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REVIEW ARTICLE

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Do educational interventions improve prescribing skills of medical students compared to no additional learning? A systematic review

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ABSTRACT

Research suggests that medical students are not confident and may be ill-prepared to prescribe competently. Therefore, changes to standard education may be required to fortify medical student prescribing skills, confidence, and competence. However, specific education to write a safe and legal prescription is generally lacking. Furthermore, the term prescribe and the skill thereof is not clearly defined. This review compares additional education for medical students to no identified additional education or another educational modality on the skill of prescription writing. Secondary aims include review of education modalities, prescribing skill assessments, educator professional background, and timing of education within the medical curriculum. This systematic review was conducted and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses. Databases searched included: CINAHL, Cochrane Library, EMBASE, Emcare (Ovid), MEDLINE (Ovid), PubMed and Scopus. Search terms included: medical education, medical undergraduate, medical student, medical school, and prescriptions. The search was conducted in February 2023, and quantitative outcomes were reported. Of the 5197 citations identified, 12 met the inclusion criteria. Eleven studies reported significant improvements in prescribing skills of medical students after additional educational intervention(s). Various educational modalities were implemented, including case-based teaching (n=3), patient-based teaching (n=1), tutorial-based teaching (n=2), didactic teaching (n=1), and mixed methods (n=6). There were no commonalities in the professional background of the educator; however, five studies used faculty members. There was no consensus on the best assessment type and time to implement prescription writing education during medical training. There are a range of interventions to educate and assess prescribing competencies of medical students. Despite heterogenous study designs, there is evidence of the superiority of additional prescription writing education versus no identified additional education to develop prescription writing skills. The introduction of formal teaching and standardised assessment of prescribing skills for medical students is recommended.

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Introduction

The Australian National Safety and Quality Health Service – Standard Four (medication safety) describes the medication management pathway as prescribing, dispensing, administering, and monitoring the use of medicines [1]. This pathway defines prescribing as the combination of clinical decision-making, supply, and monitoring of medications to treat. Past research has focussed on clinical decision-making when investigating prescribing in the medication management pathway. However, there remains a need for education on the legal and safety requirements of prescribing.

Medications are the most common health intervention worldwide, making prescribing a necessary skill for all medical doctors [1–3]. Writing the prescription is one point of the medication management pathway where errors may give rise to complications [1], such as incomplete prescriptions leading to medication misadventure. Inadequate training may lead to prescribing errors, causing wrong information to be provided to patients [4]. Poor prescribing skills may result in suboptimal or unsafe treatment, prolongation of treatment and/or recovery and possible increased cost to the health system [5,6]. Between 2% – 3% of Australian hospital admissions are medication related [7] and globally cost an estimated $US42 billion per annum [8]. The United Kingdom (UK) General Medical Council found junior doctors, who have the least experience, write the highest proportion of prescriptions in hospital settings [4], accounting for 8.9% of prescribing errors [4]. One approach to overcoming medication-related errors is to focus on prescribing. Despite medical students assumably receiving prescribing education, errors

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are still evident as junior doctors [5]. Therefore, this review will focus on one concept of prescribing – the skill to write a medication prescription that complies with all legal and safety requirements distinct from the clinical decision-making process.

Prescribing for this review is defined as writing a legal and safe prescription including all drug-, patient-, and prescriber-related components adhering to local guidelines for a pharmacist to dispense the medication(s) legally. A prescription must be legible to convey a safe and clear order for the patient and other health professionals. This review is predicated on the argument that the skill of prescription writing, as defined here, is not taught as a separate component. Rather, the skill to prescribe is assumably taught together with clinical decision-making. However, the distinction should be made between the two components of prescribing education to ensure compliance with local laws and safe medication management. Teaching technical prescribing skills to medical students would improve the legal, safety and accuracy aspects of prescriptions written by junior prescribers.

Medications must be prescribed effectively, appropriately, and economically by all newly registered doctors as stipulated by the UK General Medical Council 'Outcomes for Graduates 2018' [9]. Junior doctors have acknowledged they do not always have the necessary skills to write a prescription and often feel underprepared on their first day of practice [10–14]. International and national standards regarding prescribing education to medical students are vague and unclear [5], contributing to this reported relative under-preparedness of junior doctors. International and Australian state/territory variations in the legal requirements of prescriptions hinders the ability to target specific education on the legal skill of prescribing.

Over 25 years ago, the World Health Organisation (WHO) published the Guide to Good Prescribing (GGP), which is widely used in medical education [5]. Since then, further studies have been conducted to inform developments of this guide [15–17]. Yet prescribing education and assessment has not transitioned to a compulsory component of the medical curriculum in many countries. Whilst the GGP offers a well-known 6-step process to prescribing, there still needs to be more emphasis placed on educating students and standardised teaching and assessable requirements in medical schools. Subsequently, the GGP is a guide offered to medical schools and not a compulsory component that must be used to teach and learn the skill of prescribing as part of the curriculum.

The UK Medical Schools Council Assessment and the British Pharmacological Society developed the Prescribing Safety Assessment (PSA) in 2016. The PSA was developed to teach and assess medical student pharmacological therapies to reduce the contribution of knowledge deficits relating to prescribing errors before graduation [18]. The Prescribing Skills Assessment was established in 2017 as the international version, assessing clinical pharmacology, therapeutics and prescribing. Both tools have an educational focus on the clinical and some safety aspects to prescribing, neglecting the addition of the legal components to safe prescribing, which may be generalisable. The Prescribing Skills Assessment remains non-mandatory in most medical schools and registering bodies.

Previous reviews have examined medical students' and clinicians' inability to prescribe competently, stating they are neither prepared nor confident [19–23]. In 2018, a systematic review of observational studies to determine if final-year medical students have sufficient prescribing competencies [21] reported primarily on studies that focused on therapeutic choices rather than prescribing competency. They concluded that students have insufficient prescribing competencies, recommending changes to clinical pharmacology and therapeutics (clinical) education [21]. The Brinkman et al. review assessed prescribing competencies observationally and did not analyse interventional studies that impact the skills required to write a legal and safe prescription [21]. Competence encompasses the knowledge, behaviours, attitudes, and skills to write a prescription. Past reviews did not explore the learnt and applied technical skill of prescription writing. Some of these papers reviewed the type of educational interventions to improve prescribing skills or competencies. A review in 2009 of educational interventions to improve medical student prescribing [23] found little evidence to support standardised teaching or longitudinal knowledge retention, with most studies conducted on small cohorts [23]. Kamarudin et al. reviewed the type of educational interventions that improve prescribing competencies in 2013 [20]. This review found the range of heterogeneous study designs and outcome measures limited the validity and ability to generalise conclusions [20]. Omer et al. performed a rapid review in 2020 [19] but the skill of prescribing was not well defined. Omer et al. concluded there was a lack of innovative educational interventions. These previous reviews fail to draw conclusions on the type of educational interventions that improve medical students' ability to write a legally compliant and safe prescription, distinct from clinical pharmacology and therapeutic decision-making. Given the shortcomings of previous reviews, a targeted review of educational interventions for medical students to improve prescribing as a skill is required.

This systematic literature review will compare additional prescription writing education versus no identified additional education or another educational modality to improve prescribing skills of medical students. Secondary aims will review the mode of education delivery, how medical students' prescribing skills are assessed, the professional background of the educator, and the most appropriate time to implement education.

Methods

Search strategy

Our research question was built on the PICO model; medical students (population) undertaking any educational intervention (intervention), compared to no identified additional education or another educational modality (control), to determine if prescribing skills improve (outcome). This systematic review was conducted and reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (see Figure 1).

Two authors (SM and SP) agreed on the search terms, where SM performed the initial search in each data base. Search terms included variations of *medical education OR, medical undergraduate OR, medical student OR, medical school, AND prescriptions* (see appendix 1). A synonym search strategy allowed cross-referencing with various subject headings and key words in the different search engines to ensure sensitivity and specificity in accessing relevant studies. Pilot searches assisted in refining the search strategy. The online databases searched in February 2023 were CINAHL, Cochrane Library, EMBASE, Emcare (Ovid), MEDLINE (Ovid), PubMed and Scopus. Additional backward and forward citation searching was conducted. No limits were placed on the year of publication or language. SM and SP independently reviewed titles/abstracts and full-text studies, and consensus was reached on the final studies for review based on the inclusion and exclusion criteria.

Inclusion and exclusion criteria

The population of the studies reviewed included medical students. Students could be in any year level of medical school. Studies with interns, doctors or non-medical prescribers as the sole participants were excluded. The study population must have partaken in an educational intervention, but not limited to one type of education modality. The outcome measure was any assessment criteria reviewing a written prescription or medication order and prescribing skills, as a score and/or errors. Prescribing skills were defined as writing all patient-, prescriber- and medication-related components with the added safety check (as noted in step four of the GGP [5]. The study must have included (in part) quantitative data on at least one of the outcome measures. Studies assessing students' clinical knowledge or reasoning, rationalisation of medications, clinical decision-making, and confidence to prescribe without analysing the skill of prescribing were excluded. Studies not including original research (e.g., letters, opinion

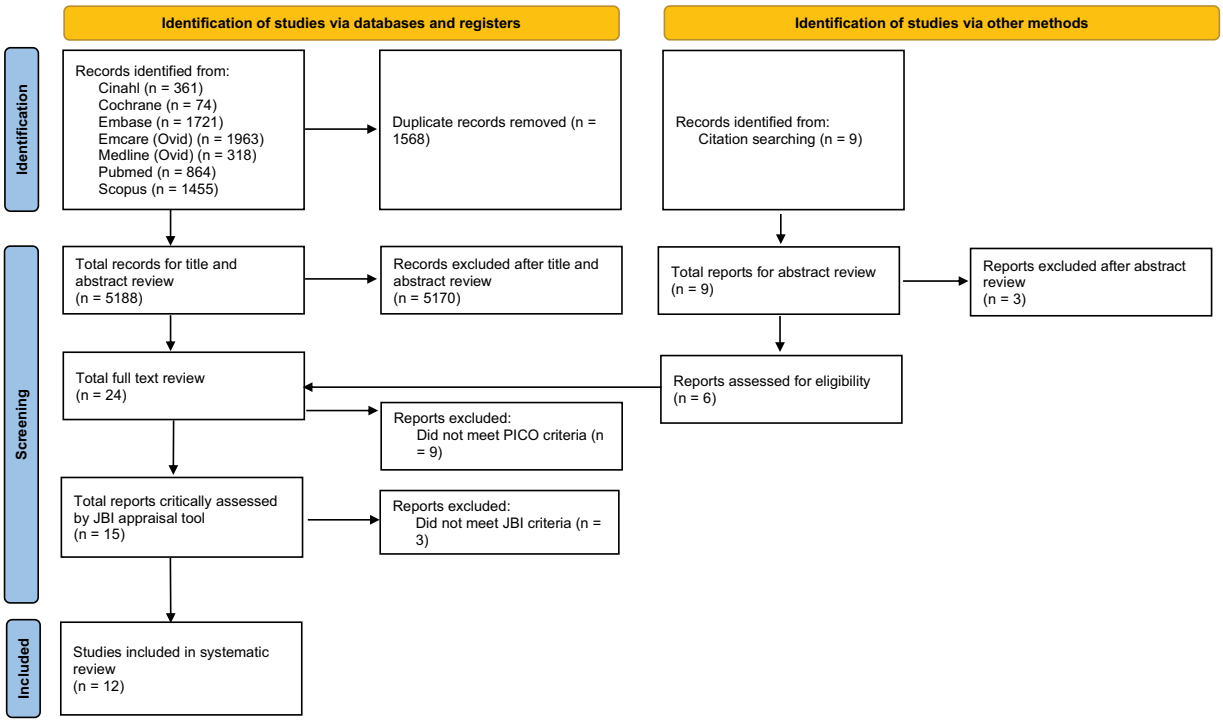

Figure 1. PRISMA flow diagram showing the search process [24].

pieces, reviews) were excluded. The Joanna Briggs Institute (JBI) critical appraisal tools for Randomised Control Trials (RCT) and Quasi-Experimental studies (QES) were used in the inclusion and exclusion process to assess quality (see Quality Assessment below).

Data extraction and quality assessment

SM and SP retrieved and assessed eligible studies using the appropriate JBI tool. Differences in quality appraisal were discussed, and agreement was reached by the same two reviewers. Included studies were those that met the appropriate JBI critical appraisal score. Data from the final studies were extracted and presented by SM and reviewed by all authors.

This review investigated if additional educational interventions improve prescribing skills of medical students. Supplementary outcomes included the effectiveness of the education intervention, modality of intervention and assessment of effect, profession of the educator, and timing of the intervention in relation to the medical school year. These outcomes formed the basis of thematic analysis of the results presented.

Results

Search results and study designs

Figure 1 illustrates the results of our search strategy. An initial search after duplicate removal identified 5188 studies across seven databases, with an additional nine studies sourced through citation searching. After title and abstract screening, 24 studies met the inclusion criteria for full review. Nine studies were excluded as they did not meet the PICO criteria: four did not implement an educational intervention, one reviewed their current curriculum, and four presented no data on prescribing as a skill or other assessable factors (e.g., presented data on confidence or clinical knowledge). Three of the 15 studies reviewed using the appropriate JBI appraisal tool were excluded for not meeting the quality score as they presented unclear results. Twelve studies were included for final data extraction. Of the 12 studies, three were RCTs and nine were QES, summarised in Tables 1 and 2.

Study quality

The Joanna Briggs Institute (JBI) RCT and QES critical appraisal tools were used to assess the quality of each study. RCT studies (Table 1) and QES (Table 2) could receive a total score of 13 or 9, respectively. In line with the JBI critical appraisal tools, only high-quality studies were included if they received a minimum score of 6 for RCTs and 4 for QES and met the inclusion criteria. Three RCT studies and nine QES designs met this quality criteria. The average quality score for all studies (RCT and QES) was seven. Raghu et al. [31] stated that their study design was a cross-sectional study. On further review by SM, SP and TP, it was noted to be a pre-post study and included as a QES and assessed as per the appropriate JBI tool.

Effectiveness of prescription writing education on prescribing skills of medical students compared to no additional or another education

Most of the included studies showed positive results for improved prescribing skills of medical student's post-educational interventions. 11 studies reported statistically significant improvements in prescription writing outcomes of the intervention group or from pre to post-test [3,6,10,12,25,26,29–33].

Modality of educational intervention

The modalities of the education interventions were case-based, patient-based, tutorial-based, didactic, and mixed education.

Please note: some categories of prescriptions (inpatient-, outpatient-, discharge-prescription) have not been identified due to lack of clarity within the studies.

Case-based teaching

Three studies implemented case-based teaching (CBT) [3,12,32]. Various research designs and methods were used to evaluate the outcomes of CBT, making it difficult to compare the effects.

Nayak et al. [3] used a pre-post-test design to measure the outcome of education effect using the WHO GGP via case scenarios. An objective structured practical examination (OSPE) assessed students writing a prescription and critically appraising other scripts.

Two studies implemented a post-test design, but with differences in their technique. Thenrajan and Murugan [32] assessed prescribing skills using written prescriptions, whereas Al Khaja et al. [12] assessed prescribing skills using an OSPE. Both used a point scoring system based off Lofholm and Katzung [27].

Two of these studies showed statistically significant improvements in prescribing scores using CBT [3,12].

Patient-based teaching

Thenrajan and Murugan [32] compared CBT to patient-based teaching (PBT). Both cohorts received a teaching intervention without comparison to a control that is without teaching (post-test

Table 1. Study characteristics and quality scoring of randomised controlled trials (NOTE: this table only presents the results specific to prescribing skills reflected in each study).

Author	Year	Location	Study Design	Population	Intervention	Assessment	Prescribing Outcome measure	Results	Critical Appraisal (JBI score/13)
Mokrzecki et al. [25]	2021	Australia	RCT Pre-post study	Final-year (3rd term) medical students; TG (*N*=10), and NTG (*N*=14)	Pharmacist-led 1.5-hour structured education session using CBL and hands-on experience. NTG had no additional education	*Marking scheme agreed between pharmacy staff. Prescription writing skills on all patient, prescriber, drug, legal and safety-related components on four prescription types (general, S4, S8, and mixed)	Two levels of analyses: number of non-clinical errors on each prescription type, and the overall pass or fail of the entire case	Overall prescribing score pre- to post-test: TG group ↑ ($P<0.004$), NTG ↓ ($P<0.012$) More cases passed pre- to post-test comparing TG and NTG ($p < 0.001$)	8
Sandilands et al. [10]	2010	UK	Randomised control trial, pre-post study	Final-year medical students (general medicine rotation); Intervention *N*=50, Control *N*=28	Eight-week focused doctor- and pharmacist-led prescribing teaching program. Control group had no additional education	*Marking scheme agreed between pharmacy and medical staff. Written prescriptions for six scenario-based questions on topics encountered by foundation year-1 doctors	Prescribing assessment score (appropriate drug choice and accuracy of prescribing) and errors per prescription (dose, route, transcription, and typographical – signature, date, time, and abbreviations)	Mean score ↑ post-test, intervention vs. control (70% vs. 62% respectively, $p = 0.007$) Intervention group mean score pre- to post-test ↑ ($p<0.0001$) and total prescribing errors ↓ (707 to 608)	7
Scobie et al. [26]	2003	UK	Randomised controlled trial, post-test	Final-year, final semester medical students from 2 universities; Intervention *N*=16, Control *N*=16	Five practical teaching stations covering 7 skills facilitated by a pharmacist who provided feedback. Control group had not additional education	**Nine-station OSCE; 7 taught skills and 2 control stations	Inpatient prescription, discharge prescription and controlled drug prescription	Intervention group performed better in four OSCE stations, including inpatient ($p=0.005$) and controlled drug prescribing ($p=0.001$)	7

Abbreviations: RCT indicates randomised control trial; TG, tutorial group; NTG, non-tutorial group; OSCE, objective structured clinical examination; S4, Schedule 4; S8, Schedule 8.
*Validity of assessment unclear or not stated.
**Validated assessment.

Table 2. Study characteristics and quality scoring of quasi-experimental studies (NOTE: this table only presents the results specific to prescribing skills reflected in each study).

Author	Year	Location	Study Design	Population	Intervention	Assessment	Prescribing Outcome measure	Results	Critical Appraisal (JBI score/9)
Al Khaja et al. [12]	2013	Bahrain	Non-randomised comparative study, post-test	Preclerkship students; Attendees in different levels of degree *N*=460, Non-attendees *N*=450	Optional 2-hour interactive session on prescribing skills attended. Feedback for 5–6 clinical scenarios completed out of session	*OSPE 2–3 weeks post intervention	Prescription writing skills (physician- and drug-related components) of attendees compared to non-attendees. Scoring system based off Lofholm and Katzung [27]	Mean total score of all year levels ↑ in attendees vs non-attendees (73.5% vs. 59.5% respectively, $p<0.0001$)	7
Akici et al. [6]	2005	Turkey	Non-randomised comparative study, pre-post study	Fourth-year medical students from first three clinical pharmacology clerkship groups (groups 1–3) *N*=94, students from the previous year followed up 1-year later (group 4) *N*=26	RP education program with PA sessions during clinical pharmacology clerkship	*PA and feedback	Prescription format audit following specific criteria, including physician and drug-related components and legibility. Rationality score (clinical choice) not presented	All four groups script format scores ↑ pre- to post-PA assessment ($p<0.01$). Format score ↓ in long-term assessment but still higher than pre-PA ($p<0.01$)	9
Celebi et al. [28]	2010	Germany	Non-randomised comparative study, post-test	Fifth-year medical students *N*=74	Number of weeks spent in internal medicine clerkship: Group 1 (0 weeks), Group 2 (1–4 weeks), and Group 3 (more than 4 weeks). Pharmacology training already completed	*Written chart prescription test on one of three randomised case pairs for a medical inpatient setting. Not assessed on general medical knowledge	Prescription writing skill on inpatient charts	Possible prescribing mistakes made: 71%, 67%, and 71% for Groups 1, 2 and 3, respectively	6
Coombes et al. [29]	2007	Australia	Non-randomised control trial, post-test	Final year medical students; Intervention *N*=99, Control *N*=134	Eight multidisciplinary-led, 90-minute, interactive, problem-based tutorials	*Written prescriptions for a series of drugs on the standard inpatient drug chart (no clinical choice in prescribing process)	Mean prescribing score and significant errors made	Mean prescribing score ↑ intervention group vs. control ($p=0.01$) with fewer significant errors (1.48 vs. 2.70, respectively)	8
Garbutt et al. [30]	2006	USA	Non-randomised, pre-post study	Third-year medical students completed pre- (*N*=28) and post-intervention (*N*=25) assessment	Two 1-hour interactive educational meetings 2 weeks apart during 12-week medicine clerkship	*Verbal 10-order transcription test onto order sheet similar to a patient chart	Prescribing errors, including incomplete, illegible and ambiguous orders and dangerous abbreviations used (84 possible errors)	Prescribing errors ↓ in all pre-post comparisons. Mean error-free orders ↑ pre- to post-test ($p<0.0001$)	6
Nayak et al. [3]	2021	India	Non-randomised, pre-post study	Fourth semester (second year) medical students *N*=60	Two educational sessions using case scenarios delivered as per WHO GGP method and one prescription writing assignment of 2–3 cases with feedback provided	**OSPE pre- and post-intervention	Prescription writing competency score of 20 for completeness, correct format, and drug-related components	Median prescription writing score ↑ pre- to post-test ($p<0.01$) and ↓ incompetent prescribing skills (49.2% to 3.4%, respectively)	6

(*Continued*)

Table 2. (Continued).

Author	Year	Location	Study Design	Population	Intervention	Assessment	Prescribing Outcome measure	Results	Critical Appraisal (JBI score/9)
Raghu et al. [31]	2017	India	"Cross-sectional, observational study" (Pre-Post)	Second-year MBBS students *N*=117	Theoretical education (lecture) on rational prescribing and hands-on training with discussions on prescribing errors	*Three case scenarios - Prescription quality, written in compliance with good prescribing patterns and the World Health Organization (WHO) core prescribing indicators	Prescriber-related components (prescriber and patient information), drug-related components and other-related components (legibility) based on Lofholm and Katzung [27]	Percentage of prescriber-related errors ↓ (p<0.05), patient-related information ↑ (p<0.05), and drug-related components ↑ (p< 0.05). Other-related components improved significantly post intervention (p<0.05)	7
Thenrajan and Murugan [32]	2016	India	Prospective comparative study, post-test	Second-year medical students; Medical rotation (test group) *N*=25, Surgical rotation (control) *N*=25	Both: general introduction to prescription writing, prescribing format, and the WHO guidelines Test: Patient-based teaching Control: Case-based teaching	*Written prescriptions for five clinical conditions discussed during teaching	Mean score of the five prescriptions based off a 14-point score system by Lofholm and Katzung [27] (prescriber-, patient-, drug, and other-related components)	Mean score ↑ test group vs. control group (p<0.001)	7
Thomas et al. [33]	2013	Australia	Non-randomised comparative, pre-post study	New graduates from University of Adelaide starting internship at Royal Adelaide Hospital; Intervention *N*=59, Control *N*=50	National prescribing curriculum online modules and attend minimum of 95% of face-to-face tutorials. Control group was the year prior, when modules were not mandatory	**Written inpatient prescription on the NIMC	Prescription writing skill and potential to cause harm on inpatient charts comparing intervention to control group. Parameters such as completeness of inpatient order and allergies recorded measured (total possible score = 32)	Average total score ↑ intervention cohort vs. control (p=0.0007). After 6 months medical practice: Control group ↑ (p=0.0004), intervention group statistically unchanged. No statistical difference control vs intervention (p=0.6125)	9

Abbreviations: OSPE indicates Objective Structured Practical Examination; RP, rational pharmacotherapy; PA, prescription audit; WHO, World Health Organisation; GGP, Guide to Good Prescribing; NIMC, National Inpatient Medication Chart.
*Validity of assessment unclear or not stated.
**Validated assessment.

assessment only). PBT produced statistically significant improvements in prescribing skills in nine of the 14-point scoring parameters [27] when compared to CBT [32].

Tutorial-based teaching (practical teaching)

Two studies implemented tutorial-based teaching [26,29]. Scobie et al. implemented a post-test randomised control trial to assess the influence of practical teaching stations on final year medical students prescribing skills [26]. Two of the five skills in the nine-station objective structured clinical examination (OSCE) assessed an inpatient and discharge prescription (including a controlled drug prescription), while the other three skills were clinically based. Results of inpatient and controlled drug prescriptions showed a significantly better mean prescribing score of the taught group compared to the control [26]. Coombes et al. assessed students' Queensland Health (Australia) inpatient prescribing skills after interactive problem-based tutorials [29]. Coombes et al. found a statistically significant improvement in the mean prescribing score of the intervention group, with fewer significant errors [29].

Didactic teaching

One study analysed the effects of didactic teaching [30]. Garbutt et al. used a verbal order transcription test before and after interactive education to assess medical students' prescribing errors on inpatient orders. The results indicated a statistically significant reduction in total prescribing errors per student following didactic teaching [30].

Mixed teaching

Six studies implemented mixed-method teaching [6,10,25,28,31,33]. Three studies combined clinical placement with educational interventions [10,25,28]. Sandilands et al. conducted a pre-post-test randomised control trial (RCT) assessing prescribing errors [10]. The intervention group received practical prescribing tutorials and bedside prescribing teaching, while the control group did not receive additional teaching [10]. Similarly, Mokrzecki et al. performed a pre-post-test RCT assessing prescribing score and pass versus fail rate. Participants in the intervention group received a tutorial session with CBL and hands-on experience. Both groups attended practical placement on medical wards [25]. Celebi et al. compared number of weeks spent on a general medical ward in combination with pharmacology training to determine if students' inpatient prescribing skills improved [28]. One study introduced combined tutorial-based teaching with online learning [33], then reviewed the long-term effects by assessing doctors' inpatient orders six months after clinical placement. In contrast, Akici et al. reviewed simulation, problem-based teaching, role-playing, and small-group discussions in combination with prescription audits using the Groningen/WHO model of rational prescribing (case-based learning) [6].

Five of these studies showed positive results in prescribing post-intervention [6,10,25,31,33]. Post-test, the intervention group of Sandilands et al. study showed a statistically significant reduction in typographical errors and an improved mean prescribing score [10]. Mokrzecki et al. demonstrated a significant improvement in prescribing score and number of cases passed by the intervention group [25]. Participants in the control group prescribing skills significantly worsened after only receiving traditional teaching and placement on a medical ward [25]. Akici et al. assessed the prescription format of students pre- and post-intervention [6]. One group was reassessed a year later to measure retention of knowledge. The results showed significant improvements ($P < 0.01$) in all groups' scores post intervention. Long-term follow-up prescription format scores were reduced compared to post-intervention but higher than the pre-intervention. Thomas et al. assessed the average total score of inpatient prescription orders [33]. There was a significant difference between the intervention versus the control group, prior to clinical practice as a doctor [33]. Raghu et al. assessed all prescriber-, patient- and drug-related components in prescribing using a scoring model based on Lofholm and Katzung [27]. After delivery of seminars, discussions and hands-on experience in prescribing there were significant improvements identified in all components of the three cases [31].

No significant improvements were seen in Celebi et al. [28] The results from Celebi et al. demonstrated the effect of learning from colleagues and the possibility of mimicking their inadequate prescribing skills. Both those who completed zero weeks and over four weeks of placement on a medical ward made 71% of possible prescribing mistakes, while those who completed 1–4 weeks made 67% [28].

Professional background of educators

The professional background of the educators varied across the studies.

Pharmacist

Four studies used pharmacists as educators for their intervention [10,25,26,29]. Two of these studies used a combination of pharmacist- and doctor-led teaching [10,29], and Coombes et al. also included a clinical nurse in three of eight education sessions [29].

Faculty members

Five studies in this review used existing faculty members as educators [3,6,12,28,32]. Three studies used educators trained in the WHO GGP methods [3,6,32]. Four studies used faculty members in the department of pharmacology to assist in education [6,12,28,32].

Other

The profession of the educator was not specified in Thomas et al., simply stating that students were required to attend 95% of the face-to-face sessions [33]. Garbutt et al. used the expert knowledge of a senior clinician and opinion leaders to deliver two interactive educational meetings [30] but whether they were guests or faculty members is unclear. It was not clear in Raghu et al. the professional background of the educator(s), referencing them as the facilitators [31].

Timing of intervention

The timing of the educational intervention during medical training varied across studies. No trends were identified in the timing of education with statistical significance of results. Five studies conducted interventions during the final year [10,25,26,29,33]. One conducted the intervention during all years of pre-clerkship (prior to the two clinical years) [12]. The three studies published from India were all implemented into the second year of medical school [3,31,32]. The remaining three studies conducted the intervention within the last two years of the medical course [6,28,30].

Discussion

The prescribing process is multifaceted, whereby research on clinical decision-making, rational prescribing and prescribing competencies have been extensively reviewed. In contrast, our review aimed to identify educational interventions and assessment tools for the skill of writing a prescription, independent of applying clinical knowledge to develop a treatment plan. Specifically, our review assessed medical students' skill in writing a safe and legal prescription including all patient-, physician- and drug-related components, distinct from clinical decision-making aspects.

Twelve studies met the inclusion criteria comparing additional education versus no identified additional education or other modalities to improve the prescribing skills of medical students. The results suggest that education is superior to no additional education in improving prescribing skills. However, due to the small number of studies and heterogeneity of study designs, the optimum modality, educator, and timing for the education to improve the prescribing skills of medical students remains unclear. Furthermore, there is substantial ambiguity regarding the definition of 'prescribing skill' and the type of scripts these skills apply (for example, inpatient orders versus outpatient prescriptions). None of the published studies assessed prescribing skills as defined for this review.

Two Australian medical group reports indicated a lack of prescribing knowledge and skills amongst Australian graduating medical students [34,35]. One report stated that students rated prescribing low in relation to perceived preparedness as a clinical skill [34]. Those with higher perceived preparedness for prescription writing rated receiving practical script writing training as more effective than teaching pharmacology and therapeutics (reflecting clinical knowledge) [34]. This supports the findings of this review that targeted education on prescription writing improves the prescribing skills of medical students.

Improvements in prescribing skills following additional education were observed regardless of the education modality. Amongst the variety of educational modalities, Thenrajan and Murugan directly compared CBT and PBT (with no control or pre-test) [32]. The results indicated that PBT was superior to CBT [32]. Combined education and placement in a hospital setting was employed in three studies [10,25,28]. The review by Ross et al. stated the benefit of having simulated real-life practice involving the completion of prescriptions by undergraduates [23]. Celebi et al. showed that long practical placement periods in a hospital setting without additional education resulted in a similar number of prescribing mistakes as students who spent no time on placement [28]. However, Celebi et al. did not individually assess each component of the prescription and incorporated clinical decision making thereby not specifically assessing the act of prescribing. Mokrzecki et al. demonstrated that exclusive practical placement without additional education, resulted in worse prescribing skills post versus pre-placement and compared to the post-intervention group results [25]. Internationally, some medical students have opportunities to learn prescribing through increased placement (or clerkship), simulation-based training, role-playing sessions, and small working groups [14]. Australian medical interns have expressed that prior to commencing their internship, it would be beneficial to have had exposure to prescribing [35]. This review shows studies using a mix of educational modalities with practical exposure to prescribing. However, it cannot be concluded which educational modalities are superior to assist in developing safe and legal prescribing skills as only one study directly compared the effects of two different interventions [32].

The WHO GGP [5] is the most common resource for prescribing education. However, it fails to stipulate the difference between inpatient orders and an outpatient or discharge prescription resulting in an ambiguous definition of prescribing as a skill. Few studies assessed discharge or outpatient prescriptions, which are equally important but have different criteria to inpatient orders. This oversight of assessment suggests a gap in the literature for education of prescription types other than inpatient orders. As each study differed in the type of assessment, there was no consistency in measurable outcomes to assess students' prescribing skills. Various terms for outcome measures were used, such as prescribing mistakes, prescribing errors, or a change in prescribing score, indicating a need to identify valid and reliable outcomes for assessing written outpatient or discharge prescriptions.

The professional background of the educator varied between studies. We identified that existing faculty members and pharmacists were regarded highly as educators of prescription writing. It is not identifiable if the existing faculty members had a background in pharmacy. Conclusions cannot be made regarding the professional background of the educator as this review did not directly compare educators and the outcome on prescribing skills.

Changing existing prescribing habits once poor skills are embedded is difficult and may be perpetuated in career-long adoption of inadequate prescribing practices [5]. Only two studies examined the longitudinal effects of prescribing education to medical students to assess knowledge retention [6,33]. Tomas et al. found that the average total score of the intervention group was statistically unchanged after 6-months of medical practice [33]. In comparison, Akici et al. found that whilst rationality scores declined significantly a year after clerkship, scores were still significantly higher than pre-intervention [6]. These two papers indicate that there is benefit in providing additional prescription writing education to medical students, separate to clinical decision making, as they do retain this knowledge and skill as they begin practicing as a doctor.

Knowledge retention as practicing doctors regarding the timing of the intervention within the medical school curriculum was not assessed and has not been well established from this systematic review. Not considering how educational interventions may be implemented within the wider context of the medical curriculum may pose as a limitation to this review. There remains a need to identify when the most appropriate time is to provide prescribing education to medical students to aid in knowledge retention of practicing doctors.

Our results reflect previous systematic reviews that findings are limited due to heterogeneity of the study design, interventions, assessment types and outcome measures [19,20,23]. Despite additional studies since the Ross et al. review in 2009, there have been no conclusions on the most effective education modality, profession of the educator or timing of education. Therefore, an evidence gap still exists in how, who and when education should be delivered to improve the prescribing skills of medical students. Strengths of this systematic review include the systematic approach and the same two reviewers for all steps. However, the conclusions are limited by the exclusion criteria and the quality of the studies retrieved. Only quantitative studies were included as we wanted to review measurable outcomes of prescribing. One difficulty in reviewing these studies was the prescription writing assessment criteria. For some studies, it was the primary outcome measure; in others, it was a small component amongst other outcomes. A positive publication bias may exist among the studies as improvements in prescribing results following additional education were described in most studies. Another limitation lies in reviewing only studies assessing medical students prescribing, with studies on junior doctors excluded. Furthermore, many of the included studies conducted interventions on small cohorts, making generalisations from the results difficult. The differences in educational interventions, educators, methods of assessment and outcome measures across the studies suggests that future studies should clarify these points.

This review highlights the lack of formal education interventions to medical students on the skill of writing a discharge or outpatient prescription. The WHO GGP uses case-based teaching and is a practical manual, guiding medical students on rational prescribing [5]. However, there remains no compulsory standardised teaching and marking criteria that are validated, reliable and generalisable. Overall, evidence suggests educational interventions improve medical students' prescribing abilities.

In the authors opinion, failure to employ a mandatory requirement for students to pass a prescribing skills assessment (separate from clinical knowledge in prescribing) leaves a gap in medical students' learning outcomes prior to gaining registration to prescribe as a doctor. Future studies should endeavour to address the following gaps. First, a comparison of different education modalities to determine the most effective at improving the skill of writing a discharge or outpatient prescription (non-inpatient ordering), separate from teaching theoretical and clinical decision-making for prescribing. Second, an in-depth analysis of prescribing outcomes based on the professional background of the educator. Third, students should be assessed on the knowledge and skill of writing a prescription using

a defined outcome measure with valid and reliable criteria. Fourth, future research should determine knowledge retention through longitudinal studies.

Conclusion

This review demonstrated a range of educational interventions and assessed the effect of additional education versus another modality or no additional education on the prescribing skills of medical students. Nevertheless, gaps remain in the literature. Most studies demonstrated an improvement in prescribing skills following educational interventions. However, there are inconsistencies in the definition of prescribing skills, teaching modalities, assessment methods and outcome measures, types of prescriptions analysed, and professional background of educators. The appropriate time at which education is implemented has yet to be well established and needs to be further reviewed with follow-up studies. Failure to provide education on prescribing will continue to avoidably burden the health system, resulting in excess costs, degraded clinical care and potential harm to patients.

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Appendix 1: Search term tree used in PUBMED

((("Students, Medical"[Mesh]) OR "Schools, Medical"[Mesh]) OR "Education, Medical"[Mesh]) AND "Prescriptions"[Mesh] [864 results]