)**	1	1
Local opinion leader: **Use of providers explicitly nominated by their colleagues to be educationally influential**	1	1
Total	157	100

Table 3

Classification of effectiveness of intervention

Effectiveness of intervention	Symbol
Intervention was ineffective or demonstrated no intended effect	o
Intervention resulted in a change in the opposite direction	–
Intervention resulted in a positive change of 20–50% from baseline, in the majority of outcomes measured at the first post measure. If one outcome was classified as a + and one was a ++, the overall classification was a +.	+
Intervention resulted in a positive change of >50% from baseline in the majority of outcomes measured at the first post measure	++
Intervention resulted in a variable change of outcome measures and included both a positive (+ or ++) and a negative (-) or ineffective outcome (0).	v

a 5 week 'teaching pharmacist' intervention targeting newly qualified doctors compared with controls.

Nearly all of the interventions were multifaceted (89%) using a variety of combinations of interventions. Within the 64 eligible studies there were 157 separate interventions (Table 2) with educational materials (28%), conferences and training (23%) and audit and feedback (18%) being the most popular. A variety of outcome measures were used in the studies but the most common were the rates of prescribing, rates of appropriate/inappropriate prescribing, prescribing errors, adherence to dosage guidelines and cost savings. The majority of interventions (46/64, 72%) were classified as being effective: 31/64 (48%) received a + and 15/64 (23%) received a ++. Of the 15 most successful strategies (classified as ++), four provided specific feedback to prescribers through audit and feedback and six required active engagement with the process through reminders. However, five and six of the 10 studies classified as ineffective (classified as 0) also involved audit and feedback, and reminders, respectively. This means no firm conclusions can be drawn about the most effective types of educational intervention.

Quality of studies

Total MERSQI scores among the 64 studies ranged from 6 to 18 with a mean (SD) of 13.3 (1.7) (Table 6). Mean domain scores were highest for type of data (3.0), data analysis (2.8) and outcomes (2.0). Only 19.4% of studies were multi-institutional. All of the studies measured a behavioural outcome, two of which included patient outcomes.

Table 4
MERSQI scale

Domain		MERSQI item	Item score	Please put x in relevant box
Study design	1.	**Study design**		
		Single group cross-sectional or single group post test only	1	
		Single group pre test and post test	1.5	
		Nonrandomized, two group	2	
		Randomized controlled trial	3	
Sampling	2.	**Number of institutions studied**		
		1	0.5	
		2	1	
		>2	1.5	
	3.	**Response rate, %**		
		Not applicable		
		<50 or not reported	0.5	
		50–74	1	
		>-75	1.5	
Type of data	4.	**Type of data**		
		Assessment by study participant	1	
		Objective measurement	3	
Validity of evaluation instrument	5.	**Internal structure**		
		Not applicable		
		Not reported	0	
		Reported	1	
	6.	**Content**		
		Not applicable		
		Not reported	0	
		Reported	1	
	7.	**Relationships to other variables**		
		Not applicable		
		Not reported	0	
		Reported	1	
Data analysis	8.	**Appropriateness of analysis**		
		Data analysis inappropriate for study design or type of data	0	
		Data analysis appropriate for study design and type of data	1	
	9.	**Complexity of analysis**		
		Descriptive analysis only	1	
		Beyond descriptive analysis	2	
Outcomes	10.	**Outcomes**		
		Satisfaction, attitudes, perceptions, opinions, general facts	1	
		Knowledge, skills	1.5	
		Behaviours	2	
		Patient/health care outcome	3	
Total score				

Discussion

The aim of this systematic review was to identify educational interventions that could change prescribing behaviour, particularly in new prescribers. A previous systematic review explored this topic but had a narrow methodological scope, did not focus on new prescribers and is now out of date. We focused on the hospital setting since this is where the majority of new prescribers are based and since we felt the issues facing prescribers in primary and secondary care were likely to be different, and might therefore require different behaviour change strategies.

We identified a reasonable size literature relevant to our aim but only 19% of studies distinguished between different grades of prescriber and even fewer (13%) focused on new prescribers. A previous systematic review investigating the effectiveness of education interventions in general (not necessarily relating to prescribing) also found very few studies on junior doctors [3]. This limited focus on educational interventions for new prescribers may reflect the predominant use of before and after studies for the evaluation, with hospital pharmacy data or patient notes as the outcome measure, which can make it difficult to differentiate between grades of staff. However, new prescribers are a distinct group with different educational needs and different organizational pressures than more experienced prescribers, and we propose that behaviour change strategies should be tailored to their needs. Our conclusion is that educational interventions designed specifically for new prescribers are urgently required.

Table 5

Studies of effects of interventions on prescribing behaviour of new prescribers

		Context				Methods			Results		Study quality
	Study	Country of study	Clinical area	Type of new prescriber	Drug prescribed	**Study design A = Single group cross-sectional or single group post test only B = Single group pre test and post test C = Non-randomized, two group D = Randomized control trials**	Type of intervention(s)	Outcome measures	Pre and post measures	**Effectiveness of intervention (o) = ineffective (+) = moderately effective (++) = highly effective**	MERSQI score out of 18
1	Akter *et al.* (2009) [32]	Bangladesh	Paediatrics	All prescribing doctors	Antibiotics	C	Conferences and training	Appropriate antimicrobial use (1. pneumonia and 2. diarrhoea)	1. 66.7 to 83.1% (P = 0.0001) 2. 28.0 to 86.8% (P = 0.007)	+	15
2	Allenet *et al.* (2004) [33]	France	Medicine	All prescribers	Not specified	A	Outreach visits, audit and feedback	Acceptance of pharmacy residents' recommendations	47%	No baseline data – not possible to calculate	10
3	Angalakuditi *et al.* (2005) [34]	Australia	Paediatrics	All prescribing doctors	Antibiotics	C	Educational materials, audit and feedback	1. Appropriate antibiotic choice 2. Appropriate dosage	1. 48% to 85% (P < 0.001) 2. 0 to 58.2%	+	15
4	Apisarnthanarak *et al.* (2006) [35]	Thailand	All clinical areas	All prescribers	Antibiotics	B	Educational materials, conferences and training, reminders	1. Rate of prescription 2. Inappropriate use 3. Drug resistant infection 4. Cost savings	1. 640 to 400 prescriptions per 1000 admissions (P < 0.001) 2. 42 to 20% (P < 0.001) 3. 48 to 33.5% (P < 0.001) 4. $84 450 to $52 219 ($P$ < 0.001)	+	13
5	Apisarnthanarak *et al.* (2007) [36]	Thailand	Medicine and surgery	All prescribers	Antibiotics	B	Educational materials, reminders	Inappropriate antibiotic use	20 to 23% (P = 0.10)	o	13
6	Apisarnthanarak *et al.* (2010) [37]	Thailand	All clinical areas	Doctors, residents, interns and medical students	Antifungals	B	Educational materials, reminders	1. Rate of prescription 2. Rate of inappropriate drug use	1. 194 to 80 prescriptions per 1000 hospitalizations (P < 0.001) 2. 71 to 24% (P < 0.001)	++	13
7	Bantar *et al.* (2003) [38]	Argentina	All clinical areas	All prescribers	Antibiotics	B	Audit and feedback, reminders, marketing	Antibiotic use	431 to 276 (P < 0.0001)	+	13
8	Belgamwar *et al.* (2005) [39]	UK	Medicine	All prescribers	Parenteral Thiamine	B	Educational materials	Average number of monthly prescriptions	1. 79 to 208 (P < 0.001)	++	14
9	Bell (2002) [40]	USA	All clinical areas	All prescribers	Antibiotics	B	Educational materials, audit and feedback	1. Antibiotic use 2. Antibiotic claims 3. Cost	Not possible to report		13
10	Bergqvist *et al.* (2009) [41]	Sweden	Medicine	All prescribing nurses	All drugs	B	Conferences and training	1. No. additional drug related problems found 2. Drug-related readmissions 3. Inappropriate drug use	1. 86 2. 59% *vs.* 54% (P = 0.64) 3. 18 *vs.* 17 (P = 0.90)	o	14
11	Buckmaster *et al.* (2006) [42]	Australia	Emergency medicine	Junior doctors	Enoxaparin	C	Educational materials, outreach visits, reminders, marketing	Appropriate drug use	3.5 fold increase (P = 0.012)	++	15
12	Burmester *et al.* (2008) [43]	USA	Paediatrics	All prescribers	Not specified	B	Outreach visits, audit and feedback, reminders	1. Prescribing errors 2. Incomplete prescriptions 3. Intercepted errors	1. 16.8 to 8.4% (P < 0.001) 2. 15.3 to 3.6% (P < 0.001) 3. 1.3 to 1.1% (P = 0.06)	+	13
13	Buyle *et al.* (2010) [44]	Belgium	Medicine and Surgery	All prescribing doctors	Antibiotics	B	Educational materials, conferences and training, reminders	1. Ratio of i.v. *vs.* total consumption 2. Number of days beyond advised i.v. 3. Cost of longer i.v. treatment	1. 44.5 to 41.2% (P = 0.011) 2. 4.1 to 3.5 (P = 0.006) 3. €188 to €103 (P = 0.037)	o	13
14	Campino *et al.* (2009) [45]	Spain	Paediatrics	All prescribers	All drugs not related to enteral and parenteral nutrition and blood products	B	Conferences and training	1. Medication errors 2. % registers with one or more incident 3. Correct identification of prescribing physicians	1. 20.7 to 3% (P < 0.001) 2. 19.2 to 2.9% (P < 0.001) 3. 1.3 to 78.2%	++	13
15	Carson *et al.* (2009) [46]	Ireland	All clinical areas	All prescribing doctors and nurses	Opioids	B	Educational materials, conferences and training, audit and feedback, outreach visits	% drug errors involving opioids	12 to 14%	–	12

Table 5

Continued

	Study	Context: Country of study	Context: Clinical area	Context: Type of new prescriber	Context: Drug prescribed	Methods: **Study design A = Single group cross-sectional or single group post test only B = Single group pre test and post test C = Non-randomized, two group D = Randomized control trials**	Type of intervention(s)	Results: Outcome measures	Results: Pre and post measures	**Effectiveness of intervention (o) = ineffective (+) = moderately effective (++) = highly effective**	Study quality: MERSQI score out of 18
16	Caswell *et al.* (2006) [47]	UK	Medicine	Junior doctors and nurses	Hypnotics	B	Conferences and training, educational materials	1. Inpatient use of hypnotics 2. Discharge use of hypnotics	1. 48 to 27% ($P < 0.001$) 2. 20 to 10% ($P < 0.001$)	+	13
17	Chaturvedi *et al.* (2008) [48]	India	Psychiatry	Resident doctors	Not specified	B	Audit and feedback	Prescriptions meeting required standards	8 to 40%	++	12
18	Cohn *et al.* (2006) [49]	USA	Medicine	All prescribers	VTE prohpylaxis	B	Conferences and training, audit and feedback, reminders	1. Rate of prophylaxis 2. Rate of appropriate prophylaxis	1. 47 to 86% at 12m ($P < 0.01$) 2. 43 to 68% ($P < 0.01$)	+	13
19	Corfield *et al.* (2006) [50]	UK	Surgery	Nurses and junior doctors	Cardiac drugs	B	Educational materials, audit and feedback	1. Proportion of patients with drugs omitted 2. Proportion of patients with a drug omitted with the reason stated as 'nil by mouth'	1. 42 to 20% ($P = 0.023$) 2. 13.3 to 0% ($P = 0.014$)	++	13
20	Cote *et al.* (2008) [51]	USA	Medicine	All prescribing doctors	GI prophylaxis	A	Outreach visits, reminders	Use of gastroprotection	43 to 61% ($P < 0.001$)	+	11
21	De Melo *et al.* (2008) [52]	Brazil	Medicine	All prescribers	Antibiotics	B	Outreach visits, marketing	1. Inappropriate antibiotics 2. Cost savings	1. 69.2%, 56.3% 39.0% reduction for 3 different drugs (statistically significant) 2. 58.6%	++	13
22	De Miguel *et al.* (2000) [53]	Spain	All clinical areas	All prescribers	Albumin	B	Educational materials, conferences and training	1. Rate of inappropriate prescribing 2. Cost	1. 76 to 39% ($P < 0.00001$) 2. \$145 000 to \$102 950	+	13
23	Donovan *et al.* (2007) [54]	USA	Medicine	Cardiologists	Eptifibatide renal dosing	C	Conferences and training	Adherence rate to dosing recommendations	37 to 69% ($P < 0.001$)	+	15
24	Foulks *et al.* (1997) [55]	USA	Surgery	All prescribing doctors and nurses	Parenteral nutrition	B	Educational materials, reminders	1. Overfeeding of kilocalories 2. Cost of delivery of a patient-day of TPN	1. 125 to 110% ($P = 0.017$) 2. 8% decrease	o	14
25	Frush *et al.* (2006) [56]	USA	Paediatrics	Doctors, nurses and paramedics	Not specified	C	Conferences and training	1. Median dosing deviation summary 2. Median dosing time summary	1. 20.1 *vs.* 7.1% ($P = 0.0002$) 2. 15 *vs.* 18 s ($P = 0.02$)	+	17
26	Garbutt *et al.* (2008) [57]	USA	Medicine and surgery	Medical house staff and surgeons	Not specified	B	Conferences and training, audit reminders	Prescribing errors for 1. surgical and 2. medical house staff	1. 1.08 to 0.85 ($P < 0.001$) 2. 0.76 to 0.98 ($P < 0.001$)	v	13
27	Gommans *et al.* (2008) [58]	New Zealand	All clinical areas	Doctors and nurses	Not specified	B	Educational materials, conferences and training, audit and feedback, reminders	Documentation of medical charts including 1. Legibility 2. Patient identification 3. Documentation of date 4. Drug dose	1. 86 to 99% in 2001 2. 92 to 99% 3. 89% to 98% 4. 89% to 98%	o	12
28	Gordon *et al.* (2000) [59]	USA	All clinical areas	All prescribers	Meperidine	B	Educational materials, conferences, audit and feedback, reminders	Hospital admissions receiving meperidine	1. 12 to 11%	o	12
29	Gyssens *et al.* (1997) [60]	the Netherlands	Medicine	Medical students, residents, junior and senior staff members	Antibiotics	B	Conferences and training, educational materials, reminders, audit and feedback	1. Antimicrobial use 2. Unjustified use	1. 31 to 21% 2. 13 to 9%	+	13
30	Kaye *et al.* (2005) [61]	Australia	Emergency medicine	All prescribing doctors	Analgesics	C	Educational materials, audit and feedback, marketing	Decrease in pethidine use	62 *vs.* 56% ($P < 0.001$)	0	14
31	Khalili *et al.* (2010) [62]	Iran	Medicine	All prescribing doctors	Acid suppressive therapy	B	Educational materials, conferences and training, outreach visits	Patients receiving AST	80.9 to 47.1% ($P < 0.001$)	+	12

32	Kozer *et al.* (2006) [63]	Canada	Paediatrics	Interns and resident doctors	Not specified	A	Conferences and training, audit and feedback	Rate of prescribing errors	12.4% *vs.* 12.7%	o	11
33	Le Claire *et al.* (2006) [64]	USA	Medicine	Medical house staff officers, physicians and pharmacists	Antibiotics	B	Educational materials, reminders	Appropriate drug use	45 to 51% ($P = 0.35$)	o	13
34	Leonard *et al.* (2006) [65]	USA	Paediatrics	All prescribers	All drugs	B	Educational materials, audit and feedback	1. Absolute risk reduction 2. Relative risk reduction	1. 38 per 100 orders ($P < 0.001$) 2. 49% ($P < 0.001$)	+	13
35	Lewis *et al.* (2010) [66]	UK	All clinical areas	All prescribing doctors	Insulin	B	Conferences and training, audit and feedback	Number of incorrect abbreviations	37.5 to 15.5% ($P = 0.004$)	++	13
36	Lipsky *et al.* (1999) [67]	USA	All clinical areas	All prescribers	Antibiotics	B	Educational materials, outreach visits, marketing	Rate of inappropriate vancomycin	70 to 40% ($P = 0.003$)	+	13
37	Lutters *et al.* (2004) [68]	Switzerland	Medicine	All prescribers	Antibiotics	B	Educational materials, conferences and training sessions, outreach visits, audit and feedback	1. Mean number of all prescribed drugs 2. Proportion of patients exposed to antibiotic agents 3. Number of antibiotics administered 4. Cost of antibiotic use	1. 5.9 to 7.6% ($P < 0.001$) 2. 15% reduction ($P = 0.08$) 3. 26% reduction ($P < 0.001$) 4. 54% reduction	+	13
38	McQuillan *et al.* (1996) [69]	UK	Medicine	All prescribing doctors and nurses	Analgesics	B	Educational materials, conferences and training, local opinion leader	1. Appropriate prescribing 2. Inappropriate prescribing 3. Pain scores getting worse	1. 12.4 to 13% ($P = 0.86$) and 5.6 to 14.4% ($P = 0.008$) 2. 3.9 to 6.2% ($P = 0.36$) and 7.3 to 0.7% ($P = 0.004$) 3. 22 to 15%	v	15
39	Metlay *et al.* (2007) [70]	USA	Emergency medicine	All prescribers	Antibiotics	D	Conferences and training, educational materials, patient-mediated interventions, audit and feedback	Antibiotic prescriptions	Decreased by 10% in intervention sites; increased by 0.5% in control sites	o	18
40	O' Connor *et al.* (2005) [71]	USA	Medicine and surgery	Residents, nurse practitioners and physician assistants	Opioids	B	Educational materials, reminders	Doses of meperidine	37.5 to 0.22 ($P = 0.001$)	++	12
41	Peeters & Pinto (2009) [72]	USA	Medicine	All residents	Not specified	B	Conferences and training, marketing	Frequency of prescribing error	2.25 to 1.51% ($P < 0.001$)	+	12
42	Perez *et al.* (2003) [73]	Columbia	Medicine, surgery and paediatrics	All prescribers	Antibiotics	B	Educational materials, conferences and training, reminders	Incorrect prescriptions	47, 7.3 and 20% reduction	+	13
43	Record *et al.* (1995) [74]	USA	All clinical areas	House staff doctors	Antibiotics	A	Educational materials, reminders	Compliance with criteria	89%	No baseline data – not possible to calculate	10
44	Regal *et al.* (2010) [75]	USA	Medicine	Attending doctors, senior medical officers and interns	Acid suppressive medications	B	Conferences and training, outreach visits	Inappropriate prescribing	59 to 19% ($P < 0.001$)	++	13
45	Richards *et al.* (2003) [76]	Australia	All clinical areas	All prescribers	Antibiotics	B	Conference and training, Reminders	1. Rate of ceftriaxone use 2. Concordance with guidelines	1. 38.3 to 15.9 2. 25 to 51% ($P < 0.002$)	++	13
46	Riggio *et al.* (2009) [77]	USA	Medicine	All prescribing doctors and nurses	Heart failure drugs	B	Conferences and training, reminders	Compliance	37 to 93% ($P < 0.001$)	++	13
47	Roberts & Adams (2006) [78]	Australia	Medicine and Surgery	All prescribers	Warfarin	A	Educational materials, audit & feedback	Uptake of DVT prophylaxis by 1. medical patients and 2. surgical patients	1. 52.8 to 67% ($P = 0.004$) 2. 86.1 to 84.1% ($P = 0.7$)	v	13
48	Roth *et al.* (2001) [79]	USA	All clinical areas	All prescribing doctors, residents and physician extenders	Anticoagulants, histamine type 2 blockers and non-steroidal anti-inflammatory drugs	B	Educational materials, audit and feedback, reminders	% decrease in use of more costly drugs	32%, 50%, 28% decrease	+	13

Table 5

Continued

	Study	Context: Country of study	Clinical area	Type of new prescriber	Drug prescribed	Methods: Study design A = Single group cross-sectional or single group post test only B = Single group pre test and post test C = Non-randomized, two group D = Randomized control trials	Type of intervention(s)	Outcome measures	Results: Pre and post measures	Effectiveness of intervention (o) = ineffective (+) = moderately effective (++) = highly effective	Study quality: MERSQI score out of 18
49	Ruttiman *et al.* (2004) [80]	Switzerland	Medicine	All prescribers	Antibiotics	B	Educational materials, conferences and training sessions, outreach visits, audit and feedback	1. Total antibiotic consumption 2. I.v. antibiotic consumption 3. Cost of antibiotics	1. 36% decrease ($P < 0.001$) 2. 46% decrease ($P < 0.01$) 3. 53% decrease	+	13
50	Sarasin *et al.* (1999) [81]	Switzerland	Medicine	All prescribing doctors	β-adrenoceptor blockers	B	Educational materials, conferences and training, reminders	Prescription of β-adrenoceptor blockers at discharge	1. 38 to 63% ($P < 0.001$)	+	13
51	Seto *et al.* (1996) [82]	Hong Kong	All clinical areas	All prescribers	Antibiotics	B	Educational materials, conferences and training sessions, audit and feedback, marketing	1. Admissions prescribed i.v. sultamicillin or coamoxiclav 2. Inappropriate route	1. 38% reduction ($P < 0.001$) 2. 75% decrease ($P < 0.001$)	+	13
52	Shaw *et al.* (2003) [83]	Australia	All clinical areas	Junior doctors	Drugs of addiction	C	Educational materials, marketing	1. Rate of errors 2. Confidence of junior doctors in writing prescriptions	1. 41 to 24% ($P < 0.0001$) 2. 3.25 to 4.14 ($P = 0.03$)	+	15
53	Shah *et al.* (2003) [84]	USA	Paediatrics	Residents	Paediatric drugs	D	Educational materials, conferences and training,	Deviation from recommended dose range	25.4% decrease ($P < 0.001$)	+	15
54	Simpson *et al.* (2004) [85]	Scotland	Paediatrics	All prescribers	Paediatric drugs	B	Educational materials, outreach visits, audit and feedback	Monthly medication errors per 1000 days	24.1 to 5.1 ($P < 0.001$)	++	13
55	Solomon *et al.* (2001) [86]	USA	Medicine	Intern and resident doctors	Antibiotics	D	Educational materials, audit and feedback	Unnecessary drug use(days)	37% decrease ($P < 0.001$)	+	15
56	St. Pierre (2005) [87]	USA	Medicine	All prescribing doctors, nurse pharmacists and therapists	Deliriogenic drugs	B	Educational materials, conferences and training	% targeted medications showing a reduction in use	57%	v	12
57	Sterné *et al.* (1996) [88]	USA	All clinical areas	All prescribers	Ranitidine	B	Educational materials, outreach visits, reminders	1. Appropriate drug use 2. Appropriate dosage form 3. Cost savings	1. 74 to 96% ($P < 0.001$) 2. 87 to 94% ($P < 0.01$) 3. $1080 to $180	+	13
58	Thamlikitkul *et al.* (1998) [89]	Thailand	All clinical areas	Student doctors, residents and doctors	Antibiotics	B	Educational materials, conferences and training, audit and feedback	1. Antibiotic use 2. Cost of antibiotics	1. 22% decrease ($P < 0.001$) 2. 20% decrease ($P < 0.001$)	+	13
59	Thompson *et al.* (2008) [23]	UK	Psychiatry	All prescribers	Antipsychotics	D	Educational materials, outreach visits, reminders	Polypharmacy prescribing rates	OR 0.43 ($P = 0.028$)	++	17
60	Thompson *et al.* (2010) [24]	UK	Psychiatry	All prescribing doctors and nurses	Antipsychotic drugs	D	Educational materials	Reduction in antipsychotic polypharmacy prescribing	OR 0.43 ($P = 0.03$)	++	17
61	Ungvari *et al.* (1997) [90]	Hong Kong	Psychiatry	All prescribers	Psychotropic drugs	B	Educational materials, conferences and training, audit and feedback	Use of multiple APS simultaneously	54.3 to 34.2%	+	13
62	Van Hees *et al.* (2008) [91]	the Netherlands	Medicine and surgery	All prescribers	Antibiotics	B	Conferences and training, marketing	1. Quantity of prescriptions per 1000 admissions 2. Relevant microbiological investigation	1. 81 to 32 2. 53.6 to 75.7 ($P = 0.01$)	+	13
63	Webbe *et al.* (2007) [25]	UK	Emergency medicine and medicine	Junior doctors	Not specified	D	Educational materials, conferences and training, outreach visits, audit and feedback	Rate of prescribing errors	37.5% reduction ($P = 0.14$)	+	15
64	Zamin *et al.* (1997) [92]	Canada	Medicine	Residents, interns, medical students and pharmacists	Antibiotics	B	Educational materials, conferences and training sessions	Inappropriate prescribing	41 to 26% ($P < 0.001$)	+	12

v, variable.

Table 6

Scores of included studies on applicable MERSQI domains

MERSQI domains	Total achievable score	Mean score	% Mean score	SD
Study design	3	1.7	57%	0.5
Sampling	1.5	0.7	47%	0.4
Type of data	3	3.0	100%	0.2
Data analysis	3	2.8	93%	0.4
Outcomes	3	2.0	66%	0.2
Total Score	13.5*	9.8	73%	1.7

*MERSQI scores in Table 5 were calculated as the percentage of total achievable points (accounting for 'non-applicable' responses) and then adjusted to a standard denominator of 18.

The educational interventions reported in the included studies were varied and used mainly in various combinations. Only 11% of our studies reported single interventions compared with 67% in the Gill *et al*. study [20]. This shows a marked temporal shift from single to multifaceted interventions. While our study did not provide reliable evidence that multifaceted interventions were more effective, other studies have indicated that this is the case [26, 27]. Furthermore there were only six RCTs included in our study, compared with 64 in the Gill *et al*. review [20]. We believe this represents a real decrease in the number of RCTs performed. The findings also showed that 72% of interventions were deemed effective in changing prescribing behaviour in the intended direction but, similar to the Gill *et al*. study [20], no clear differences in the effectiveness of particular types or combinations of interventions could be deciphered. This contrasts with the Davis *et al*. [19], Bloom [18] and Grindod *et al*. [26] studies which found particular types of interventions, like audit and feedback, reminders and outreach, were consistently effective (although none of the studies contained information on the sustainability of effect of these interventions). The inconsistencies in findings probably relates to the fact that prescribing behaviour is complex and therefore, by definition, unpredictable: '*any cogent interpretation of the results of these studies requires a disentangling of the variation in the characteristics of the targeted professionals, the targeted behaviours and the study designs*' [28]. Our conclusion is that a successful strategy in one setting will not necessarily be successful in a different setting or context.

The strength of the research includes the considerable efforts that went into locating relevant studies and the systematic approach taken to summarizing the studies found. A limitation of the research is the subjective nature of the direction and magnitude of the effect scores. Another is the MERSQI scale, which was helpful for assessing the quality of studies, but like most quality assessment tools had some limitations. The perfect score of 3.0 for type of data for all studies reflects the limited applicability of the scale to prescribing interventions. Other limitations were the reliance on pre–post test designs which can be confounded by improvement of prescriber with time and clinical experience, the possible absence of blinding in studies with risk of observer bias, selective outcome reporting with a tendency to report favourable outcome measures and publication bias [29], particularly given that the majority of the interventions were effective. One wonders whether the authors would have sought to publish them if they had not had the desired effect.

Despite these limitations, our research was successful in identifying educational interventions that were effective in changing prescribing behaviour. However, despite including all types of study design, there was very little that contributed to the picture of why or how particular behaviour change strategies produced their effect and this is an important next step. Different types of literature review may be helpful [30]. Traditional systematic reviews can answer questions about the effectiveness of interventions but provide limited insight as to why an intervention worked or did not work when applied in different contexts or circumstances, deployed by different stakeholders or used for different purposes [30]. A newer approach called realist review is designed to work with complex social interventions or programmes and provides an explanatory analysis aimed at discerning what works, for whom, in what circumstances and in what respects. Mixed methods study designs, particularly nested, qualitative process evaluations, are also required.

In summary, this study has identified an urgent need to create educational interventions that support the development of desirable behaviours in junior doctors undertaking new prescribing roles. It has also highlighted that interventions that work in one setting will not necessarily work in another, which has implications for clinical educators and for researchers. Future research needs to enhance our understanding of what underpins observed behaviour changes [31], for example, by including a qualitative process evaluation within quantitative study designs. None of the studies we identified did this. Finally we have identified the need for another type of literature review, a realist review of 'what works, for whom and in what circumstances' in changing prescribing behaviour. We believe a systematic programme of educational intervention development and evaluative research in this area could significantly reduce the morbidity and mortality resulting from prescribing errors.

Competing Interests

There are no competing interests to declare.

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