EDUCATION

in appropriate pharmacotherapy in older patients

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Education in appropriate pharmacotherapy in older patients

Onderwijs over geschikte farmacotherapie bij oudere patiënten
(met een samenvatting in het Nederlands)

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Table of contents

1 General introduction 08

2 The education 28

2.1 Geriatric pharmacology and pharmacotherapy education for health professionals and students: a systematic review 30

2.2 Education on prescribing in older patients in the Netherlands: a curriculum mapping 58

3 Health professionals' knowledge and skills 86

3.1 A comparison of medical and pharmacy students' knowledge and skills of pharmacology and pharmacotherapy 88

3.2 Pharmacists' and general practitioners' knowledge and skills in pharmacology and pharmacotherapy 104

4 Educational interventions 124

4.1 Implementation of the WHO-6-step method in the medical curriculum by a learning programme to improve medical students' pharmacology knowledge and pharmacotherapy skills 126

4.2 Structured pharmaceutical analysis of the STRIP is an effective method for final-year medical students to improve polypharmacy skills: a randomised controlled trial 152

5 Summary and general discussion 170

5.1 Summary and general discussion in English 172

5.2 Samenvatting in het Nederlands 194

6 Appendices 204

6.1 List of co-authors 206

6.2 List of publications 210

6.3 Curriculum vitae 214

6.4 Dankwoord 218

1

GENERAL INTRODUCTION

> *Education is the best provision for the journey to old age*
>
> **Aristotle**

GENERAL INTRODUCTION

Geriatric pharmacotherapy is an important issue in medicine.[1] Life expectancy is increasing, the drug arsenal is expanding, and polypharmacy for curative, symptomatic, or preventive goals is increasingly common among older individuals with multimorbidity,[2] which means that health professionals will see more elderly patients in the future, many of whom are frail. Appropriate prescribing is always essential, but particularly so in older patients. Appropriate prescribing should not only carefully weigh the benefits and potential harms of drugs, but also take the patient's health and life expectancy, preferences, and values into consideration.[1, 2] Most prescribing guidelines are not entirely applicable to patients with comorbidity or who use multiple medications.[3] Patients with multiple medical conditions may be prescribed several medications that are individually appropriate for each medical condition, but the combination may be harmful to the older patient.[3] In addition, most drug registration studies have not included vulnerable older patients, even though most drug prescriptions are for older patients. This means that prescribers do not have information on how best to prescribe for older patients.[4] Moreover, patients, especially those with additional risk factors such as advanced age, polypharmacy, multimorbidity, renal failure, and cognitive decline, are at high risk of drug-related problems (DRPs), such as adverse drug reactions (ARDs), which can result in hospital admission or even death.[5-7] Thus prescribing for old patients is challenging because of its complexity, not only for doctors but also for pharmacists and nurses.[6-10] Pharmacists are increasingly involved in medication reviews in addition to their role in dispensing and monitoring medication use,[11] and nurses are involved in the administration of drugs and in detecting DRPs, especially among older individuals living at home.[10, 12]

Health professionals often inadvertently cause DRPs, many of which are preventable.[7, 13, 14] It is estimated that about 30% of DRPs are caused by poor application of available knowledge and skills.[14, 15] This, in turn, is suggested to be due to educational changes over the decades, such as problem-based learning (PBL), which was widely adopted in the 1970s onwards and will be discussed in more detail later on.[13, 16] Today's medical students report feeling unprepared to prescribe after graduating, and junior doctors cause the highest numbers of prescription errors.[17, 18] These concerns are not unique to pharmacology and pharmacotherapy education, as similar concerns are expressed about pain management education.[19] An underlying cause of the inadequate knowledge and skills, or their poor application, could be shortcomings in training and education in pharmacology and pharmacotherapy, both in quality and quantity.[20] It could also theoretically be a problem with knowledge retention after graduation, although it is still debatable to what extent knowledge is retained.[21, 22] Worldwide, steps have been taken to improve education in geriatric medicine, but these have not focused on pharmacotherapy (www.POGOe.org). Other, national, initiatives have a focus on pharmacotherapy or pharmacotherapy education, but not on geriatric medicine, such as in the Netherlands, the Nijmegen Expertise Centre for Complex Pharmacotherapy (www.necf.nl) and the Research and Expertise Centre In Pharmacotherapy Education (RECIPE) (www.vumc.com/branch/recipe/). In 2009, a specialist centre for pharmacotherapy in the elderly was set up, the Expertise Centre Pharmacotherapy in Old Persons (Ephor) (www.ephor.nl and www.ephor.eu). One of the goals of Ephor is to improve education in geriatric pharmacotherapy.

One of the motives for the studies described in this thesis is that improved education in geriatric pharmacotherapy might improve the knowledge and skills of health professionals in complex pharmacotherapy, thereby decreasing the number of DRPs.[1, 6, 7, 9, 13, 23, 24]

Prescribing to older patients

In order to give an idea on possible educational content, how to prescribe in older patients will be discussed first. The presented principles could be the ‘ingredients’ for the education. A general basis for rational prescribing, regardless of patient age or sex, is the WHO guide to good prescribing, which includes the *WHO 6-step method for rational prescribing* (WHO-6-step) as shown in Box 1.[25] Proper use of the WHO-6-step method requires cognitive, communicative, and motor skills.[26, 27]

This method was designed for prescribing a single drug. While prescribing guidelines do not often focus on the suitability of a drug for a specific patient, for example, an elderly patient, the WHO-6-step guideline does, in step 3b.[3] This step takes into consideration several risk factors, such as interactions at the level of drug-drug or drug-diseases, possible side effects, contraindications, adherence problems, and pharmacodynamics and pharmacokinetic changes in elderly patients.[2] However, this requires a basic knowledge of these potential problems. Step 4 focuses on the correctness of the prescription and of communication with the pharmacist. Problems in interprofessional communication create potentially harmful situations. For example, ADRs, such as side effects, are often not properly recorded or communicated among different health professionals.[28] As with step 4, step 5 requires

BOX 1. **WHO-6-step of rational prescribing from the Guide to Good Prescribing**

WHO-6-STEP OF RATIONAL PRESCRIBING

1 Patient’s problem	· Symptoms · Diagnosis · Patient characteristics	**4** Start treatment	· Writing prescription · Starting treatment
2 Therapeutic objective	With parameters · curative · symptomatic · preventive · palliative	**5** Give patient information, instruction	· Patient information · Instructions · Warnings
3 Treatment choice	**a)** standard treatment based on available evidence **b)** verify suitability for patient · contraindications · interactions · comedications	**6** Monitor treatment	Monitor treatment based on effect · continue · adjust · or stop

good communication skills, this time with the patient. This is important because good patient–physician communication is associated with drug adherence.[29] Step 6 involves the evaluation and monitoring of treatment. Home-care nurses have an important role in this when it comes to elderly patients who live at home, as they can use the Dutch *HOME instrument* (Home Observation of Medication related problems by homecare Employees) to detect ADRs or other DRPs.[12, 30] The WHO-6-step programme has been adopted by several medical schools worldwide and is used to teach prescribing to medical students.

While the WHO-6-step programme is available to improve the prescribing of single drugs, what if multiple drugs are already prescribed? The WHO-6-step assumes that these previous prescriptions were chosen properly. How can inappropriate polypharmacy with potential harmful rather than beneficial effects to the patient be avoided?[2, 3] It is often assumed that physicians are afraid to prescribe to patients with complex problems, which is possibly why underprescribing is common in patients with comorbidity and polypharmacy.[24, 31, 32] As Steinman et al. stated with regard to achieving a balance in medication choices in clinically complex old patients: "there's got to be a happy medium".[33] Several medication review methods have been developed to help health professionals achieve this happy medium in patients requiring polypharmacy.[11] Interdisciplinary collaboration is essential in order to perform a medication review and findings can be beneficial for patients.[11] One such review method has been adopted in the Dutch multidisciplinary guideline 'Polypharmacy in older people', namely, the '*Systematic Tool to Reduce Inappropriate Prescribing (STRIP*)'.[34] It is based on the Polypharmacy Optimization Method (POM) and has proven effective when used by general practitioners (GPs).[35] The STRIP is a clinical medication review and involves the patient and his/her pharmacist and physician (see Box 2). The second step of the STRIP is the *structured pharmaceutical analysis,* in which indication, treatment goals, undertreatment, unnecessary treatment, side effects, interactions, contraindications, and dosage are weighed to create an appropriate list of medications.[11] The checklists of *START (Screening Tool to Alert doctors to Right Treatment)* and *STOPP (Screening Tool of Older Persons' Prescriptions)* are used as a tool in the STRIP. These checklists were developed by O'Mahony and Gallagher et al.[36] and have been widely adopted. They are regularly updated and have been translated into Dutch.[37] The START criteria address the most frequently undertreated diseases in older patients, and the STOPP criteria focus on the most frequent contraindicated or overdosed drugs in older patients.

Thus nowadays there are methods to improve prescribing for old patients in daily practice: the WHO-6-step method for a single prescription, and the STRIP for polypharmacy when patients have multiple comorbid disorders. The question is whether they can be used in an educational context. This was another reason to perform the studies described in this thesis.

Current status of pharmacology and pharmacotherapy education

One way to evaluate education is to look at the *learning goals* of a curriculum. In the national blueprint for learning goals, the so-called "het Raamplan 2009", for Dutch *medical curricula,* there are only five learning goals related to pharmacology and/or pharmacotherapy and none related to geriatric pharmacology and pharmacotherapy.[38] A number of articles and reports on the learning goals of a core curriculum for pharmacology and pharmacotherapy for medical students have recently been published. These articles mentioned about 50 learning goals, many of which overlapped.[39-45] The national Dutch learning goals for *pharmacy* were described since 2007.[46, 47] While most of these learning goals address pharmacology and pharmacotherapy, none address prescribing for older people or specific problems such as polypharmacy. Only one article was found that described goals concerning geriatric pharmacology and pharmacotherapy for pharmacy students.[48] In the last decades, pharmacology and pharmacotherapy have almost disappeared from the learning goals of nursing curricula, with emphasis currently being on the correct administration and registration of drugs and not on

BOX 2. **Systematic Tool to Reduce Inappropriate Prescribing (STRIP) method for reviewing polypharmacy**

SYSTEMATIC TOOL TO REDUCE INAPPROPRIATE PRESCRIBING (STRIP)

The following steps should be taken for a medication review

1. structured history taking of medication use
2. structured pharmaceutical analysis
   - a. undertreatment — + START criteria
   - b. ineffective treatment
   - c. unnecessary treatment — + STOPP criteria
   - d. (potential) adverse effects — + STOPP criteria
   - e. contraindications and interactions — + STOPP criteria
   - f. dosage or problems in use
3. pharmaceutical care plan (pharmacist-physician)
4. patient consultation
5. follow up and monitoring

START = Screening Tool to Alert doctors to Right Treatment
STOPP = Screening Tool of Older Persons' Prescriptions

the detection of medication-related problems or on underlying basic principles.[49] National quality assurance committees have expressed concern about the lack of clearly defined learning goals in medical and pharmacy curricula, especially in view of patient safety issues and the increase in the number of prescribing errors. As stated by the Dutch committee with regard to medical undergraduate education: “The basic principles of pharmacology do not receive enough attention in the education….The education was not systematically assessed at all faculties… Given the importance of medication safety in the students’ future practice as physician, pharmacotherapy should be assessed”[50] Committees have also mentioned the incomplete list of learning goals for pharmacy during site visits.[46, 47] The audit says: “The national blueprint gives a clear description of the training to become a pharmacist; however, is defined too restricted to function as a domain specific reference of learning goals“ [46, 47] Recent reports on the quality review of nursing curricula were not found.

Another approach to assessing education is to look for evidence-based education. In medical practice, evidence-based medicine is the standard. In line with this, *best evidence medical education (BEME)* is a relatively young, but increasingly important, quality standard in medical education.[51, 52] BEME is the implementation of methods and approaches to education by teachers, based on the best evidence available. A systematic review of pharmacotherapy education found that the WHO-6-step programme was the only educational intervention for medical students with high quality evidence of effectiveness.[25, 53] No systematic reviews on pharmacology and pharmacotherapy education for other health professionals were found, and only one review on geriatric pharmacology and pharmacotherapy education was found.[54] Four articles included in the review used different interventions to reduce inappropriate prescribing to the elderly and reported mixed, mostly negative or non-significant, results. The only significant and clinically relevant study was that of Wessel et al., which showed that performance reports in combination with visits and meetings resulted in a small annual decline of 0.018% in inappropriate medication.[55] It can be concluded that geriatric pharmacology and pharmacotherapy education is a relatively unexplored field, which makes it difficult to know how to train health professionals in these subjects in an evidence-based way. Moreover, it is not clear to what extent clinical methods such as the WHO-6-step and STRIP are suitable for educational goals, although there is increasing evidence about the effectiveness of the WHO-6-step.

The introduction of BEME is not the only change to health professionals’ curricula.[51, 52] From the 1970s onwards, but mainly in the last 20 years, the curricula of health professionals has seen major changes, and worldwide there has been a shift from the traditional basic science-oriented focus of medical and pharmacy curricula to a disease-oriented focus with more or less *problem based learning* (PBL).[20, 46, 47, 56] Most curricula nowadays offer pharmacology and pharmacotherapy education integrated in a horizontal and vertical manner. *Horizontal integration* is the clustering of knowledge and skills from disciplines around themes (e.g., the cardiovascular system), and *vertical integration* is the integration of different disciplines traditionally taught in different study years, such as pharmacology in earlier years and pharmacotherapy later on, but also preclinical and clinical topics.[57, 58] Nursing curricula have seen a shift from a biomedical model focused on curing to a holistic model focused on caring.[49, 59] These changes in educational systems may have led to students having insufficient knowledge of basic pharmacology,[16, 20, 59, 60] a phenomenon described for other basic sciences as well.[61, 62] Recent curricular changes have involved the content (what is taught), teaching and learning strategy (how is it taught), assessment (is it assessed and how), and evaluation (how is it evaluated) of curricula and educational goals.[63] A consequence of these changes is that some subjects, such as pharmacology and pharmacotherapy, are no longer assessed as individual subjects.[20] Moreover, changing the assessment methods may influence the learning strategy of students and thereby curricular results in terms of knowledge and skills.[16, 64]

It is recognized that curricular changes often lead to a feeling that things were better in the past and to feelings of incompetence among the new generation of students.[65, 66] It is generally assumed that curricular changes have led to students having less basic knowledge of, for example, pharmacology, which in turn might cause medication errors.[16, 67] Indeed, there has been an alarming increase in the number of medication errors and adverse reactions over the past decades;[23] however, this may be due to other causes, such as the increased throughput of patients, the broader range of drugs available, and the increased complexity of health problems in an ageing population.[16]

Thus education has changed over the decades and little is known about the current status of (geriatric) pharmacology and pharmacotherapy education. That is another motive for our studies.

Health professionals' knowledge and skills

As described above, it is often assumed that health professionals lack appropriate knowledge and skills, possibly as a result of educational changes, but this assumption has not been tested. While ideas about what are appropriate learning goals reflecting core knowledge and skills are available for all professions,[38, 46, 47, 49] it is not clear to what extent these learning goals are being met. It is difficult to answer the question what is *enough knowledge* for appropriate (geriatric) pharmacology and pharmacotherapy, and this is also true for other basic sciences.[68, 69] There does not seem to be a *clear norm*. However, as long as errors in prescriptions, dispensing, administration, and communication result in high numbers of medication errors, mostly in older patients with sometimes even fatal outcomes, it is obvious that there is room for improvement. While a clear norm might never be available, safe patient care could be used as a standard, especially as different committees have expressed concern about this issue.[46, 47, 50] In addition, while a lack of knowledge might be a problem, so too could *knowledge retention* after graduation.[21, 22] Again, it is difficult to study how knowledgeable health professionals are because there is no norm. The only way to study this is to compare them with another and/or with a gold standard, for example, experts in the field of pharmacology and pharmacotherapy. A recent study showed nurses to possess 76% of the knowledge considered to be essential to their profession, in this case knowledge about drugs used the most often by old people.[12] Although a comparison between professionals may seem illogical, it can be beneficial because the various disciplines need to work together in order to provide optimal pharmaceutical care, to improve patient care.[11, 70] Such a comparison may provide insight into the strengths and weaknesses of each profession in terms of pharmaceutical care. For example, a study compared the knowledge and attitudes of three groups of health professionals to pain management. Physicians were most knowledgeable about opioid pharmacology, nurses about pain measurement, and pharmacists about drug costs.[71] Another study compared the knowledge of physicians and nurses regarding ADRs.[72] The physicians outscored the nurses in knowledge of ADRs, but the nurses had more knowledge about how to report ADRs. For nurses, in particular, the ability to calculate drug doses and dilutions has been mentioned in relation to medication errors.[73] In a number of studies comparing the knowledge of medical and pharmacy students, pharmacy students outscored medical students in knowledge of drug-drug interactions and in recognizing prescription errors.[74-76] As far as we know, there are no studies comparing qualified pharmacists and physicians.

Therefore, although assumed, it has not been proven that health professionals lack sufficient knowledge and skills. Moreover, it is not known to what extent knowledge and skills of general and geriatric pharmacology and pharmacotherapy are shared or differ between the different health professions. This, together with the lack of a knowledge norm, was the last reason to perform the studies described in this thesis.

Taken together, although it is often stated that shortcomings in education lead to shortcomings in health professionals' knowledge and skills, which can ultimately result in prescribing errors with negative patient outcomes, there are few studies that have unequivocally confirmed this.

AIMS AND OUTLINE OF THE THESIS

The ultimate goal of this thesis is to improve education in geriatric pharmacology and pharmacotherapy for different health professionals. From the above, we know that learning goals in medical and pharmacy curricula are not always clearly stated, that little is known about the specific knowledge and skills of health professionals and students, and that it is not known whether prescribing tools used in daily practice can also be used in an educational setting. To this end, three aims were formulated.

AIM 1

To study the quantity and quality of available (geriatric) pharmacology and pharmacotherapy education, to try to establish whether poor undergraduate training in these topics can explain the lack of health professionals' knowledge of (geriatric) pharmacology and pharmacotherapy.

Chapter 2 provides an overview of education in geriatric pharmacology and pharmacotherapy relative to that in general pharmacology and pharmacotherapy. **Chapter 2.1** focuses on evidence-based education for all health professionals as described in the literature. In the study described in **chapter 2.2**, curriculum mapping was performed to evaluate the general and geriatric pharmacology and pharmacotherapy education, currently provided in Dutch medical schools. In this study, all Dutch medical curricula were studied in detail in terms of content, teaching strategies, assessment, and evaluation procedures.

AIM 2

To gain insight into the current level of knowledge and skills of students, pharmacists, and physicians and the influence of work experience, with a view to assessing pharmacists' and physicians' strengths and weaknesses in knowledge and skills brought to multidisciplinary collaborations. Knowledge of potential differences might help improve future interdisciplinary education and collaboration.

The study reported in **chapter 3** investigated the knowledge and skills of physicians, pharmacists, and students. Pharmacy and medical students (**chapter 3.1**) as well as physicians and pharmacists (**chapter 3.2**) were asked to complete a formative knowledge test on the domains basic pharmacology knowledge, clinical or applied pharmacology knowledge, and pharmacotherapy skills, as defined below. Differences and potential explanatory variables, such as undergraduate education and work experience, were investigated.

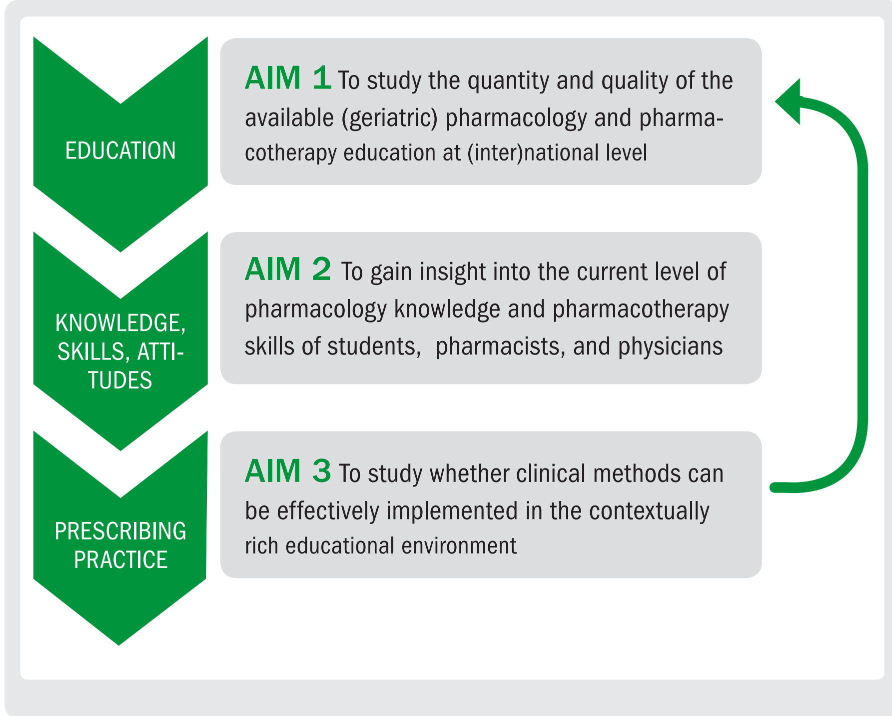
AIM 3

To study whether clinical methods (e.g., the WHO-6-step for prescribing in general, the STRIP for optimizing polypharmacy) can be effectively implemented in the contextually rich educational environment for health professionals.

In the study described in **chapter 4**, different interventions were implemented in an educational environment. In medical education research, several types of outcome can be chosen as described by *Kirkpatrick in a four-level model*.[77] Outcomes can be measured at the level of 1) reaction of the learner, such as satisfaction, 2) learning outcomes, such as knowledge or skills, 3) behaviour in real situations, and 4) results such as patient outcomes, e.g. fewer medication errors. In this thesis, endpoints were chosen to reflect the different levels of the Kirkpatrick model. For medical students, the WHO-6-step, which is used throughout the medical curriculum, was studied with regard to its effect on knowledge, skills, and satisfaction (**chapter 4.1**). In addition, the structured pharmaceutical analysis of the STRIP was studied in a multicentre study with regard to its effect on satisfaction, skills, and patient-related outcomes. The STRIP was provided with and without an E-learning environment (**chapter 4.2**).

Figure 1 shows how the different aims relate to another.

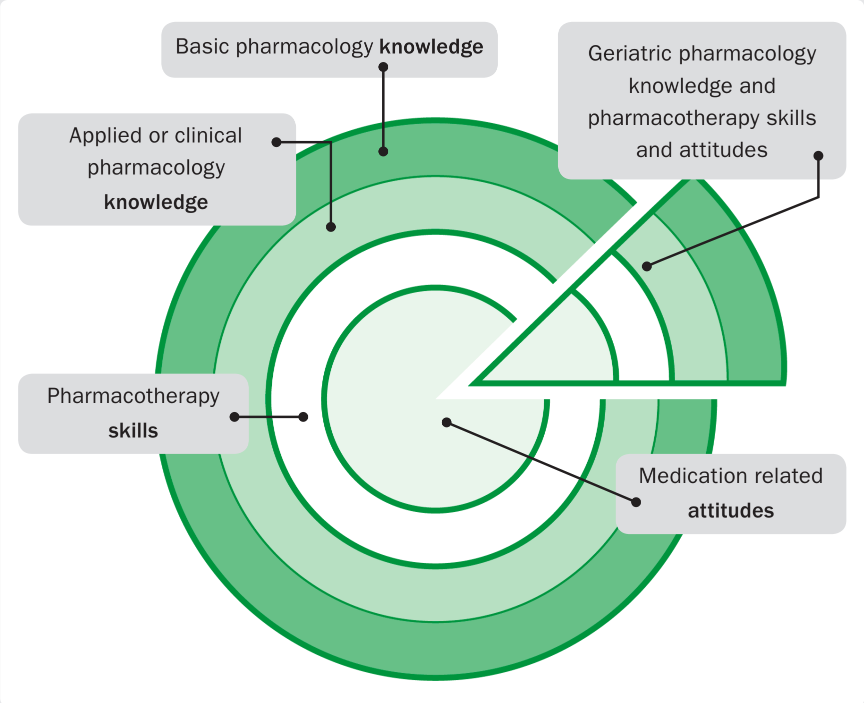
FIGURE 1. **aims of this thesis graphically displayed**



DEFINITIONS USED IN THIS THESIS

There is no clear definition of geriatric pharmacology and pharmacotherapy education, other than education on pharmacology and pharmacotherapy in older people.[2] Yet definitions have to be given in order to study this topic in detail. Education often distinguishes between knowledge, skills, and attitudes.[27] Knowledge can be further subdivided into factual knowledge and applied knowledge, which are closely related to the levels of Millers Pyramid, namely, knows and knows how.[27, 78] Pharmacological knowledge can be also further divided into basic pharmacology (such as pharmacokinetics), clinical pharmacology (application of basic knowledge in relation to the patient), pharmacotherapy (prescribing on the basis of available knowledge). Lastly, the right prescribing attitudes are needed.[45, 79] Taken together, in this thesis a distinction is made between basic pharmacology knowledge, clinical or applied pharmacology knowledge, pharmacotherapy skills, and medication-related attitudes, in general and in relation to geriatric pharmacology and pharmacotherapy. Figure 2 shows the terminology used in this thesis.

FIGURE 2. **definitions used in this thesis presented in an onion-model**



ABBREVIATIONS

ADR	Adverse drug reaction
BEME	Best evidence medical education
DRP	Drug related problems
GP	General Practitioner
START	Screening Tool to Alert doctors to Right Treatment
STOPP	Screening Tool of Older Persons' Prescriptions
STRIP	Systematic Tool to Reduce Inappropriate Prescribing
PBL	Problem Based Learning
P&P	Pharmacology and Pharmacotherapy
WHO-6-step	WHO 6-step method for rational prescribing from the Guide to Good Prescribing

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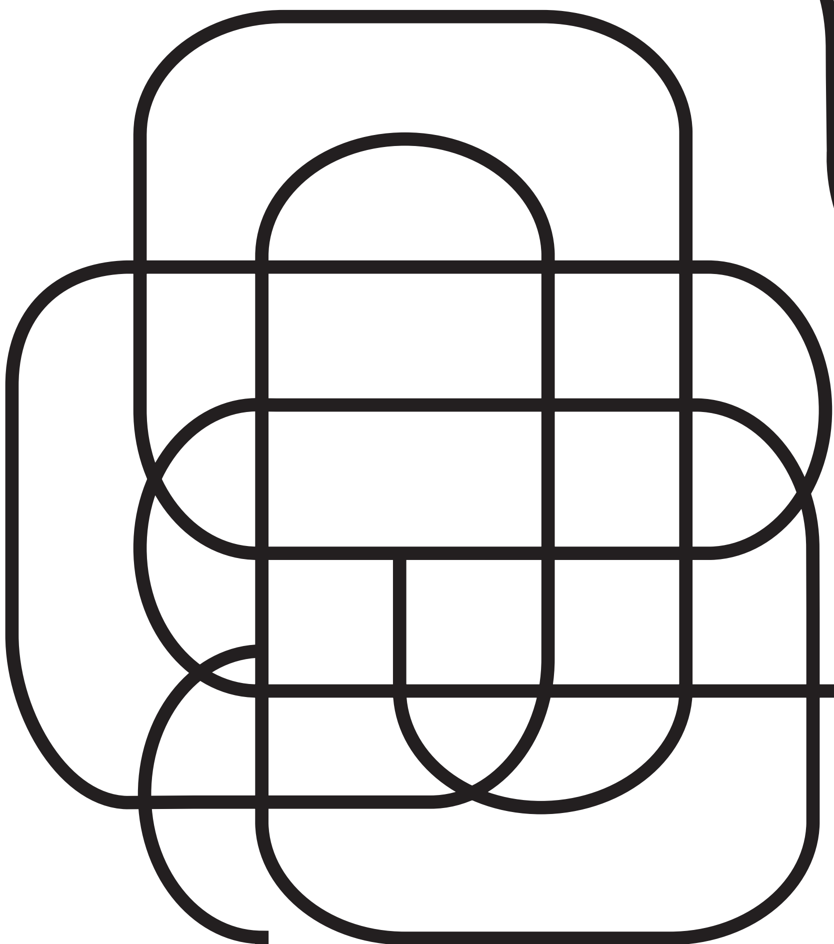
2

THE EDUCATION



If you would thoroughly know anything, teach it to others.

T. Edwards

2.1

Geriatric pharmacology and pharmacotherapy education for health professionals and students: a systematic review

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ABSTRACT

Aim Given the reported high rates of medication errors, especially in elderly patients, we hypothesized that current curricula do not devote enough time to the teaching of geriatric pharmacology. This review explores quantity and nature of geriatric pharmacology education in undergraduate and postgraduate curricula for health professionals.

Methods PubMed, Embase, and PsycINFO databases were searched (01-01-2000 to 01-11-2011), using the terms pharmacology and education in combination. Articles describing content or evaluation of pharmacology education for health professionals were included. Education in general and geriatric pharmacology was compared.

Results Articles on general pharmacology education (252) and geriatric pharmacology education (39) were included. The number of publications on education in general, but not geriatric, pharmacology has increased over the last 10 years. Articles on undergraduate and postgraduate education for 12 different health disciplines were identified. A median of 24 hours (15 minutes-4956 hours) devoted to pharmacology education and 2 hours (1-935 hours) devoted to geriatric pharmacology were reported. Of the articles on education in geriatric pharmacology, 61.5% evaluated the teaching provided, mostly student satisfaction with the course. The strength of findings was low. Similar educational interventions were not identified and evaluation studies were not replicated.

Conclusions Interest in pharmacology education has recently increased, possibly because of the high rate of medication errors and the recognized importance of evidence-based medical education. Nevertheless, courses on geriatric pharmacology have not been evaluated thoroughly and none can be recommended for use in training programmes.

INTRODUCTION

Medication errors due to human mistakes have raised concern about the pharmacological knowledge of different health professionals.[1, 2] Medication errors may lead to adverse drug reactions (ADR),[3] which, in turn, are responsible for 3.0% to 6.5% of all hospital admissions.[3-6] The numbers are even higher for elderly individuals, ranging from 3.6 to 13.3%.[4-6] About 47–72% of ADRs are potentially preventable.[3, 5] The main cause of medication errors is insufficient knowledge of drug therapy on the part of doctors and other health professionals.[1, 7] Moreover, pharmacotherapy is becoming more complex, especially in older patients.[7] Worldwide, elderly people form the largest group of people admitted to hospital, and the elderly population is increasing rapidly.[8, 9] This means that most health care professionals will face the challenge of prescribing for elderly patients. In the last decade, medical and nursing curricula have changed, with less time being devoted to basic sciences such as pharmacology.[10, 11] The focus of medical curricula has changed from basic science discipline-based to integrated organ- and disease-based approaches since the introduction of problem based learning in the 1970-1980s in many places in the world,[11-13] and in nursing curricula there has been a shift from a biomedical model focused on curing to a holistic model focused on caring.[10] This has frequently resulted in abandoning separate pharmacology courses and integrating pharmacology in problem-oriented courses. The lack of a thorough grounding in the medical sciences might contribute to insufficient knowledge of clinical pharmacology and drug therapy.[14] Moreover, there seem to be few effective programmes for teaching health professionals' prescribing skills. The systematic review of Ross et al. identified the "World Health Organization (WHO) guide to good prescribing" as the only effective programme for teaching medical students how to prescribe.[15, 16] Little is known about the education in pharmacology given to health professionals other than medical students, and even less is known about their education in geriatric pharmacology.

Given the high rates of medication errors worldwide, we hypothesized that health professionals receive insufficient education in pharmacology, and especially in geriatric pharmacology, during their training. We performed a systematic review to gain insight into education in geriatric pharmacology in terms of its volume and content in curricula and to establish what constitutes effective education in geriatric pharmacology.

METHODS

The review was performed using the PRISMA guidelines for systematic reviews and meta-analysis and the Cochrane guidelines.[17, 18]

Data sources and search strategy

To put education in geriatric pharmacology in the context of education in general pharmacology, we searched the literature for studies on education in pharmacology, focusing on the literature after 2000. The reason to limit the search to the period between 2000 and 2011 is to minimize results from curricula that do not exist anymore. Medical curricula change regularly and many turned to problem-based formats. An 11 year period provides a reasonable chance to report on current practices.

The databases PubMed, Embase, and PsycINFO were searched from 1 January 2000 to 11 January 2011 using the terms "pharmacology" (in title/abstract) combined with "education" (in title), and synonyms. Articles on education in geriatric pharmacology were manually selected from this broader search, because adding the term "geriatric" and synonyms resulted in an improbably low number of articles. Limits other than time limits were not used in the searches. The search syntax used in PubMed, Embase, and PsycINFO is depicted in Figure 1.

FIGURE 1. **syntax of search in PubMed, Embase and PsycINFO**

PubMed [title]	Education OR educating OR educate OR educated OR educators OR educator OR educative OR educates OR educations OR educationist OR educationally OR educational OR training OR teaching OR lessons OR train OR teach OR lesson OR learning OR learn OR learned OR taught OR trained OR skill OR skills OR curriculum OR curricula OR courses OR course
PubMed [title/abstract]	Pharmacology OR pharmacy OR pharmacological OR pharmaceutical OR pharmacotherapy OR medication OR prescribing OR prescription OR prescribe OR drug therapy

All duplicate articles were excluded and the remaining articles were screened on title, abstract, and full text. If an abstract was not available, the full text of the article was screened. If the full-text article was not retrievable from the corresponding author or from national university libraries, the article was excluded. Articles cited by another article for the description of the education were included as related article.

Study selection

First, all titles were screened for relevance using the following exclusion criteria: (a) animal studies or non-human pharmacology education, (b) content not (pharmacology) education, (c) education for patients or informal caregivers, (d) educational terminology used with a non-educational meaning e.g. teaching hospital. Second, the abstracts were screened for relevance using the same exclusion criteria as above with the additional exclusion criterion language different from English, German, or Dutch. Third, all relevant full-text articles were screened using the following exclusion criteria: (a) language different from English, German, or Dutch, (b) education for patients or informal caregivers (not health professionals), (c) does not contain description of pharmacology education in terms of content or quantity, (d) only congress abstract available without a description of education, (e) full text not available.

Study eligibility criteria

We considered all articles on education in geriatric pharmacology for health professionals. Education was defined as any structured educational activity. First, all articles describing pharmacology education for health professionals were selected. Articles were eligible if the education was described in terms of study load (study hours or content; content was described in terms of educational topic and teaching method). Second, articles on education in geriatric pharmacology were selected from the articles on pharmacology education, namely, articles covering geriatrics as educational topic, specific geriatric syndromes (e.g., Alzheimer's disease, delirium), or specific problems common in a geriatric population (e.g., polypharmacy, renal failure). There were no eligibility criteria for study design. All articles on education in geriatric pharmacology were independently assessed by three authors (CK, LvH, LJ) in terms of the educational content, load, and evaluation. The reviewers reached full consensus on eligibility of the studies after discussion.

Data extraction

To enable comparison of education in geriatric pharmacology and general pharmacology, we extracted information about the status of the education (mandatory or elective). If the education was given as part of a university or school curriculum, it was assumed to be mandatory if not mentioned otherwise. The study load was extracted and described in terms of study hours devoted to pharmacology education, and in proportion to the total study load, if this information was provided. Credit hours (CH) were transformed to 40 study hours, ECTS (European Credit Transfer System) to 28 study hours, and 1 day to 8 study hours if not described otherwise in the article. Education was classified by health profession and by undergraduate or postgraduate level.

Qualitative grading

The methodology used to evaluate the education, summarized as strength of findings, and the impact of the studies were graded. The Best Evidence Medical Education (BEME) criteria were used to grade the methodology.[19] The BEME score is based on critical appraisal of the study and reflects the credibility of study results. Scores range from 1 to 5: level 1, no clear conclusions can be drawn, not significant; level 2, results ambiguous, but there appears to be a trend; level 3 conclusions can probably be based on the results; level 4 results are clear and very likely to be true; and level 5 results are unequivocal. The Kirkpatrick model of hierarchy of evaluation, modified by Freeth, was used to evaluate the impact of the education.[20, 21] Scores range from 1 to 4: level 1, learners reaction; level 2a, modified attitude; level 2b, acquisition of knowledge or skills; level 3, behavioural changes; level 4 a, change in organisation practice and level; 4b, benefits to patients.

Data synthesis

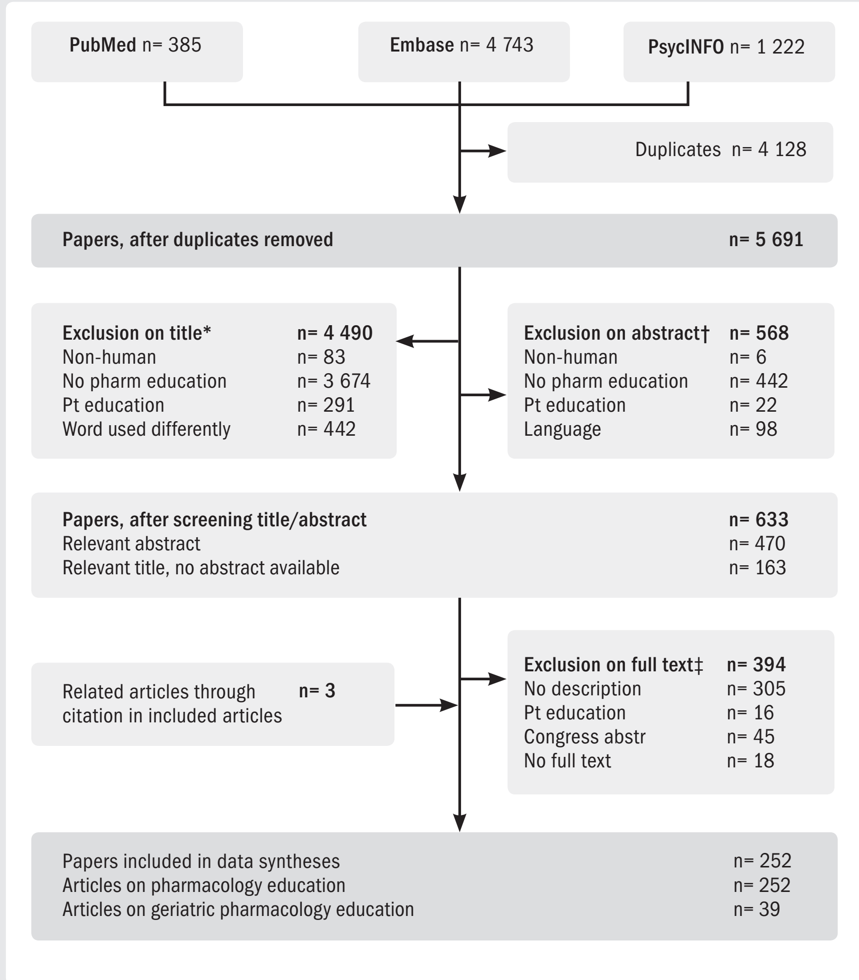
All descriptive analyses were performed in SPSS 15.0. The proportion of articles published in different years, in different continents, and with regard to different health professions were calculated. When ranges of study hours were given in an article, these were not used to calculate median values.

RESULTS

Search results

Figure 2 shows the flowchart of the review. Of 9819 articles retrieved, 252 concerned pharmacology education and were included. Of these 252 articles, 39 reported on education in geriatric pharmacology as defined in the eligibility criteria.

FIGURE 2. **search results with reasons for exclusion**



* ***Exclusion criteria:*** *Non human = animal studies or non-human pharmacology education No pharm education = content not (pharmacology) education Pt educ = education for patients or informal caregivers (not health professionals) Word used diff = the word education is used in a different way than education (e.g. teaching hospital, learning disabilities)*

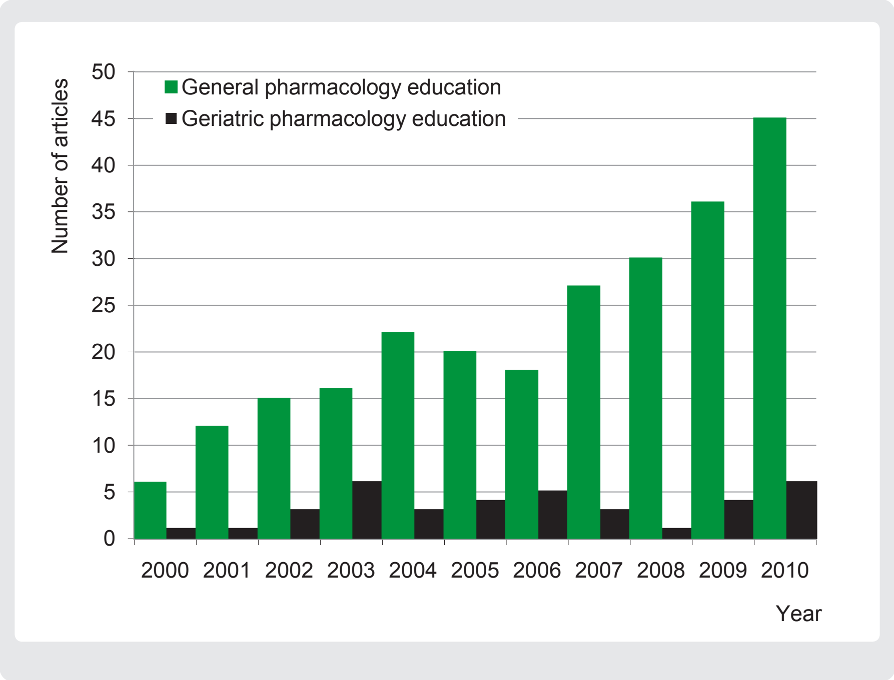
† ***Exclusion criteria:*** *Language = language other than English*

‡ ***Exclusion criteria:*** *No description = does not contain objective and quantitative description of pharmacology education. Congress abstr = only congress abstract available without a quantitative description of education No full text = not available in full text for screening, despite all efforts, and thus excluded.*

Study characteristics

The number of articles on pharmacology education appeared to have increased in the past decade, from 6 articles in 2000 to 45 articles in 2010. No such trend was seen for articles on education in geriatric pharmacology (Figure 3).

FIGURE 3. **number of articles found for general and geriatric pharmacology education per year**



Most articles came from North America and Europe, 106 (42.6%) and 82 (32.9%) respectively, and mainly from the USA (n=90, 36.1%) and the UK (n=37, 14.9%). However, all continents were represented in the literature on pharmacology education. The topics described in most articles on pharmacology education were clinical pharmacology and therapeutics (28.5%), different medication groups (9.2%), geriatrics (6.4%), and basic knowledge of pharmacology (6.0%).

TABLE 1. **time spent on education in general pharmacology and geriatric pharmacology for different health professionals and students.**

TIME SPENT ON EDUCATION BY HEALTH PROFESSIONAL		ARTICLES (n)		GENERAL PHARMACOLOGY EDUCATION†	GERIATRIC PHARMACOLOGY EDUCATION†
	HEALTH PROFESSIONAL	general pharm educ	geriatric pharm educ	education time median h (range)	education time median h (range)
UNDERGRADUATE	Medical student	61	12	80 (1.5-4956)	1.5 (1-23)
	Pharmacy student	85	13	20 (1-400)	10 (1-160)
	Nursing student	16	2	13 (1.25-85)	na
	Paramedical student	2	na‡	20	na
	Dental student	1	na	20	na
	Nurse practitioners students	1	1	na	na
POSTGRADUATE	Physician	47	11	8 (0.5-160)	2 (1.25-23)
	Pharmacist	21	2	20 (0.25-935)	471 (7-935)
	Nurse	25	na	15 (0.25-304)	na
	Physician Assistant	1	na	3	na
	Nurse Practitioners	1	na	3	na
	Other paramedical health prof	2	na	38	na
	Total*	**263**	**41**	**24 (0.25-4965)**	**2 (1-935)**

the proportion to the total study load could not be calculated due to lacking data on total study load in the majority of studies.
† *89 articles lacked a description of the education time and were left out of the calculations*
* *11 articles had descriptions of education for more than one health professional*
‡ *na:data not available*

Education in general and geriatric pharmacology

A median of 24 hours (range 0.25–4965 hours) was devoted to education in general pharmacology and a median of 2 hours (range 1–935 hours) to education in geriatric pharmacology.(Table 1) The majority of studies did not provide information about the total study load, therefore the proportion of the total study load could not be calculated for neither general nor geriatric pharmacology education.

There were no studies reporting education in geriatric pharmacology for paramedical students, dental students, nurses, nurse practitioners, and physician assistants, and other paramedical health professionals. As shown in Table 1, the geriatric pharmacology study load was described for undergraduate and postgraduate medical and pharmacy courses only.

Table 2 describes the content, study load, and evaluation of education in geriatric pharmacology in undergraduate (n=18) and postgraduate (n=14) curricula. Twenty-four of the 32 articles (61.5%) presented data on the evaluation of education in geriatric pharmacology.

Undergraduate education in geriatric pharmacology

As shown in Table 2, there was no uniform course on geriatric pharmacology for medical, pharmacy, or nursing students, with courses differing in terms of topics covered and/or teaching method. There was little evidence that the education in geriatric pharmacology was effective: 67% (12 out of 18) of the educational programmes had methodological problems and/or low levels of impact, such as students' satisfaction. No evaluation studies were replicated. Of articles reporting on courses for medical students, Franson et al. described an effective e-learning programme for pharmacology, in which geriatrics was one of the topics covered.[22] Dubois et al. reported that a therapeutic plan-writing course improved the therapeutic plan-writing skills of students who completed the course.[23] With regard to pharmacy students, Sauer et al showed that an ambulatory care service rotation improved students' attitude towards the elderly.[24]

Seven survey studies have provided a general overview of education in geriatric pharmacology for different student health professionals, but did not describe its content or evaluation.[10, 25-30] Of these studies, five concerned surveys with large methodologically differences of the American and Canadian schools and universities for pharmacy showing large differences in the provision of courses on geriatric pharmacology. Taken together, these studies describe that 53-100% of the schools and colleges provided some education on the topic within separate non-integrated courses, integrated education, or during geriatric clerkships.[25-29] One study showed that all UK colleges of nursing provided some form of education in medicine and the elderly.[10] Another survey of the schools for nurse practitioners shows that 96% covered the topic “elderly individuals” in the pharmacology and pharmacotherapy course.[30]

Taken together, no single undergraduate course in geriatric pharmacology has been broadly implemented, i.e. no examples of geriatric pharmacology education were reported to be used inter-institutionally, and no studies evaluating educational interventions have been replicated.

Postgraduate geriatric pharmacology education

Again, there were no uniform postgraduate courses on geriatric pharmacology for physicians or pharmacists, with courses differing in their content and/or teaching methods. Twelve of the 14 articles (86%) evaluated courses, but there were methodological problems in most studies. In contrast to the undergraduate courses, the postgraduate courses were mostly evaluated in terms of improving patient care. Again, no educational programme was evaluated more than once. For general practitioners, Midlov et al showed that outreach visits could decrease benzodiazepine use in elderly patients.[31] Pimlot et al showed that educational bulletins and feedback on prescriptions for general practitioners could cause a small, probably not relevant, decrease in the use of long-acting benzodiazepines.[32] For residents, Naughton found a reduction in inappropriate NSAID use after polypharmacy medication review and lectures.[33] Baum et al showed that a lecture for senior physicians and residents on renal failure adjustments led to a decrease in medication misdosing.[34] Demirkan et al evaluated a course for pharmacists containing lectures and workshops about drug therapy for groups at risk.[35]

Taken together, there was no broadly implemented course on geriatric pharmacology in postgraduate curricula for physicians or pharmacists, i.e. no examples of geriatric pharmacology education were reported to be used inter-institutionally, and no studies evaluating educational interventions have been replicated.

TABLE 2. pre- and postgraduate geriatric pharmacology education, sorted by health professional

PRE- AND POSTGRADUATE GERIATRIC PHARMACOLOGY EDUCATION									
Author	Health professional	Course description	Quantitative description†	Type of teaching	In curriculum‡		Evaluation	Level of evaluation◊	Strength of findings¶
UNDERGRADUATE									
Estus 2010 [52, 53]	pharm students* (pharmD)	geriatric pharmacotherapy	120 hours (3 CH)	Facebook, "adopt a patient", patient cases, book & film clubs, lectures, scientific and reflective writing	yes	elective	students' (n=28) satisfaction on Facebook use: 93% valuable. Students' (n=92) satisfaction on other teaching methods: 3.8-4.7 out of max 5 points	1	1
Jaedhe 2009 [54]	pharm students	individual pharmaco-therapy 1/6 topics geriatric patients	5 h for 6 topics	lectures	yes	both	?		
Divine 2009 [55]	pharm students	polypharmacy adherence as part of geriatric course	total course 120 hours (3 CH)	polypharmacy medication simulation project, reflective assignment	yes	elective	qualitative research on students' satisfaction (n=173, response rate 100%): 83% positive comments on education open ended questions	1	1
Ross 2006 [56]	pharm students	vertical integrated course. 68 topics of which Alzheimer, M Parkinson	80 h for 68 topics	small groups	yes	mand	?		
Sauer 2005 [24]	pharm students	ambulatory care service learning, community geriat-rics experience	6 wk, half time	rotations	yes	mand	qualitative research using portfolio essays: 107 of 117 portfolios studied, essay pre-experience and post-experience. Students' attitudes towards elderly improved.	2a	4
Lam 2005 [57]	pharm students	geriatric clerkship	160 h	clerkship	yes	elective	students n=24. 65% of written advice to prescrib-ers were accepted	4b	1
Bratt 2003 [58]	pharm students	CNS § pharmacol-ogy, 1 topic: Al-zheimer	10 h	integrated, hybrid lecture and PBL containing lectures, seminars and self study	yes	mand	of 104 students 51.4% preferred traditional lectures to the PBL. 54.2 % PBL did aid knowledge retention. Mature students (44%) vs younger students (25.8%) preferred PBL over traditional lectures (p<0.01, Mann-Whitney U rank sum test)	1	1
Strohkirch 2003 [59]	pharm students	clinical pharmacol-ogy. Topics: geriat-rics, renal failure, medication review	?	lectures, workshops, bedside teaching, practice simulation	yes	elective	?		
George 2011 [60]	medical students, residents, fellows	geriatric pharmacotherapy	23 times, 1 h sessions	seminars using the Medication Screening Questionnaire	yes	?	qualitative evaluation of education. 163/241 participants. 99% (strongly) agreed that overall quality of the sessions was excellent. All (strongly) agreed on meeting learning goals.	1	1

TABLE 2. **continued**

Author	Health professional	Course description	Quantitative description†	Type of teaching	In curriculum‡		Evaluation	Level of evaluation◊	Strength of findings¶
PRE- AND POSTGRADUATE GERIATRIC PHARMACOLOGY EDUCATION									
UNDERGRADUATE									
Naritoku 2009 [61]	medical students	pharmacotherapeutics, 1 topic alzheimer	1 h	(interactive) lectures	yes	mand	n=39, response rate 64%. Students' satisfaction on Alzheimer topic: 4.7±0.61 (out of 5)	1	1
Franson 2008 [22]	medical students	pharmacology, 1 topic geriatrics	average time 1-2 h	e-learning	yes	mand	1100 students, >175000 hits. Time spent on the program associated to grades on topic: regression equation grade = 5.02+0.034*time spent on program	2b	3
Dubois 2007 [23]	medical students	geriatric pharmacotherapy	?	therapeutic plan writing and self-study computer materials	yes	both	cohort 1999 vs cohort 2000 with intervention: percent students sufficient result on therapeutic plan writing in intervention cohort compared to pre-intervention cohort (two sample t-test, p<0.05)	2b	4
Smith 2006 [62]	medical students	polypharmacy as part of rational prescribing course	12 modules	e-learning	yes	?	in total 363 students on online survey (response rate 6-13% in different years): 91-92% content module appropriate, 78-86% felt equipped to prescribing	1	1
Eroglu 2003 [63]	medical students	pharmacology education, geriatrics 1/17 subjects	24 h for all 17 subjects	PBL	yes	mand	?		
Herzig 2003 [64] Antepohl 1999 [65]	medical students	pharmacology course, 1 topic M Parkinson	3 h per topic	PBL tutorials, classroom teaching vs lectures	no		pre-test, post-test, post-test after 18 month showed no differences in the PBL group (n=55, mean score on final test 20.1 ± 5.0) versus the lecture based learning group (n=57, mean score on final test 19.0 ± 4.7) on pharmacology knowledge. 80 students were lost to follow up for the final post test.	2b	1
Faingold 2002 [66]	medical students	CNS. Topics: M Parkinson, Dementia	1.5 h for both topics together	integrated, lectures, small groups	yes	mand	?		
Lathers 2002 [67]	medical students, residents	geriatric clinical pharmacology	2 h	clin pharmacology problem solving unit (CPPS). Case based learning	yes	?	of 455 students and residents 40% (range in different years 25-65%) found it useful for learning	1	1
Lim 2006 [68]	nursing students	elderly pharmacokinetics	?	integrated, PBL	yes	mand	?		

TABLE 2. **continued**

PRE- AND POSTGRADUATE GERIATRIC PHARMACOLOGY EDUCATION									
Author	**Health professional**	**Course description**	**Quantitative description†**	**Type of teaching**	**In curriculum‡**		**Evaluation**	**Level of evaluation◊**	**Strength of findings¶**
POSTGRADUATE									
Leikola 2009 [69]	pharmacists	comprehensive medication review, rational prescribing, clinical pharmacology	935 h (35 ECTS)	seminars, e-learning, learning in practice	yes	elective	online evaluation (n=38, response rate 90%): 92% met educational needs, 95% would recommend training to peers.	1	1
Demirkan 2004 [35]	pharmacists	good practice pharmacists, 1 topic: group at risk (geriatric, renal and liver failure)	7 h	lectures, workshops	yes	elective	95 pharmacists participated: score on pretest vs posttest on all topics: 36.1±7.9 vs 56.6±10.3	2b	3
Strohkirch 2003 [59]	pharmacists	clinical pharmacology	1 year, 4 modules at University	practice in own work environment, online support	yes	elective	?		
Warshaw 2010 [70]	GP	medication management as part of geriatric education	1.25 h medication management	presentations	yes	?	60 GPs: response rate 80-93% (over different years). Score 3.8 out of 4 on presentation content, quality and meeting educational needs	1	1
Midlöv 2005 [31]	GP	psychoactive drugs	2 visits	outreach visits	no		decrease in benzodiazepine prescribing after 9 month in intervention group (n=23) compared to control group (n=31) (p<0.05). GP's satisfaction: median 8-10 out of 10 on 6 subjects.	1,4b	4
Straand 2006 [71]	GP	pharmaco-therapeutics	2 visits, 8 h workshop	outreach visits, workshops, feedback reports	no		?		
Pimlott 2003 [32]	GP	benzodiazepine use in elderly	3 times in 6 months	educational bulletins, feedback on prescriptions	no		randomisation of physicians. Intervention (n=168) vs control group (n=206): 0.7% decrease vs 1.1% increase in long-acting benzodiazepine (p=0.036, not clinical relevant), no other significant differences	4b	3
Lutters 2004 [72]	hospital physicians	antibiotics prescriptions in elderly	weekly ward rounds	ward rounds with infectious disease specialist, lectures, individual counselling, pocket cards	yes	mand	interventional cohort study (before, during and after intervention): 680 patients receiving antibiotics included: 15% reduction in proportion patients receiving antibiotics (p=0.08), 26% reduction in number of antibiotics administered (p< 0.001). In 83/110 patients, guidelines correctly implemented	4b	2

TABLE 2. **continued**

PRE- AND POSTGRADUATE GERIATRIC PHARMACOLOGY EDUCATION									
Author	**Health professional**	**Course description**	**Quantitative description†**	**Type of teaching**	**In curriculum‡**		**Evaluation**	**Level of evaluation◊**	**Strength of findings¶**
POSTGRADUATE									
George 2011 [60]	residents and fellows, medical students	geriatric pharmacotherapy	23 times, 1 h sessions	seminars using the Medication Screening Questionnaire	yes	?	qualitative evaluation of education. 163/241 participants. 99% (strongly) agreed that overall quality of the sessions was excellent. All (strongly) agreed on meeting learning goals.	1	1
Naughton 2010 [33]	internal medicine residents	polypharmacy training as part of NSAID prescribing training	7 monthly modules	patient chart review, lectures	yes	mand	35 postgraduate internal medicine residents. preintervention vs post intervention: reduction in NSAID prescribing after 1 year: 29% vs 16% (p=0.002), reduction NSAID and diuretics 14% vs 7% (p=0.024)	4b	3
Baum 2009 [34]	residents, senior physicians	renal failure adjustments	2 h	lecture	yes	?	8 physicians. 2 patient cohorts: pre-education (n=85) versus post-education (n=85). Cohort 1 55/85 misdosing vs cohort 2 28/85 misdosing at day 2 of hospital admission (p=0.05)	4b	3
Montagnini 2004 [73]	internal medicine residents	geriatric and palliation rotation	month rotation. Hours education on pharm?	lectures, bedside teaching, conferences, practice based learning	yes	mand	28 residents completed the evaluation forms (prerotation and postrotation). On palliation topics (incl delirium), residents self-assessments increased from 2.89-3.71 to 4.10-4.67 (out of 5). p< 0.00001	2b	2
Lathers 2002 [67]	residents (medical, psychiatry), med stud	geriatric clinical psychopharmacology	2 h	clinical pharmacology problem solving unit (CPPS)	yes	?	of 455 students and residents 40% (25-65%) found it useful for learning	1	1
Meagher 2009 [74]	health care workers	pharmacotherapy in delirium	2 h	workshop	no		congress workshop. N=66 (response rate unknown). Pre-education vs post-education on rating adverse events: concerns regarding extrapyramidal side effects reduced (52% vs 21%; p<0.001). Post-education survey on future pharmacotherapy: positive attitude regarding prophylaxis in high risk patients: 56% respondents.	2a	1

** Pharm students= pharmacy students*
† CH= credit hour, ECTS= European Credit Transfer System
‡ Mand= mandatory
§ CNS= central nerve system
◊ Modified level of evaluation of Kirkpatrick
¶ Strength of findings after critical appraisal

DISCUSSION

The increasingly complex pharmacotherapy, especially in elderly, and medication errors due to health professionals' lack of knowledge of drug therapy, leads to an urgent need to improve health professionals' geriatric pharmacology knowledge. This review shows that interest in education in general pharmacology is increasing, with undergraduate and postgraduate courses providing a median of 24 hours of teaching in general pharmacology. In contrast, interest in education in geriatric pharmacology has not increased in the last decade, with undergraduate/postgraduate courses providing a median of 2 hours of teaching in geriatric pharmacology per course. Taken together, we found that undergraduate and postgraduate curricula for different health professionals devote relatively little study time to general and geriatric pharmacology. We could not retrieve reliable information on the proportion of time spent on geriatric pharmacology education relative to general pharmacology or to the total study load in the described curricula. Above, we could not find any information on the ideal study load on and content of geriatric pharmacology education. Educational programmes in geriatric pharmacology have not been broadly implemented in curricula and have hardly been proven to be effective in evaluation studies. We conclude that there is no inter-institutional consensus about a best approach to geriatric pharmacology education.

While one would expect more time to be devoted to geriatric pharmacology education research, given the increasing interest in evidence based medical education[36] and the high rate of medication errors in the vulnerable elderly,[1, 37] this would not appear to be the case, even though databases such as PubMed showed increased numbers of publications searching for geriatrics, pharmacology, and education separately. This review shows that the interest in research in general pharmacology education does increase in contrast to research in geriatric pharmacology education. Above, the need for improvement in geriatric education seems to be a worldwide issue for different health professionals.[38, 39] Taken together, it remains unexpected and unclear why education in geriatric pharmacology specifically does not have an increasing interest as pharmacology and geriatric education seem to have. This may underline the need for improvement in geriatric pharmacology education and research on this topic.

In contrast to ideas about the content and study load of a core curriculum for medical students, no mention is made of how many hours should be devoted to teaching geriatric pharmacology.[11] Although a clear norm on study load is not available, given the problems of complex pharmacotherapy in elderly the current study load probably isn't sufficient.[1]

None of the courses in geriatric pharmacology have been thoroughly researched and been proven to be effective, and no studies reporting education in geriatric pharmacology for paramedical students, dental students, nurses, nurse practitioners, physician assistants, and other health professionals were found. We did not find clear best practices, but many interventions concerned polypharmacy, dose adjustments in elderly and in renal failure, and psychopharmacotherapeutics. This seems to be a logical choice for the content of the education, because, these are all known risk factors for medication errors.[3, 40, 41] Odegard et al. suggested teaching geriatric pharmacology to pharmacy students in terms of values, attitudes, knowledge, and skills.[42] Besides, in contrast to education in geriatric pharmacology, there is an effective educational programme for general pharmacotherapy. Medical students and junior doctors can be taught how to prescribe with the WHO "Guide to good prescribing", or WHO-6-step method, a broadly evaluated educational intervention on prescribing.[15, 16]

The need to improve the pharmacological training of different health professionals is clear because it may decrease harmful medication errors.[1] In general, training is most effective if it fulfils three criteria: it is offered throughout the study, it is integrated in the curriculum, and it is placed in the context of clinical cases. Studies have shown that knowledge is best acquired and retained if it is imparted regularly in small portions,[43] and that integration in the curriculum can lead to a more contextualized approach to learning.[44] Integration can be horizontal, with a more-or-less interdisciplinary approach within study years, or vertical, with integration between theoretical knowledge and clinical practice throughout the study years.[44, 45] Moreover, education with a focus on contextualisation of pharmacology problems has been shown to improve pharmacotherapeutics.[46] A longitudinal course on clinical pharmacology and pharmacotherapy, although not specifically on geriatric pharmacology education, is described by Richir et al. and fulfils these criteria.[47]

This study had several limitations. It was based on the literature, and the literature might not accurately reflect the amount of teaching devoted to specific topics in existing curricula. A large publication bias is likely. Therefore, it is difficult to draw conclusions about how many hours are actually spent on the topic. In this review, we primarily focused on evidence based education with proof of efficacy of the education. However, in medical education research this proof is difficult to acquire since it is methodologically difficult to effectively tie curricular interventions to relevant long term outcomes. This is due to the large and partly unclear set of variables of the contextual rich environment of medical education. One way to improve education might be to focus on understanding collective theoretical problems in this contextual rich environment e.g. students' motivation, instead of looking for proof of the efficacy of a specific intervention.[48] Related to this problem, it must be noted that the evidence for improving pharmacotherapy education leading to a reduction in medication errors in clinical practice is still weak. However, it is a generally accepted focus for preventing medication errors.[1, 49] Since mainly junior doctors are involved in medication errors it can be assumed that quite some knowledge acquisition occurs, often implicitly, through experience in the workplace.[50, 51] Explicit learning such as courses might make this implicit learning more explicit. In this review we only addressed explicit learning. Lastly, as we concentrated on studies published after the major curricular innovations of the late 1990s and the shift to problem based learning, we do not know how effective the 'traditional' curricula were in teaching general pharmacology and geriatric pharmacology in particular.

CONCLUSIONS

This review shows there is a considerable need to improve education in geriatric pharmacology for health professionals at both undergraduate and postgraduate levels, and that in general current curricula do not devote enough time to the teaching of pharmacology. Moreover, the best way to provide this education needs to be investigated. The content of geriatric pharmacology education should be related to known risk factors of medication errors in elderly, and especially focus on the appropriate prescribing in case of polypharmacy and renal failure and on the prevention of inappropriate prescribing of psychotropic drugs. The literature suggests that training in pharmacology might be most effective if it is offered throughout the medical curriculum, is integrated in the different disciplines, and is given clinical relevance in the form of case studies. More research in the field of geriatric pharmacology education may contribute to improving the care for older people.

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2.2

Education on prescribing in older patients in the Netherlands: a curriculum mapping

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ABSTRACT

Aim In recent decades pharmacology and pharmacotherapy education has become integrated in medical curricula. This may result in loss of specific knowledge on pharmacology and pharmacotherapeutics. This could result in prescribing errors and harm, especially in vulnerable older patients.

Methods At Dutch Medical Schools a structured interview on quantity and quality of (geriatric) pharmacology and pharmacotherapy education was performed with coordinating teachers. A list of core learning goals was developed.

Results All Dutch Medical Schools participated. Contact hours ranged from 39-107h, ECTSs ranged from 0-3. On average, 79% of all learning goals were covered by the curriculum: knowledge: 85%, skills: 76%, attitudes: 66%. And more specific for geriatric goals: knowledge: 88%, skills: 66%. All geriatric learning goals were covered if a geriatrician was among the coordinators. 4/8 medical schools lacked an appropriate assessment procedure. Evaluation was mostly based on students' opinions. The teachers rated their students as mediocre prepared for daily practice.

Conclusions Within the Netherlands, large differences in quantity and quality of (geriatric) pharmacology and pharmacotherapy education are shown. Skills and attitudes could receive more attention, especially geriatric pharmacotherapy skills. Assessment procedures should receive additional attention. This study indicates which best practices could be adopted.

INTRODUCTION

Medical education has changed in the last decades. Since the 1970s, problem-based learning (PBL) with integrated education has gradually become the standard in medical education worldwide.[1] These changes have improved the clinical performance of students during and after graduation and increased students' satisfaction.[1, 2] However, there is also ongoing debate about the potential disadvantages of PBL, such as a loss of knowledge of basic sciences,[1-3] and especially in pharmacology and pharmacotherapy.[4] Studies of drug safety have shown that the number of prescribing errors is high, which could adversely affect patient outcomes, leading to hospitalization or even death.[5, 6] An estimated 30% of these errors can be attributed to insufficient knowledge and skills on the part of prescribers.[7] Medical students tend to copy the drug treatment choices of their teachers during clinical clerkships instead of basing their choices on their own independent analysis of the problem,[8] which might be why junior doctors feel that they are not adequately prepared to prescribe after graduating.[9] Frail older people are at highest risk of prescribing errors because they often have multiple medical conditions for which they receive polypharmacy.[6] The relative number of older people will continue to increases as the life expectancy increases, and so in the future most physicians will have to prescribe for these individuals. For this reason, all future prescribers should receive adequate training in prescribing for patients with multiple comorbid conditions and polypharmacy.

However, there is little evidence-based education regarding geriatric pharmacology and pharmacotherapy. In fact, a literature review could not advise a specific educational intervention,[10] although the WHO-6-step method for rational prescribing is effective in the short and longer term.[11,12] There is still discussion about whether undergraduate curricula provide medical students with enough knowledge to prevent harm and negative patient outcomes. In 1994, Walley et al found that most curricula (89%) of UK medical schools had a traditional format with pharmacology and pharmacotherapy given as separate courses, followed by specific assessment of the content of the courses.[13] In 2009, O'Shaughnessy et al found large differences between UK medical schools in the content, learning strategies, and assessment procedures of curricula. In most medical schools, pharmacology and pharmacotherapy education was integrated vertically and/or horizontally.[14] However, given that most medical schools are still changing their curricula, these studies seem out of date.

We performed the current curriculum mapping study of training and education in pharmacology and pharmacotherapy, and with emphasis on prescribing for older people, provided by Dutch medical schools, with a view to gaining insight into the content, teaching and learning strategies, assessment, and evaluation procedures.

METHODS

Design

This was a cross-sectional observational study of the general and geriatric pharmacology and pharmacotherapy education given in Dutch medical schools, during the academic year 2012-2013. The curricula were studied by means of structured interviews.

Domain

All eight medical schools of the Netherlands with regular curricula participated. Two medical schools also offer shorter four-year medical courses with a bachelor degree in a biomedical science as entry requirement instead of a secondary school degree. The curricula of these medical courses were not included because they are not comparable with the other curricula. In the Netherlands, all coordinators of (geriatric) pharmacology and pharmacotherapy education at medical schools were asked to participate. They are all members of the Dutch Society of Clinical Pharmacology and Biopharmacy (NVKF&B).

Instrument: structured interview

A structured interview on the domains content, teaching and learning strategies, assessment and evaluation was developed for this study, based on the literature on curriculum mapping.[15] Items were classified by quantity and quality. Quantity was defined as the number of contact hours, the number of ECTS (European Credit Transfer System, 1 h represents a 28-h student workload), the number of learning goals taught, and the number of Full Time Equivalent (FTE) teachers. Because self-study hours can vary largely, these were not included. Quality of the education was studied by determining whether there were procedures for assessment and evaluation and by self-assessment, with coordinators being asked “to what extent does the curriculum prepare medical students for their future tasks as prescribers”. High quantity scores, high quality, or innovative teaching practices are described in more detail and are considered “best practices”.

List of core learning goals

The national blueprint for medical education “het Raamplan” was searched for pharmacology and pharmacotherapy learning goals, especially with reference to older people.[16] Although five items were identified, none referred to older people, and so we considered the national blueprint inadequate for our study goal. For this reason, we searched PubMed for articles on the core curriculum content of pharmacology and pharmacotherapy, using the terms “pharmacology” OR “pharmacotherapy” OR “prescribing” AND “curriculum” with synonyms (search date 29 April 2013). A total of 1354 hits yielded nine articles. After the addition of (inter)national report by grey search online, ten articles and eight reports were used as sources for learning goals. All goals mentioned at least twice were included in a final list of 47 core learning goals, divided into the categories knowledge, skills, and attitude.[17] Overall, there were 19 learning goals in basic and clinical pharmacology knowledge, 13 in general pharmacotherapy skills, 4 in general pharmacotherapy attitude, 7 in geriatric pharmacology knowledge, and 4 in geriatric pharmacotherapy skills. No learning goals were found for geriatric pharmacotherapy attitude.

Table 1 shows the learning goals by category. A detailed list is shown in appendix 1, which includes subheadings and references. This list was used in the interviews.

Data collection

Participants from all Dutch medical schools were sent a structured questionnaire before they completed it during an interview with the researchers CK and SB, who visited the medical schools for this purpose. These interviews, in which the questionnaire was systematically worked through, were tape-recorded for completeness; the researchers also took notes during the interview. All participants received their data by email so that they could provide feedback on misunderstandings or misinterpretations and then, after adjustment, to confirm that the data were correct.

Data analyses

Data were analysed with SPSS version 22.0. Apart from descriptive statistics, percentage of learning goals met was calculated as the number of learning goals the curriculum offered divided by the number of learning goals in the core learning goals list (Table 1).

Ethical approval

The national Ethical Review Board of Medical Education (ERB-NVMO) declared that this study did not involve the data of human subjects.

TABLE 1. list of core learning goals derived from literature divided by category

LIST OF CORE LEARNING GOALS		
Category	**Knowledge/ Skills/ Attitudes**	**Learning goals (n=47)**
Basic pharma-cology	Basic knowledge	· Introduction to pharmacology and therapy · Pharmacodynamics* · Pharmacokinetics* · Intra-individual variance and pharmacogenetics
Clinical pharma-cology	Applied knowl-edge	· Drug adherence, compliance and concordance · Therapeutic Drug Monitoring* · Adverse Drug reactions* · Drug interactions · Medication errors · Drug Development and regulation · Medicines Management · Evidence Based Prescribing · Ethical and legal aspects of prescribing · Prescribing for patients with special requirements (expect older patients) · Rational prescribing* · Clinical toxicology · Misuse of drugs · Complementary and alternative medicine · Use of antimicrobial drugs and resistance
Geriatric pharma-cology	Knowledge	· Altered physiology in old people · Altered pharmacokinetics in old people · Altered pharmacodynamics in old people · Different response in frequent used drugs in old people · Principles that underlie prescribing in old people · Polypharmacy · Finding relevant information on drug and dose adjustments
Geriatric pharma-cotherapy	Skills	· Basic elements of geriatric pharmacotherapy · Avoid potentially harmfull drugs · Monitoring medication in old people · Interpret physical, laboratory, and diagnostic test results in accordance with age related changes
Medication related attitudes	Attitude	· Risk-benefit analysis recognition · Recognizing personal limitations in knowledge · Recognition of balanced approach to the introduction of new drugs · A new prescription as an experiment

TABLE 1. continued

** These five learning goals are also described in the National educational blueprint "het Raamplan"*

RESULTS

All eight medical schools in the Netherlands participated and their seventeen coordinators were interviewed in the period June-October 2013. Table 2 presents the results of these interviews.

Teaching and learning strategies

All medical schools had a planned curriculum for general and geriatric pharmacology and pharmacotherapy, and all had a more-or-less integrated and problem-oriented curriculum. Four of eight curricula offered pharmacology and pharmacotherapy as a longitudinal learning course throughout the curriculum, with learning activities in different study years. The learning strategies most frequently used were the tutorials, (web) lectures, and e-learning. Two e-learning programs have been developed in the Netherlands: Pscribe for rational prescribing and Teaching Resource Centre for pharmacology and applied pharmacology (TRC).[18, 19] Learning resources clearly differed. Although identical books were often used, at some schools students mostly relied on practice tests, whereas others mostly used Web lectures on Youtube. All medical schools used the WHO-6-step method.[12]

TABLE 2. **summary of results**

SUMMARY OF RESULTS	
Domain	**Results**
Teaching and learning strategies	
Curriculum design	All less or more integrated and problem oriented
Teaching strategy	Dominant strategies: · Tutorials · (webbased)lectures · E-learning · Learning course throughout curriculum 4/8 · WHO-6-step: 8/8
Study materials	Most frequently: books
Content	
Contact hours	Mean 71h (SD±25, range 39-107)
ECTS	Mean 1.0 (SD±1,2, range 0-3)
Learning goals	Compared to Dutch Blueprint: 90% (SD ±15%) Compared to core list (table 1 and appendix 1) · Pharmacology knowledge: 85% (SD±12%). · Pharmacotherapy skills: 76% (SD±19%) · Pharmacotherapy attitudes: 66% (SD±33%). · Geriatric pharmacology knowledge: 88% (SD±30%) · Geriatric pharmacotherapy skills: 66% (SD±27%)
Assessment procedures	
	4/8 medical schools offer separate assessments 4/8 medical schools offer only integrated assessments
Evaluation	
Procedure	Mostly students evaluations 3/8 at the level of individual teacher or learning activity
Self-assessment of students level after graduation	Mostly mediocre

Quantity

Contact hours and ECTS: The number of contact hours assigned to pharmacology and pharmacotherapy education varied among schools (mean 71±25 h, range 39 h-107 h). Subdivisions over the different topics could not be made, due to the integrated design of the educational program. Few credit points were specifically awarded for pharmacology or pharmacotherapy education (0-3 ECTS, mean 1.0 (SD ±1.2)).

Learning goals: Overall, the coordinators thought that on average 90% SD ±15% of the learning goals of the Dutch list of learning goals “Raamplan” would be met by the time students graduated, but there were differences between the medical schools regarding which goals that would be met in comparison to the list of learning goals derived from literature as shown in Table 1.

FTE available: The number of FTE available for the coordination of education and training could not be compared because the medical schools used different financial systems. For example, in some schools FTE covered only the coordination of education, with extra FTEs being awarded for teaching activities, whereas other schools considered the FTEs for coordination to include all activities.

Quality

Assessment: 50% of the medical schools (4/8) explicitly assessed students’ pharmacology and pharmacotherapy knowledge and skills. At the other schools, assessment of this knowledge was integrated in other exams.

Evaluation structure: Three medical schools had an evaluation cycle specified by learning activity and teacher, usually based on student evaluations. While the other medical schools also had evaluation cycles, these were tightly integrated so it was difficult to identify specific activities that could be improved.

Self-evaluation: The teachers/coordinators thought that medical students were moderately well prepared for their future tasks as prescribers.

Best practices

Dutch medical schools adopt different practices to optimize and monitor training and education. Two medical schools met more than 90% of the learning goals given in Table 1. Both schools had a clear matrix of learning goals that should be reached at a given time in the curriculum; the two schools had an average number of contact hours. At the medical schools where a geriatrician was part of the coordination team, all learning goals for geriatric pharmacology and pharmacotherapy were met. Newly developed learning methods had been introduced to all medical schools, such as Web lectures on Youtube, two e-learning programs Pscribe and Teaching Resource Centre's (TRC) Pharmacology, and the patient letter (an information letter for the patient after discharge with an explanation of changes to their medication list). Four medical schools had a longitudinal learning program throughout the curriculum. With regard to assessment, one medical school had a form of continuous assessment: the test scores for pharmacology and pharmacotherapy were collected throughout medical training and students could only graduate if their summed score was adequate. Another medical school used a 'prescribing Observed Structured Clinical Examination (OSCE)' to assess the students' knowledge and skills in a real-life clinical setting.[20] The other medical schools mostly relied on written assessments. Two medical schools were involved in research in pharmacology and pharmacotherapy education.

DISCUSSION

This study gives an overview of how well Dutch students are prepared to become safe prescribers, especially for the vulnerable old. In general, the curricula are based on PBL and education in pharmacology and pharmacotherapy is integrated throughout the curriculum. In half of the medical schools a longitudinal learning course is available. The WHO-6-step method is used at all medical schools.[12] The number of teaching hours for pharmacology and pharmacotherapy ranged from 39 h to 107 h and, on average, only 1 ECTS (representing a student workload of 28 h). Although the number of curriculum learning goals that were met was quite acceptable for knowledge items (85%), this was not the case for skills and attitude, and geriatric skills in particular (66%). Teachers rated their own students as being only moderately well prepared for their careers after graduation. Half of the schools hardly assessed the knowledge, skills, and attitude of their students before graduation.

Are these findings relevant to patient care? Medication-related patient safety is currently a hot topic in research, given the increase in the number of reports of the harmful effects of, often preventable, medication errors, and particularly in older patients.[21, 22] Changes to undergraduate curricula, which may result in poorer pharmacology knowledge and therapeutic skills, are often mentioned as a possible cause of prescribing errors.[4, 23] Although the curricula provided 39–107 contact hours of teaching in pharmacology and pharmacotherapy and additional

self-study is required, only a mean of 1 ECTS, representing 28 study hours, was dedicated to the teaching of pharmacology and pharmacotherapy. Moreover, because curricula tend to focus on pharmacology knowledge instead of skills and attitude, medication-related errors may occur. This is in contrast with the general notion that knowledge is a prerequisite for safe prescribing[23] and that the current curricula have a greater focus on skills and attitude than more traditional curricula.[2] Shortcomings of contemporary curricula may contribute to the increasing number of medication-related problems. Other plausible explanations include the increasing complexity of prescribing to often-frail old patients with multimorbidity and polypharmacy, the growing number of medicines, the increasing use of medication generally, the more rapid throughput of patients, and the increased specialization.[24] Although investigators mention that prescribing knowledge and skills will improve if education and training are improved, there is little empirical evidence for this.[22, 23] It is promising that the WHO-6-step method, which has proven to be effective, has been adopted by all Dutch medical schools.[11, 25] Moreover, in general it is best to provide education throughout medical training, with emphasis on the patient-related context.[26-28] The curricula of all the medical schools offered this integrated, patient-oriented approach. Taken together, both the WHO-6-step method and integrated education can form the basis from which to improve curricula. But what are the major points for improvement identified in this study?

Although prescribing without a "prescribing exam" is like driving without a driving license, pharmacology and pharmacotherapy skills and knowledge were assessed in only half of the medical schools. Hence, a major point for improvement is the assessment procedure, which may also improve learning efficiency.[29] Another suggestion is to give more emphasis to the acquisition of skills and attitude, and in particular geriatric pharmacotherapy skills. While knowledge is certainly needed as a solid basis, safe prescribing is a skill.[23] Attitude, such as "knowing limitations in own knowledge", is also important. It is difficult to assess skills and attitude, but two medical schools use an OSCE and a patient information letter to assess these skills.[20] The core learning goals presented in this study could be used as a test matrix, an overview of topics to be addressed in assessments, in order to optimize assessment procedures. This study shows several other best practices which can be adopted from another. Moreover, because in the Netherlands all coordinating teachers are united in the Dutch Society of Clinical Pharmacology and Biopharmacy (NVKF&B), which has regular meetings, a platform for improvement at a national level is available. As far as we know, such a platform and national cooperation on pharmacology and pharmacotherapy education is unique.

Although the results of this study involving all Dutch medical schools offer unique insights, they should be interpreted with appropriate caution. Perhaps the major limitation is our national approach, which decreases the generalizability of our findings to other settings. However, face-to-face contact is the only way to gain real insight into medical education and training. We spent an estimated 8 h per medical school. Findings would probably be more general or superficial if we had participated in an international study. We compared the number of contact hours based on self (coordinator)-report; we did not verify the accuracy of these data. Moreover, we might have introduced bias by using an interview design. Furthermore, it is possible that students are offered other learning activities within the integrated curriculum but which are outside the mandate of the curriculum coordinators, a so-called hidden curriculum.[30] We also did not include self-study hours, which vary per student. However, as these aspects are probably uniform to all the medical schools, we think that self-report bias was minimized. We only assessed certain aspects of education quality and did not investigate student satisfaction. Moreover, the experienced or learned curriculum may differ substantially from the offered and planned curriculum, which was studied in this article.[15] While UK medical students feel unprepared after graduation,[9] it is not known whether this is also true for Dutch medical students. The coordinators were of the opinion that the students were moderately well prepared for their prescribing tasks. Lastly, in order to give an idea on the contribution of the current curriculum to the increasing number of prescription errors, data for the previous curricula, before PBL and integration were introduced, are needed, but these data are not available or studied.

CONCLUSIONS

This study indicates that, in general, Dutch medical curricula are well constructed, although improvements could be made. For example, more attention should be paid to general and geriatric pharmacotherapy skills and attitude so that after graduation junior doctors should have good prescribing skills for patients of all ages, including the frail elderly. It would be appropriate to evaluate students' prescribing skills before graduation in a “prescribing exam” in a real-life clinical setting. The core learning goals presented in this study can be used to optimize assessment procedures, both nationally and internationally, so that by the time they graduate, students have been trained in good prescribing practice.

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APPENDIX 1

Pharmacology and pharmacotherapy knowledge, skills and attitudes for medical students in detail

BASIC PHARMACOLOGY KNOWLEDGE (N=4)

Introduction to Clinical Pharmacology and therapeutics

Introduction

- Explain the terms pharmacology, clinical pharmacology and thera-peutics
- Recognize the breadth of topics embraced by clinical pharmacology
- Recognize the importance of clinical pharmacology as the scientific discipline that underpins a rational approach to prescribing medicines

Drugs in healthcare and society

- Explain the terms drug and medicine
- Explain the extent of medicines use within the NHS
- Recognize the impact of prescription drugs in society
- Explain the extent of illicit drug use and its public health consequence

Pharmacodynamics

Mechanisms of drug action

- Define the term pharmacodynamics
- Identify molecular targets for drug action including receptors, ion channels, enzymes and transporters
- Identify cellular mechanisms of action including excitation, contraction and secretion
- Describe how these actions translate into responses at the tissue and organ level

Dose–response relationships

- Explain the relationship between drug dose and response
- Define the terms agonist, antagonist and partial agonist
- Explain the effect of antagonists on the dose–response curve of an agonist
- Explain the assessment of receptor selectivity
- Define the terms efficacy and potency
- Define the term 'therapeutic index'
- Describe the phenomena of desensitization and tolerance

Pharmacokinetics

Introduction to pharmacokinetics

- Explain the term pharmacokinetics
- Explain the four phases of pharmacokinetics
- Explain why an understanding of pharmacokinetics is relevant to prescribers

Drug absorption

- Explain the mechanisms of drug movement across physiological barriers
- Explain fundamental differences between various routes of drug administration
- Describe first pass metabolism and its importance
- Describe how one drug can influence the absorption of another

Drug distribution

- Explain the distribution of drugs across body compartments
- Define volume of distribution
- Explain how the distribution of a drug influences its pharmacokinetics

Drug metabolism and excretion

- Define phase I and II metabolism
- Explain the important role of the liver in drug metabolism
- Explain why drug metabolism is a potential point of interaction between drugs
- Explain the important routes of drug excretion from the body

Concentration–time relationships

- Describe the typical concentration–time curve for a drug with first order kinetics
- Explain the importance of zero order (saturation) kinetics
- Define clearance and half-life
- Define bioavailability

Repeated drug dosing

- Explain the pharmacokinetic factors that determine choice of dose, route and frequency of drug administration
- Explain the pharmacokinetics of repeated dosing including time to 'steady-state'

Explain fundamental differences between drugs with long and short half-lives

- Explain the rationale for loading doses

Individual variability in the response to drugs

Overview

- Identify the main factors influencing variability in response
- Explain how different pharmaceutical factors produce variation in response
- Explain how altered pharmacokinetic handling of drugs produces variation in response
- Explain how pharmacogenetic variation can influence the response to drugs
- Explain how pharmacodynamic factors can affect drug response (e.g. receptor sensitivity, tolerance, organdisease)

Pharmacokinetic variability

- Identify important groups of patients where pharmacokinetic handling of drugs altered is altered
- Explain in each of the cases above why handling is altered
- Explain in each of the cases above how this might have been predicted and the adjustments that might have to be made by prescribers

Pharmacogenetic variability

- Identify common ways in which genetic variation influences the handling and response to drugs
- Provide common examples where pharmacogenetic variation influen-ces prescribing
- Explain how increasing knowledge of pharmacogenetic variation will influence future prescribing practice

CLINICAL PHARMACOLOGY KNOWLEDGE AND APPLIED KNOWLEDGE (n=15)

Drug adherence, compliance and concordance

Adherence to medication

- Define the terms adherence and compliance, separating them from concordance
- Explain the scale of non-adherence and its consequences
- Identify measures to improve poor adherence whether intentional or unintentional
- Make an accurate assessment of adherence to medication

Concordance – partnership with patients

- Define the term concordance
- Describe the influence of patients' beliefs on adherence
- Identify the barriers to achieving shared decision making with patients
- Explain ways in which concordance can be improved(e.g. presenting accessible information)
- Describe how to discuss the benefits and risks of drug therapy with patients
- Describe how to explore patients' views and wishes in relation to drug treatment

Therapeutic drug monitoring

Overview

- Explain the importance of monitoring the impact of drug therapy

- Describe the ways in which therapy can be monitored including clinical outcomes, pharmacodynamics responses and plasma drug concen-trations
- Identify the prerequisites, advan-tages and disadvantages of each approach
- Identify common examples of where monitoring drug concentrations are important

Using drug effect
- Identify ways in which drug effects can be measured
- Explain why the impact of drugs on clinical outcomes is difficult to measure
- Identify the difference between a surrogate and hard outcome
- Explain what makes a good surrogate outcome

Using drug concentration
- Explain the variable relation between dose and plasma drug concentration, and between drug concentration and effect
- Describe the characteristics that make a drug suitable for monitoring by measurement of concentration
- List common medicines whose use is facilitated by measurement of drug concentration
- Describe the practicalities of measuring plasma drug concen-trations
- Explain how to interpret drug concentration measurements appropriately
- Explain how to adjust dosage in light of drug concentration measurements

Adverse drug reactions
Basic principles
- Define an adverse drug reaction and other adverse outcomes of drug therapy
- Explain the frequency of adverse drug reactions and their impact on public health
- Explain why all drugs have both beneficial and adverse effects
- Describe the common classification of adverse drug reactions (e.g. ABCDE)
- Explain the alternative classification based on dose, timing and susceptibility (e.g. DOTS)

Drug allergy
- Discuss risk factors for allergy/anaphylaxis
- List medicines that are commonly implicated in allergic reactions
- Explain how to identify and characterize an allergic drug reaction
- Explain the importance of accurate diagnosis and recording of allergic reactions to drugs
- Explain the precautions that should be taken to prevent allergic reactions

Diagnosis, interpretation and management
- Describe the principles of assessing drugs as a possible cause of new symptoms and signs
- Explain how to respond if an adverse drug reaction is suspected
- Explain how to manage a suspected adverse drug reaction

Avoiding adverse drug reactions
- Describe important risk factors that predict susceptibility to adverse drug reactions
- Describe how identification of those risk factors can influence prescribing decisions
- Identify sources of information about adverse drug reactions
- Explain the importance of warnings and monitoring in preventing adverse reactions

Pharmacovigilance
- Explain the ways in which adverse drug reactions can be identified (e.g. drug development, voluntary reporting, record linkage)
- Explain why the adverse drug reaction profile of individual drugs is unclear at launch
- Discuss the importance of and the prescriber's responsibility in pharmacovigilance

- Describe how to report a suspected adverse drug reaction using an on-line Yellow Card

Drug interactions
Overview
- Explain the potential for interacting drugs to cause beneficial and harmful effects
- Recognize the main ways in which interactions occur (e.g. pharmacokinetic, pharmacodynamic)
- Explain why the potential for drug interactions in increasing
- Identify sources of information about drug interactions to inform prescribing
- Explain how to predict and avoid drug interactions
- Explain how to adjust drug dosage in anticipation of a drug interaction that cannot be avoided

Liver metabolism
- Explain the importance of liver cytochromes as a point of drug clearance
- Identify the importance of liver metabolism as a point of interaction between drugs
- Explain how liver enzyme metabolism can be inhibited and the impact this has on drug handling
- Explain how liver enzyme metabolism can be induced and the impact this has on drug handling

Medication errors
Frequency and causes
- Define medication errors, including subtypes
- Describe human error theory in simple terms
- Identify individual and systems factors leading to error
- Describe how medication errors are reported
- Explain how to respond when a medication error isdiscovered

Prevention
- Explain how prescribers can reduce error
- Explain the importance of collaboration with pharmacists in preventing errors
- Explain how to identify and correct errors
- Describe the role of electronic prescribing and other approaches in reducing prescribing error

Drug development and regulation
Drug development
- Explain in simple terms how drugs are discovered
- Explain the various stages of development (preclinical, phase I to phase IV)
- Explain the risks and costs involved in developing drugs

Clinical trials
- Classify the different forms of clinical trial and explain their advantages and disadvantages
- Describe the requirements of a good clinical trial including consent, ethics, bias, statistics and dissemination of information

Drug regulation
- Explain why drugs need to be regulated
- Identify the major regulatory authorities in the UK and Europe
- Describe the approval process for new drugs in simple terms
- Explain the importance of market exclusivity and patents
- Explain how drug sales can be protected when patents expire

Drug marketing
- Explain the basics of how drugs are marketed by the pharmaceutical industry
- Explain the legal constraints on the marketing process
- Recognize the role of the ABPI code of conduct
- Describe the potential for the marketing

process to change attitudes
- Identify the uses and abuses of the drug promotionprocess

Medicines management

National processes
- Describe how new medicines are assessed on the basis of safety, efficacy and cost-effectiveness
- Describe the basic principles of pharmacoeconomic assessments
- Describe the roles of the National Institute for Health and Clinical Excellence (NICE) and equivalent bodies

Local processes
- Describe the role of local committees
- Explain the role of local formularies and guidelines in the choice and use of medicines
- Identify the factors that influence individual prescribingchoices and why these have to be limited (e.g. cost, antibiotic resistance)
- Explain the responsibility of prescribers to avoid wasteful prescribing and consumption of limited resources

Formularies
- Explain the relationship between the British National Formulary and local formularies
- Explain the reasons for creating limited lists of medicines
- Explain the processes involved in creating a formulary
- Identify the important issues relating to coordination of prescribing in primary and secondary care

Guidelines
- Describe the definition and purpose of a clinical guideline
- Explain some of the potential limitations and harms of clinical guidelines
- Describe the optimal development, dissemination and implementation of clinical guidelines
- Describe the legal standing of guidelines

British National Formulary
- Explain the history and development of the British National Formulary
- List the important resources contained within the British National Formulary
- Explain the limitations of the information contained in the British National Formulary

Evidence-based prescribing

Overview
- Explain the extent of the evidence base
- Explain the terms randomized controlled trial, cohort study, case control study, systematic review and meta-analysis
- Identify different kinds of evidence and their hierarchy in terms of validity
- Explain the limitations of applying clinical trial data to individual patients
- Explain the importance of keeping one's prescribing practice up to date with advances in medical knowledge

Critical appraisal of clinical studies
- Describe the process of critical appraisal of clinical studies
- Explain the approach to identifying methodological flaws, including sources of bias
- Differentiate between true and surrogate endpoints
- Explain the concept of external validity and problems with extrapolating clinical trial results

Finding reliable information about drugs
- Identify important information resources that mightinform prescribing decisions
- Explaining how prescribers can keep up to date withchange
- Identify potential sources of unreliable information

Ethical and legal aspects of prescribing

Legal aspects of prescribing
- Explain the legal categorisation of drugs into general sales list, pharmacy medicines, prescription only medicines and controlled drugs
- Explain who is entitled to prescribe medicines and the legal requirements involved
- Explain who is entitled to supply medicines and the legal requirements involved
- Describe the legal requirements associated with prescribing controlled drugs
- Explain common ways that drugs can be supplied illegally(e.g. internet pharmacy)

Prescribing outside marketing authorization
- Recognize the circumstances in which drugs are prescribed 'off-label'
- Explain the additional responsibilities associated with prescribing 'unlicensed' or 'off-label' medicines
- Describe what information should be given to patients to allow them to make informed decisions about 'offlabel' treatment

Ethical aspects of prescribing
- Explain the responsibilities of prescribing in a resource limited healthcare system
- Describe the sometimes conflicting responsibilities to individual patients and the wider healthcare community
- Explain the reasons for adhering to therapeutic guidelines and drug formularies, as appropriate
- Explain why it is important to recognize limits of competence and to ask for help when needed
- Explain the responsibility of all prescribers to update their knowledge

Prescribing for patients with special requirements (excluded older patients)

Prescribing for patients with impaired liver function
- Describe how altered physiology, pharmacokinetic handling and pharmacodynamic response occur in patients with impaired liver function
- List common medicines that are especially likely to cause harm to patients with impaired liver function
- Discuss the principals involved in selecting medicines and designing dosage regimens for patients with impaired liver function
- Explain where to find relevant information about choosingand adjusting drug dosage in patients with impaired liver function

Prescribing for patients with impaired renal function
- Describe how altered physiology, pharmacokinetic handling and pharmacodynamic response occur in patients with impaired renal function
- List common medicines that are especially likely to cause harm to patients with impaired renal function
- Discuss the principals involved in selecting medicines and designing dosage regimens for patients with impaired renal function
- Explain where to find relevant information about choosing and adjusting drug dosage in patients with impaired renal function

Prescribing for pregnant women and women of childbearing potential
- Explain the reasons for caution when prescribing for pregnant women and women of child-bearing potential
- Describe how altered physiology, pharmacokinetic handling and pharmacodynamic response occur in pregnancy
- List common medicines to which pregnant women are especially likely to respond differently
- Describe the possible effects of drugs on the developing foetus, in relation to the stage of gestation
- Explain the principles involved in selecting medicines and designing dosage regimens

for pregnant women and women of child-bearing potential
- Explain where to find relevant information about choosing and adjusting drug dosage in pregnant women and women of child-bearing potential

Prescribing during lactation
- Explain the reasons for caution when prescribing for women who are breast feeding
- List common medicines that are especially likely to cause harm to the newborn as a result of transmission via breast milk
- Discuss the principals involved in selecting medicines and designing dosage regimens for women who are breast feeding
- Explain where to find relevant information about choosing and adjusting drug dosage in women who are breast feeding

Prescribing for children
- Describe how altered physiology, pharmacokinetic handling and pharmacodynamic response occur in children
- List common medicines to which children are especially likely to respond differently
- Explain where to find relevant information about choosing and adjusting drug dosage in children
- Explain the principles that underlie prescribing in children

Rational prescribing
Rational approach to prescribing
- Explain the importance of individualizing the prescription
- Describe the selection of an appropriate medicine based on its comparative efficacy, safety, convenience and cost
- Explain the importance of identifying diagnosis (if possible) and therapeutic objectives
- Describe the factors that influence the choice of formulation, dose, route, frequency and duration of treatment
- Provide examples of irrational prescribing

Dose selection
- Explain the importance of accurate calculation of drug dosage, especially for intravenous infusions
- Interpret different expressions of drug concentration or dose and be able to convert them
- Calculate appropriate doses for individual patients, based on age, body weight and surface area
- Explain how to select drug dosage using widely available nomograms
- Identify factors that may necessitate amendments of standard doses

Clinical toxicology
Principles of assessing poisoned patients
- Explain the epidemiology of poisoning
- Describe the principles of assessment of a poisoned patient
- Discuss the role of urine and blood sampling in poisoned patients
- Describe the clinical features of overdosage with commonlyused medicines (e.g. paracetamol, salicylates, tricyclic antidepressants, opioids and benzodiazepines)

Principles of treating poisoned patients
- Describe the principles involved in treating a poisoned patient
- Explain how to access and obtain information from the National Poisons Information Service (e.g. TOXBASE)
- List drugs and toxins to which effective antidotes are available
- Explain the means by which the elimination of drugs or toxins can be hastened

Misuse of drugs
- List drugs that are commonly misused (e.g. cannabis, ecstasy, hallucinogens, olatile solvents, cocaine, opiates) and some of their important pharmacodynamics effects
- Explain the legal classification of drugs
- Describe the epidemiology of drug misuse

in the population
- Define tolerance, physical dependence and psychological Dependence

Complementary and alternative medicines
- Describe the extent of the popularity of complementary therapeutic approaches
- Identify the motivations that lead patients to seek complementary and alternative therapies
- Describe common therapies used by practitioners of complementary and alternative medicine and the evidence for their efficacy and safety
- Explain the potential of complementary and alternative medicines to cause adverse effects
- Describe the regulation of complementary and alternative medicines

Use of antimicrobial drugs and resistance
- Know how to interpret sensitive, low-grade resistance, high-grade resistance, outpatient strains vs. inpatient strains, trends over time

GERIATRIC PHARMACOLOGY KNOWLEDGE (n=7)
Altered physiology in old people

Altered pharmacokinetics in old people

Altered pharmacodynamics in old people

Different response in frequent used drugs in old people

Principles that underlie prescribing in the old people
- Distinguish the influences of aging on drug therapy

Polypharmacy
- Special problems with polypharmacy

Finding relevant information on drug and dose adjustments

Skills

GENERAL PHARMACOTHERAPY SKILLS (n=13)
Medication history taking
Take a medication history
- Elicit and record an accurate medication history, including current and recent medicines, to support effective medicines reconciliation
- Identify, where possible, for each drug the original indication, formulation, dose, route, duration and effects
- Ensure that over the counter, complementary medicines and the contraceptive pill are specifically included
- Identify alternative sources of information about current treatment, understand the limits of information sources and compensating for them
- Interpret the medication history so that allergies and ADRs can be identified (distinguish between a history of drug allergy and intolerance)
- Identify common potentially important drug interactions

Prescribe a new medicine
Prescribe drugs safely, effectively and economically
- Define problem(s) to be treated
- Define the therapeutic objective(s) for new therapy
- Consider risks and benefits of specific drug therapies
- Recognize drugs with a narrow therapeutic index or high potential for serious adverse effects/interactions, and take appropriate precautions when prescribing them
- Follow clinical guidelines, protocols and formularies where appropriate

Write prescriptions that take into account the needs of individual patients
- Consider possible contraindications, drug–drug interactions, previous ADRs,

any special circumstances, age and gender, and diseases
- Choose the appropriate formulation, dose, route, frequency and duration of a drug
- Interpret data that is relevant to prescribing decisions (e.g. renal function, drug concentrations)
- Other prescribing related skills
- Document the rationale for new prescribing decisions in patient notes
- Recognize the potential for medication errors and take steps to reduce the risks
- Recognize situations where their prescribing skills are not sufficient, and seek advice before proceeding

Calculate drug doses

Drug calculations

- Calculate appropriate doses for individual patients by weight and body surface area, and based on a normogram
- Convert doses between common units and convert between concentrations expressed as percentage and mass

Prescription writing

- Prescribe on hospital in patient prescription charts
- Write an unambiguous, legible, complete and legal prescription
- Including approved name, appropriate form and route, correct dose, any other necessary instructions, and signature
- Avoid abbreviations and other ambiguities when writing a prescription
- Prescribe 'once only', regular and 'as required' medicines

Prescribing on other documentation

- Prescribe on hospital supplementary prescription charts
- Prescribe 'to take out' drugs on discharge from hospital
- Prescribe on general practice prescription forms (GP10)
- Keep accurate records of prescriptions and responses
- Cancel prescriptions appropriately

Communication

Discussing prescribing options with patients

- Communicate treatment plan and instructions to patient, at a suitable level of information
- Engage in shared decision making where appropriate

Discussing prescribing decisions with colleagues

- Communicate treatment plans and monitoring arrangements clearly with other members of staff, in both verbal and written form
- Keep accurate written records of management plans
- Write accurate discharge prescriptions and letter toGPs

Reviewing prescriptions

- Reviewing current lists of prescribed medicines
- Identify and correct prescription writing errors
- Identify and manage inappropriate prescribing

Adverse drug reactions

- Managing, reporting and avoiding adverse drug reactions (ADRs)
- Assess and manage common ADRs and interactions in the context of current clinical situation
- Report a suspected ADR using an on-line yellow card
- Find information about adverse drug reactions

Obtaining information to support rational prescribing

Find reliable sources of drug information

- Find information from the Summary of Product Characteristics
- Find information from the paper and online British National Formulary
- Find Poisons Information Services (e.g. TOXBASE)

Prescribing high risk medicines

Oxygen

- Prescribe oxygen safely using appropriate documentation
- Monitor the clinical effects of oxygen

Warfarin

- Prescribe warfarin safely using appropriate documentation
- Monitor the clinical effects of warfarin

Insulin

- Prescribe insulin safely using appropriate documentation
- Monitor the clinical effects of insulin

Intravenous fluids

- Prescribe intravenous fluids safely using appropriate documentation
- Monitor the clinical effects of intravenous fluids

Drug administration

Administering parenteral medicines

- Administer drugs by subcutaneous injection
- Administer drugs by intramuscular injection
- Administer drugs by intravenous injection
- Administer drugs by intravenous infusion pumps

Administering medicines by other routes

- Administer drugs using an inhaler
- Administer drugs using a nebulizer
- Administer drugs to the eye
- Administer drugs to the ear
- Administer drugs to the skin

Clinical pharmacokinetics

- Students should be able to indicate how knowledge of a particular pharmacokinetic profile of a drug would alter the way in which it should be prescribed in common clinical problems, and in addition indicate how alterations of renal and hepatic function might alter the pharmacokinetics of a drug.

Prescribing drugs to relieve pain and distress

- Palliation of pain and other distressing symptoms

Drug therapy versus non-drug therapy

GERIATRIC PHARMACOTHERAPY SKILLS (n=4)

Basic elements of geriatric pharmacotherapy

Monitoring medication in old people

Avoid potentially harmful drugs

Interpret physical, laboratory, and diagnostic test results in accordance with age related changes

Attitudes

MEDICATION RELATED ATTITUDES (n=4)

Risk-benefit analysis

- Recognizing that there are risks and benefits associated with all drug treatments; recognizing that these may differ between patients, depending on a variety of factors; recognizing that doctors should monitor the impact of the drugs they prescribe

Balanced approach to the introduction of new drugs

- Recognizing the need to assess the benefits and hazards of new therapies (Maxwell 2003)

Recognizing personal limitations in knowledge

- Recognizing the need to seek further information about drugs when faced with unfamiliar prescribing problems.

A new prescription as an experiment

- Students should develop the attitude that every prescription is really a carefully designed experiment that can produce a useful clinical effect, toxicity, or both.

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3

HEALTH PROFESSIONALS' KNOWLEDGE AND SKILLS

"Coming together is a beginning;
keeping together is progress;
working together is success."

Henry Ford

3.1

A comparison of medical and pharmacy students' knowledge and skills of pharmacology and pharmacotherapy

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ABSTRACT

Aim Pharmacotherapy might be improved if future pharmacists and physicians receive a joint educational programme in pharmacology and pharmacotherapeutics. This study investigated whether there are differences in the pharmacology and pharmacotherapy knowledge and skills of pharmacy and medical students after their undergraduate training. Differences could serve as starting point from which to develop joint interdisciplinary educational programmes for better prescribing.

Methods In a cross-sectional design, the knowledge and skills of advanced pharmacy and medical students were assessed, using a standardised test with three domains (basic pharmacology knowledge, clinical or applied pharmacology knowledge, and pharmacotherapy skills) and eight subdomains (pharmacodynamics, pharmacokinetics, interactions and side-effects, Anatomical Therapeutic Chemical Classification groups, prescribing, prescribing for special groups, drug information, regulations and laws, prescription writing).

Results 451 medical and 151 pharmacy students were included between August 2010 and July 2012; response rate 81%. Pharmacy students had better knowledge of basic pharmacology than medical students (77.0% vs 68.2% correct answers; $p<0.001$, $\delta=0.88$), whereas medical students had better skills than pharmacy students in writing prescriptions (68.6% vs 50.7%; $p<0.001$, $\delta=0.57$). The two groups of students had similar knowledge of applied pharmacology (73.8% vs 72.2%, $p=0.124$, $\delta=0.15$).

Conclusions Pharmacy students have better knowledge of basic pharmacology, but not of the application of pharmacology knowledge, than medical students, whereas medical students are better at writing prescriptions. Professionals' differences in knowledge and skills therefore might well stem from their undergraduate education. Knowledge of these differences could be harnessed to develop a joint interdisciplinary education for both students and professionals.

INTRODUCTION

Pharmacists and physicians goals in patient management are optimisation of the pharmaceutical care for, and outcomes of, their patients,[1] and their collaboration can be a crucial factor in this process.[2] Effective collaboration between pharmacists and physicians can lead to improved clinical outcomes, such as fewer adverse drug events, less severe illness, and greater patient satisfaction.[3] Historically, prescribing used to be done by a physician in the combined role of prescriber and dispenser, but the two roles have since diverged, and nowadays physicians and pharmacists have different duties and tasks, culture, undergraduate education, and knowledge and skills.[4] It is only in the last two decades that there has been interest in physician-pharmacist collaboration.[1,5] Differences in professional culture and lack of awareness of each other's knowledge and skills can cause interdisciplinary barriers,[2] although the same differences could be regarded as complementary, and when combined potentially lead to improved patient care.[2, 4]

Differences in the knowledge and skills of physicians and pharmacists may be the result of learning in practice or differences in their undergraduate training and education. For example, Harrington et al. found that pharmacy students outperformed medical students in their knowledge of drug-drug interactions,[6] These differences increase after a 1 year follow up, indicating a better knowledge retention for pharmacy students on drug-drug interactions.[7] Warholak et al found pharmacy students to be significantly better at recognising prescription errors.[8] No other studies were found in which pharmacy and medical students were compared on pharmacology or pharmacotherapy knowledge or skills. Joint training and education has been suggested as a way to improve interdisciplinary collaboration with a view to improving patient care.[4,9] For instance, interdisciplinary education has been found to lead to a more uniform knowledge of drug-drug interactions.[6] However, it should be appreciated that there is a difference between basic pharmacology or factual knowledge, clinical pharmacology or the application of knowledge in relation to a patient, and pharmacotherapy skills.[10,11] The previous studies only addressed minor aspects of these different domains. It is essential to take earlier learning experiences and the knowledge acquired into consideration when developing a meaningful interdisciplinary curriculum.[12] For this reason, it would be useful to gain insight into the knowledge and skills that pharmacy and medical students have acquired with current curricula.

The goal of this study was to investigate differences in the pharmacology and pharmacotherapy knowledge and skills of pharmacy and medical students after their undergraduate training. Knowledge of potential differences can be used to develop joint educational programmes, both undergraduate and postgraduate, with a view to improving interdisciplinary collaboration and pharmaceutical care.

METHODS

Study design

The study was designed as a cross-sectional comparison between pharmacy and medical students at the University of Utrecht, the Netherlands. A specially developed test was used to assess students' basic pharmacology knowledge, clinical pharmacology or applied knowledge, and pharmacotherapy skills. Students were recruited during two academic years (August 2010- July 2012). Medical and pharmacy students who signed up to a specific one week course that was mandatory for both disciplines were asked to volunteer to take a formative written examination of their pharmacology and pharmacotherapy knowledge and skills.

Previous training of study population

Table 1 shows the hours of tuition scheduled according to the medical and pharmacy curricula. The medical curriculum offered optional courses but the uptake was very low, only two students. The pharmacy curriculum offered 120 hours of optional courses, and most students followed about 30 hours of these courses (year 5).

The medical curriculum can be described as problem oriented, with an early focus on clinical skills, which are acquired during practical lessons from the first year onwards and during junior clerkships from the third year onwards. The pharmacy curriculum is also problem oriented, with students having rotation at a pharmacy in the first year. However, in general, the pharmacy curriculum has less emphasis on patient care and clinical subjects than the medical curriculum. In both curricula, most education is provided in the form of small group discussions and tutorials, lectures, and practical lessons, with the addition of rotations and clerkships in the last 2 years of the medical curriculum.

Time spent in self-study was not considered when calculating the hours of tuition because self-study differs substantially per student. Since both curricula are problem oriented, and pharmacology and pharmacotherapy education is often integrated, only scheduled hours (e.g. seminars or lectures on a given topic)

were considered as tuition time. This probably led to underestimation of the time devoted to basic pharmacology knowledge, clinical pharmacology or applied knowledge, and pharmacotherapy skills, because these topics probably arose during other forms of tuition, such as tutorials and other small group discussions. Both curricula put emphasis on self-study and we did not expect there to be systematic differences in the time spent in self-study between medical and pharmacy students.

TABLE 1. **hours of scheduled classes on pharmacology and pharmacotherapy that are mandatory for pharmacy and medical students.**

HOURS OF CLASSROOM EDUCATION FOR THE PARTICIPANTS		
	Pharmacy students	*Medical* students
Study year	**hours**	**hours**
Year 1	10	18
Year 2	72	0
Year 3	50	0
Year 4	51	17
Year 5	14	0
Year 6	0	0
Total	**197 hours**	**35 hours**

All participating medical and pharmacy students had at least completed the first 3.5 years of their 6-year course. At time of inclusion, medical students had completed 100% of their mandatory tuition on pharmacology and pharmacotherapy and pharmacy students 93-100%.

Sampling

All medical and pharmacy students actively studying during two academic years 2010 and 2011 were asked to complete the test during an interdisciplinary scheduled lecture hour during a mandatory one week course. To gain access to courses, students normally have to enrol in an online registration system

Osiris. As a result, the system registers the number of active students during a certain time frame. No information about the study was provided before students signed up for the course, in order to prevent selection bias. Both the lecture and test participation were voluntary. In addition, students were asked to fill in a short questionnaire about their age, sex, year they started their study, previous relevant study, such as other biomedical studies, etc. All data were collected anonymously; students were not asked to give their names.

Pharmacology and pharmacotherapy test: construction

The pharmacology and pharmacotherapy test covered the domains basic pharmacology knowledge, clinical pharmacology or applied knowledge, and pharmacotherapy skills. The content of the test was derived from the available literature on core curricula.[10, 13, 14]

A test matrix, as shown in table 2, was developed to guide the selection of items for the assessment (basic pharmacology knowledge, clinical pharmacology or applied knowledge, and pharmacotherapy skill) and the eight subdomains. All questions on basic pharmacology assessed the factual knowledge students are expected to acquire from study books (canonical knowledge); questions that assessed clinical pharmacology knowledge contained a short case vignette that required students to apply their theoretical knowledge. Pharmacotherapy skills were assessed by asking students to write a prescription. Other pharmacotherapy skills, such as patient communication, cannot be tested in writing and were not assessed. Three similar parallel tests were developed, using a database of 170 questions prepared by experts in the field of pharmacotherapy and clinical pharmacology. These three parallel tests were used alternately.

Pharmacology and pharmacotherapy test: validity and reliability

The test matrix was used to ensure that the different question (sub)domains were equally distributed over the test (content validity). Ten clinical pharmacologists, with different backgrounds, but mostly in pharmacy and geriatric medicine, were asked to complete the test, to establish its construct validity. The scores of these experts were compared with those of the students, using a student t-test for independent samples. For the test to be a valid reflection of the knowledge students should possess, the experts should have a mean of >90% correct answers. The mean score of the expert group was 91.2% (SD 6.1) and that of the

TABLE 2. **design of the assessment by use of test matrix for each parallel test**

ASSESSMENT DESIGN BY TEST MATRIX		
Question type (n)	**Domains & example of question**	**Subdomains** (n)
3 options MCQ* n=25	**Basic pharmacology knowledge** e.g. What is a ´first pass effect´?	• Pharmacodynamics (n=7) • Pharmacokinetics (n=7) • Interactions and side effects (n=4) • ATC groups knowledge† (n=7)
3 options MCQ n=24	**Clinical pharmacology or applied knowledge** e.g. a 80 year old women with renal failure and a complicated urinary tract infection is presented to the GP. What is the best treatment for the UTI in this woman?	• Prescribing (n=7) • Prescribing in special groups (n=7) • Interactions and side effects (n=3) • Drug information, regulations & laws (n=7)
Open n=1	**Pharmacotherapy skill** e.g. Write the prescription for your ambulant patient for amoxicillin/clavulanic acid 625 mg 3 times a day for 7 days	• Prescription (n=1)

* *MCQ: multiple choice question*
† *ATC groups: drug groups by the Anatomical Therapeutic Chemical Classification system*

students was 71.4% (SD 8.4). On a t-test for independent groups, the expert group scored significantly higher ($t(611)=7.351$, $p<0.001$, 95% CI [-.25 - -.14]) with a very large effect size (Cohen's d = 2.68), indicating that the test had good construct validity.

To study test reliability, the internal consistency of the parallel tests, the p-values, and the item-rest correlation scores (r_{ir}) for the different questions were calculated. None of the questions from any of the parallel tests had a negative r_{ir}-value in either student group. Therefore none of the questions had to be excluded from the analyses. The Guttman lambda was used for internal consistency, because it gives a more reliable value than Cronbach's alpha.[15] All parallel tests had an internal consistency ranging between 0.5 and 0.7. Because the assessment was not used to determine individual scores but to compare groups, an internal consistency higher than 0.5 can be considered acceptable.[16] The p-values (% of correctly answered questions) for the individual questions of the three different assessments ranged between 0.29 and 0.99, 0.15 and 1.00, and 0.16 and 0.99, respectively, indicating that the difficulty of the questions was variable, with some easy questions having high p-values.

Data analysis

All assessment and questionnaire results were collected in Excel and SPSS version 20.0. Analyses were performed with SPSS version 20.0. Descriptive analyses of student characteristics were used. All previous biomedical studies were considered to be relevant previous studies. Response rates were determined by calculating the proportion of the students who volunteered relative to the number of students who enrolled for the course, as indicated by the online study administration system.

All multiple choice questions were scored as right or wrong (0-1); each correct item included in the prescription (or skill) written by a student was awarded a score of 1 point (by researcher CK): 1) name patient and date of birth, 2) name physician and signature, 3) drug and dose, 4) number, 5) label instruction. Scores were expressed as a percentage of the maximum score for each domain and subdomain. The mean domain and subdomain scores of the medical and pharmacy students were compared using a t-test for independent samples in the case of a normal distribution or a Mann-Whitney U test in case of a skewed distribution of data. Effect sizes were calculated to magnify the differences. Effect sizes < 0.5 were considered small, 0.5-0.8 medium, and > 0.8 large.[17] Covariance analyses were performed to correct for possible confounders such as age, sex, previous relevant other study, and study duration. In the pharmacy group, the effect of different study durations on test scores were compared with an ANOVA.

Ethical considerations

This study falls outside the scope of the Dutch Law on Medical Research (WMO), and when the study started the Dutch Ethical Review Board of Medical Education, which could provide study approval, was not yet operational. The students, all of whom were older than 18 years, were told about the study and gave their verbal consent to voluntary participation.

RESULTS

Population characteristics

Table 3 shows the characteristics of the study population. Of the 602 students who participated, 451 were medical students. The overall response rate was 80.8% (602/745), 83.2% (451/541) for medical students and 74.5% (151/204) for pharmacy students compared to all students from the academic years 2010 and 2011. All students present at the scheduled lecture participated (100%). Most of the students completed the assessment within 40 minutes.

TABLE 3. **students' characteristics**

STUDENTS' CHARATERISTICS				
		Medical students (n=451)	**Pharmacy students (n=151)**	**p-value**
Age	median (range)	22 (19-45)	23 (20-40)	**<0.001** †
Gender	female (%)	75,0	72,2	0.355 ‡
Year of inclusion	2010-2011 (n) 2011-2012 (n)	222 229	41 110	**<0.001** ‡
Duration study (inclusion date-start study)	median (range)	3 yr 8 mnth (1 yr 11 mnth- 6 yr 9 mnth)	4 yr 10 mnth (3 yr 2 mnth - 12 yr 7 mnth)	**<0.001** †
previous study	not or not relevant (n) relevant (n)	411 40	142 8	0.166 ‡

** Students t-test, † Mann-Whitney, ‡ Chi-square*

Main results

Comparison of the basic pharmacology knowledge, applied pharmacology, and pharmacotherapy skills of the pharmacy and medical students showed that, overall, the pharmacy students outperformed the medical students with regard to basic pharmacology knowledge (77.0% (SD 10.3) vs 68.2% (SD 9.8) correct answers, t(600)=-9.4, p<.001, CI [-.11 - -.07], δ=0.88), whereas the medical students outperformed the pharmacy students when it came to writing prescriptions (68.6% (SD 26.7) vs 50.7% (SD 35.2), t(600)=6.5, CI [0.13 – 0.23], p<.001, δ=0.57). The two groups of students had a similar knowledge of applied pharmacology (73.8% (SD 10.5) vs 72.2% (SD 10.8), t(600)=-1.5, p=.124, CI [-.04 - .004], δ=0.15) (Table 4).

TABLE 4. **differences in knowledge and skills (main domains and per subdomain) between pharmacy and medical students**

DIFFERENCES IN KNOWLEDGE AND SKILLS					
	Medical students Score in % (SD)	Pharmacy students Score in % (SD)	p-value*	adjusted p-value†	Effect sizes (Cohens D)
Basic pharmacology knowledge	**68.2 (9.8)**	**77.0 (10.3)**	**<0.001**	**<0.001**	0.88
• pharmacodynamics	69.1 (15.1)	74.4 (15.7)	**<0.001**	**<0.001**	0.34
• pharmacokinetics	69.6 (16.2)	78.6 (14.7)	**<0.001**	**<0.001**	0.58
• interactions & side effects	71.6 (17.0)	77.3 (16.7)	**<0.001**	**<0.001**	0.34
• ATC groups‡	63.8 (19.3)	77.6 (18.0)	**<0.001**	**<0.001**	0.74
Clinical pharmacology or applied knowledge	72.2 (10.8)	73.8 (10.5)	0.124	**0.007**	0.15
• prescribing	65.3 (16.0)	65.8 (15.5)	0.734	0.482	0.03
• prescribing in special groups	72.8 (18.8)	74.8 (16.6)	0.198	0.210	0.12
• drug information, regulation & laws	79.2 (18.3)	83.2 (18.1)	**0.020**	**0.009**	0.22
• interactions & side effects	71.6 (17.0)	77.3 (16.7)	**<0.001**	**<0.001**	0.34
Skills / prescription writing	68.6 (26.6)	50.7 (35.3)	**<0.001**	**<0.001**	0.57

* *Student-t test for independent samples*
† *Adjusted by covariate analyses (ANCOVA), covariables: age, sex, previous study, study duration, inclusion year.*
‡ *ATC groups: drug groups by the Anatomical Therapeutic Chemical Classification system*

As the pharmacy students came from different years in their master's degree programme, we investigated whether the number of years of training and education influenced their pharmacological knowledge. There were no significant differences between the different study years in the three domains basic pharmacology knowledge, clinical or applied pharmacology, and pharmacotherapy skills or in the eight subdomains.

DISCUSSION

This study demonstrates that medical and pharmacy students differ in their pharmacology and pharmacotherapy knowledge and skills. Pharmacy students tended to have better basic pharmacology knowledge whereas medical students tended to have better skills in writing a prescription. There were only minor, borderline significant and not clinically relevant, differences in clinical pharmacology or applied knowledge. Given the differences in education, with pharmacy students having six times more mandatory classes, these results are surprising. Medical students, although their basic knowledge of pharmacy was less than that of pharmacy students, performed equally well in applying their knowledge in relation to a patient and had better prescribing skills. These findings suggest that the differences between pharmacists and physicians arise during their undergraduate training.

Both pharmacy and medical students should have appropriate pharmacology and pharmacotherapy knowledge at the end of their undergraduate training in order to provide safe medical care.[18] Although a gold standard of sufficient knowledge is not available, the test represents the learning goals of international core curricula and might be used as such a standard. Medication errors are a major problem in medical care,[19] and one would hope that not only pharmacy students but also medical students would have an adequate basic knowledge of pharmacology to allow them to prescribe safely.[9] In our study, the medical students had an overall score of 68% for basic knowledge, not corrected for chance on multiple-choice questions. This deficit relative to pharmacy students has been reported previously with regard to drug-drug interactions.[6] However, pharmacy students should know what information should be given in a prescription,[8] yet many pharmacy students could not actively write out a prescription (overall score 51%), even though students had been taught, early in their study, what the core elements of a prescription are in order to be able to check whether a prescription is complete. Although prescribing is not a daily task for pharmacists, at least in the Netherlands, it would seem unlikely that pharmacists could recognise mistakes in a prescription if they are not able to actively reproduce the key elements of a prescription. However, another study suggests that pharmacy students do have relevant knowledge of a prescription.[8]

Given that the aim of training is the safe delivery of pharmaceutical care, we did not find either student group to substantially outperform the other. While both groups had a similar performance on topics closely related to patients, namely, prescribing and prescribing for special groups, there were performance differences on other, less patient-related, topics, differences that could constitute a starting point for curriculum improvement. As the strengths and weaknesses of the two groups tended to complement each other, joint interdisciplinary education might be useful and effective, allowing both groups of students to profit from the knowledge and skills of the other profession: pharmacy students would benefit from medical students' clinical experience and skills, and medical students would benefit from a further grounding in basic pharmacology knowledge. In addition, educational collaboration can improve interprofessional understanding and collaboration in patient care.[4, 20, 21]

Despite the fact that this study clearly demonstrated differences in several knowledge and skills domains, measured with a formative test so that differences in study behaviour between the two groups of students would not have influenced the results,[22] the results should be interpreted in the light of some limitations. The students' level of knowledge might not be representative of that of other students, nationally and internationally. Since this was a single-centre study, the differences found might be due to the curricula of the university involved. The assessments had a rather low internal consistency, which could suggest that reliability was a problem. The internal consistency might have been negatively affected by the relatively short assessment and the relative homogeneity of the study population. However, because the study used a formative assessment, this level of internal consistency is considered acceptable.[16] Moreover, a low internal consistency primarily leads to underestimation of the relation between the studied variables, but since we found significant differences, the low consistency probably did not affect our findings.[16] As the pharmacy students were more advanced in their study than the medical students, we used study phase as covariate in the ANCOVA but did not find it to affect the main results. In addition, most students had completed their mandatory courses: medical students 100% and pharmacy students 93-100%. Additional analyses using data for the pharmacy students showed that study duration at the time of the assessment did not influence the results, which suggests that the final 2 years of the study do not significantly increase the knowledge and skills of pharmacy students. Moreover, it is debatable whether a pharmacy student needs to be able to write a prescription, as this is not a skill they use in daily practice. The test investigated whether the core information of the prescription was present, and not whether it was present in the right order. All students had received training on the core information required for prescriptions, to enable them to check or write a prescription. Writing a prescription is just one pharmacology and pharmacotherapy skill, but it is one that can be tested in a written test. Other skills, such as patient communication, can only be tested in simulations.[23] There is no literature supporting the involvement of other potential differences between pharmacy and medical students, such as students' character, motivation, and school results. In the Netherlands, pharmacy and medicine courses have a restricted number of places, and students with better grades are more likely to be admitted. As medicine is more popular than pharmacy as a study in the Netherlands, the medical students might have needed better school grades than the pharmacy students in order to gain admission to their study. Lastly, there is no clearly defined norm for what constitutes 'sufficient knowledge'; however, since it is essential to avoid medication errors, pharmacotherapy skills should be improved regardless of the norm.

CONCLUSIONS

The differences between pharmacists and physicians appear to arise during their undergraduate training and education: pharmacy students had better basic pharmacology knowledge and medical students had better prescribing skills, whereas applied knowledge was similar in the two groups of students. The findings suggest that joint interdisciplinary education would be a rational and useful way to improve curricula, whereby pharmacy students would gain knowledge of prescriptions and patient care and medical students would gain more knowledge of basic pharmacology. More research is needed to study whether these differences in knowledge and skills are still present in pharmacists and physicians after their first years of work experience.

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3.2

Pharmacists' and general practitioners' knowledge and skills on pharmacology and pharmacotherapy

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ABSTRACT

Aim Understanding the differences in pharmacology knowledge and pharmacotherapy skills between pharmacists and physicians is vital to optimizing interprofesional collaborations and education. This study investigated these differences and the potential influence of work experience.

Methods Pharmacists, general practitioners (GPs) and trainees were compared on pharmacology knowledge and pharmacotherapy skills by a 51 question standardized assessment with three domains (basic pharmacology knowledge, clinical or applied pharmacology knowledge, and pharmacotherapy skills) and eight subdomains. Years of work experience was studied as an explanatory variable.

Results 294 participants were included. Overall scores (mean±SD) ranged from 69.3±6.5% to 76.5±9.5% for basic knowledge, 70.3±10.8% to 79.7±8.4% for applied knowledge, 66.3±21.1% to 84.7±20.7% for pharmacotherapy skills (ANOVAs all $p<0.001$). The pharmacists had the highest scores for all domains ($p< 0.05$), with the exception of pharmacist trainees, with comparable scores for basic knowledge ($p=0.253$) and pharmacotherapy skills ($p=0.283$). The GPs scored the lowest for pharmacotherapy skills ($p<0.05$). More work experience was associated with better pharmacists' knowledge of applied pharmacology (by 2% per 10 work years), but diminished pharmacists' and GPs' (by resp 3% and 4% per 10 work years) pharmacotherapy skills.

Conclusions Pharmacists and GPs differ in their pharmacology knowledge and pharmacotherapy skills. These differences become more pronounced with more work experience. Pharmacist generally spoken outperformed their trainees, where GP trainees outperformed GPs. These differences could be important to both interdisciplinary collaboration and education.

INTRODUCTION

Drug safety issues in patients is an international concern,[1,2] especially given the increasing complexity of pharmacotherapy, particularly in older patients.[3] Another problem is the inadequate knowledge of pharmacology among health professionals, such as physicians and pharmacists.[2, 4] Increasing awareness of medication errors was one of the triggers to improve interdisciplinary collaboration and education in the pharmaceutical care of patients, and in recent years the medication review, which involves pharmacists and physicians, has become a way to optimize pharmaceutical care for the vulnerable old.[5] Cooperation between physicians and pharmacists, with each professional contributing their own specialist knowledge, can improve clinical outcomes, such as adverse drug events, severity of illness, and hospital (re)admission.[5-7] Such collaborations are most effective if professionals have insight into each other's knowledge and skills.[8] The same can be said for interprofessional education.[8] However, although differences in the pharmacology knowledge and pharmacotherapy skills have been found between pharmacy and medical students,[9] little is known about whether similar differences exist between practising physicians and pharmacists. This topic is so far not addressed by other studies.

Medical students outperform pharmacy students with regard to pharmacotherapy skills, and pharmacy students outperform medical students with regard to basic pharmacology knowledge. There are hardly any differences in their applied knowledge.[9] Differences in undergraduate curricula may underlie or contribute to these differences, but less is known about what happens after students graduate. After graduation, knowledge retention may be an issue, especially knowledge gained early in the undergraduate curriculum – the average half-life of unrehearsed knowledge is estimated to be 2 years.[10, 11] Work experience provides "learning by doing", and in combination with postgraduate education may increase knowledge and skills over time.[12, 13] Taken together, it is unclear whether findings for students can be generalized to practising health professionals because several factors contribute to knowledge and skills, above and beyond what is learned during undergraduate training.

The aim of this study was therefore to investigate whether there are differences in the pharmacology knowledge and pharmacotherapy skills of pharmacists and general practitioners (GPs) and whether work experience influences potential differences.

METHODS

Study design and population

This study compares pharmacists' and GPs' pharmacology knowledge and pharmacotherapy skills, measured by a standardized formative assessment. GPs, GP trainees, community pharmacists, and community pharmacist trainees participated, all from the Netherlands.

Tools

The written assessment, which was based on core elements of a pharmacology and pharmacotherapy curriculum,[9] contained 51 questions, 49 multiple-choice questions and 2 open questions. Half of the assessment addressed basic pharmacology knowledge and half case-based or applied pharmacology knowledge; the 2 open questions assessed the pharmacotherapy skill of writing a prescription. The assessment contained eight subdomains: pharmacodynamics, pharmacokinetics, drug interactions and side-effects, Anatomical Therapeutic Chemical Classification groups, prescribing, prescribing for special groups, drug information, regulations and laws, prescription writing. Table 1 shows the design of the assessment by a test matrix.Since other skills, such as patient communication about medications, could not be tested by a written assessment, this was not a part of this study.

The validity of the assessment was established using a test matrix (content validity) and the scores of an expert panel of ten clinical pharmacologists (both pharmacists as physicians), which, with an average score of 81% (SD±6.1%), showed that the assessment evaluated knowledge known by experts in the field (construct validity). The reliability of the assessment was calculated using the Guttman Lambda 2, which was 0.66 in this population, meaning that it had an acceptable reliability.[14, 15] The item-rest correlation scores (r_{ir}) for all questions were positive in at least one of the studied groups, so no questions were excluded from analyses. An additional questionnaire on participants' characteristics was used to collect information on possible confounders, such as age, years of work experience, sex, and other relevant education.

Data collection procedure

During scheduled voluntary study days for pharmacists, GPs, and trainees, participants were asked to volunteer to complete a 1-hour assessment as start of

TABLE 1. **design of the assessment by use of test matrix**

ASSESSMENT DESIGN BY TEST MATRIX		
Question type (n)	**Domains & example of question**	**Subdomains** (n)
3 options MCQ* n=25	**Basic pharmacology knowledge** e.g. Which of the following ans-wers is a phase-1 reaction in the liver?	- Pharmacodynamics (n=7) - Pharmacokinetics (n=7) - Interactions and side effects (n=4) - ATC groups knowledge† (n=7)
3 options MCQ n=24	**Clinical pharmacology or applied knowledge** e.g. a 60 year old women visits a general practitioner. She has a complicated urinary tract infection and has renal failure in her medical history. What is your first choice treatment for this patient?	- Prescribing (n=7) - Prescribing in special groups (n=7) - Interactions and side effects (n=3) - Drug information, regulations & laws (n=7)
Open n=2	**Pharmacotherapy skill** e.g. write a prescription for your ambulant patient who uses metformin twice a day 500 mg	- Prescription (n=2)

* *MCQ: multiple choice question*
† *ATC groups: drug groups by the Anatomical Therapeutic Chemical Classification system*

the study day. The assessment was formative, which means that the result did not influence study results in any form, to prevent test-driven learning prior to the study day which could bias the outcome measurement, namely the actual knowledge and skills available in daily practice.[16, 17] All data were collected and analysed anonymously. Data were imported to Excel and IBM SPSS 22.0 (IBM).

Power calculation

The results of a similar study of the performance on three domains (basic pharmacology knowledge, applied pharmacology knowledge and pharmacotherapy skills) of pharmacy and medical students were used for power calculations.[9] Differences in basic knowledge and skills were expected, similar to those found in students. A power calculation based on this study showed a minimum of n=50 for each group (Mean 1 68.6 (SD±26.6) and Mean 2 50.7 (SD±35.3), double sided, α=0.05 and β=0.20).

Data analysis

Response rates were calculated by dividing number of participants who provided written informed consent by the number of participants on the entry lists of the various study days. The characteristics of the four groups were compared using ANOVA for continuous data or Chi square for categorical data. In the main analysis, ANOVA was used to compare performance in the domains basic pharmacology knowledge, case-based or applied pharmacology knowledge, and pharmacotherapy skills, and their subdomains. Hochberg's GT2 was used for post-hoc analyses, because it is the most appropriate test if there are different group sizes with normal variances. Differences in age and work experience were expected and enabled more experienced professionals to be compared with less experienced professionals. These differences were considered to be a group feature and therefore not added as covariates to the ANOVA. Effect sizes were calculated using r for the ANOVA as a whole and Cohen's d for a comparison between the groups with the highest and lowest scores. A $r<0.30$ was considered small, of 0.30-0.50 medium and > 0.5 large. A Cohen's d of <0.5 was considered small, 0.5-0.8 medium and >0.8 large.[18]

Linear regression applied to the main domain scores separately was used to evaluate the effect of work experience. All pharmacists and pharmacist trainees were combined to form a group and all GPs and GP trainees were combined to form another group. Theoretically, a certain number of years of work experience would have an optimal effect on assessment scores, in which case a curved rather than linear regression line would fit the data better. These non-linear models were estimated by adding a quadratic interaction term to the linear regression model. To avoid multi-collinearity between the main effect and the interaction term, standardized scores (z-scores) were used in this model. To prevent the influence of outliers in work experience, such as the few participants with more than 40 years of work experience, the range of ±2 SD of the mean score was used in this analysis.

Ethical considerations

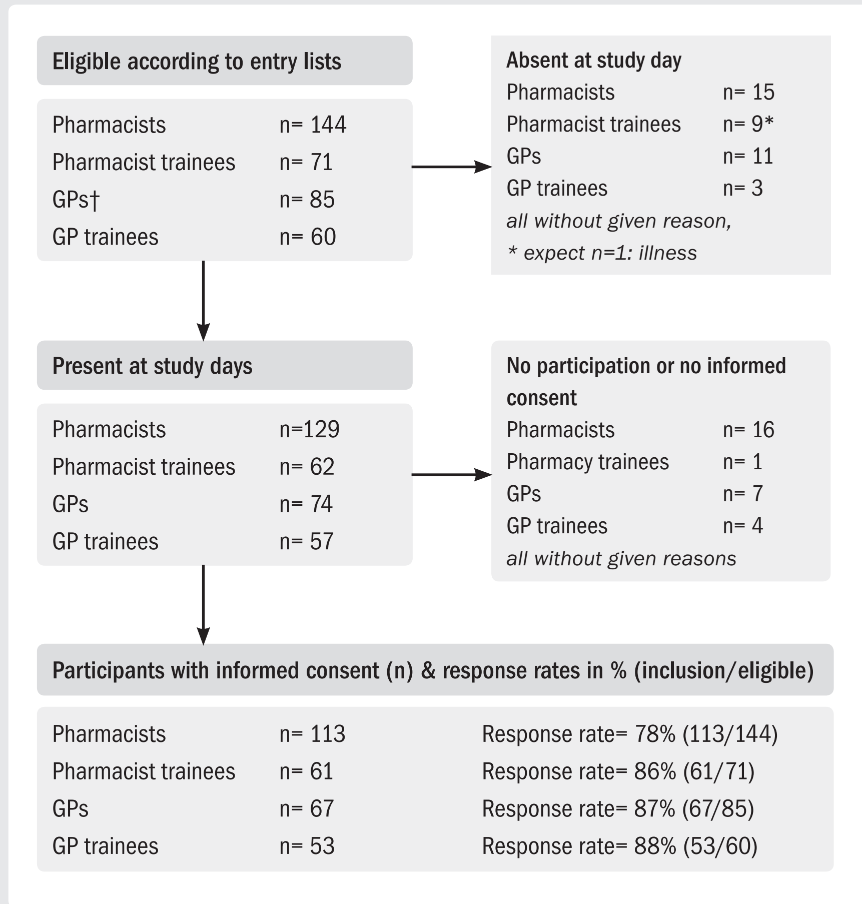
The Dutch Ethics Review Board of Medical Education (NVMO-ERB) approved this study. Informed consent was obtained from all participants.

RESULTS

Participant characteristics

From 22 January 2013 to 9 April 2014, 294 participants were included. Figure 1 shows the inclusion and response rates. The groups differed in terms of age and work experience, which was due to the study design (Table 2). Most pharmacist trainees (98.2%) and GP trainees (82.6%) had a maximum of 6 years of postgraduate practical and patient-related work experience.

FIGURE 1. **flowchart of the inclusion and response rates**



† GP= General Practitioner

TABLE 2. **groups characteristics**

GROUPS CHARACTERISTICS					
	Pharmacists n=113	Pharmacist trainees n=61	GPs n=67	GP trainees n=53	p-value
Age (mean±SD)	41.3 (8.7)	27.5 (2.5)	47.7 (11.1)	31.0 (3.0)	<.001*
Sex (female, %)	65%	62%	55%	77%	0.09†
Work experience					<.001‡
- (mean±SD)	17.2 (8.9)	1.6 (0.9)	21.1 (10.4)	5.1 (2.4)	
- range	2-42	1-6	4-44	2-14	
Previous education (n)					0.48†
- no	105	57	66	50	
- yes, not relevant	3	0	0	1	
- yes, relevant	5	4	1	2	

* *ANOVA, Hochberg's GT2 as post hoc test. All categories were significantly different from each other (all p<0.001), except for pharmacist trainees and GP trainees (p=0.09)*

† *Chi-square*

‡ *ANOVA, Hochberg's GT2 as post hoc test. All categories were significantly different from each other (pharmacists and physicians p=0.007, all others p<0.001), except for pharmacist trainees and GP trainees (p=0.124)*

Main results

Table 3 shows the main results. In the between-group comparisons, pharmacists had the highest scores for all domains (p< 0.05), except for pharmacist trainees who had comparable scores for basic knowledge (p=0.825) and pharmacotherapy skills (p=0.283). GPs had significantly lower scores than the other groups for pharmacotherapy skills (p<0.05). The pharmacy trainees outperformed the GPs, but not the GP trainees, in terms of basic pharmacology knowledge and pharmacotherapy skills. GP trainees outperformed the GP's on the pharmacotherapy skills (p <0.01).

Similar findings were found for the subdomains as shown in Table 3. Pharmacists outperformed physicians (GPs and GP trainees) on all subdomains, but had comparable scores to those of the pharmacy trainees on 5 of 8 subdomains. Pharmacy trainees and GP trainees had comparable scores for all subdomains except for "interactions and side effects", in which the pharmacy trainees outperformed the GP trainees (p=0.032). GP trainees outperformed their supervisors the GPs on prescribing in special groups (p <0.01). Pharmacokinetics was the only subdomain for which scores were not significantly different across the four groups (p=0.05).

Magnitude of the differences

Effect sizes for the different ANOVAs were small to medium, with *r*'s ranging from 0.16 to 0.40 for the different domains and subdomains. However, the difference between the lowest (mostly GPs in 8/10 comparisons) and the highest (pharmacists 10/10 comparisons) scores revealed a medium or large effect size, with Cohen's d values ranging from 0.42 to 1.10.[18] The GP trainees had the lowest scores for pharmacokinetics and the pharmacist trainees for pharmacotherapy skills. The absolute differences between the groups ranged from 6.5% to 18.4% for the (sub)domains. After correction for chance on the three-option multiple-choice questions, these absolute differences ranged from 9.8% to 23.4%.

Work experience as explaining variable

Linear regression models were applied to the data for the pharmacists and GPs separately, to test whether the number of years of work experience affected assessment scores.(Table 4) Whereas longer work experience was associated with poorer GP (-0.41% assessment score per year) and pharmacist (-0.31% assessment score per year) pharmacotherapy skills, it was associated with higher scores for pharmacists' clinical or applied pharmacology knowledge (+0.19% assessment score per year).

To establish whether a linear or curved line would fit the data better, non-linear models were estimated by adding a quadratic interaction term to significant linear regression models (Figure 2). Data for pharmacists' applied knowledge showed the best fit with a linear line whereas data for pharmacists' and GPs' pharmacotherapy skills showed the best fit with a curved line (F-change=11.19, p = .001 and F-change=7.922, p=0.006, respectively). Pharmacists had the best scores for pharmacotherapy skills when they had 12 years work experience, whereas the scores for GPs' pharmacotherapy skills decreased with work experience up to 23 years and then increased.

TABLE 3. **main results: scores for knowledge and skills (main domains and per subdomain) for the four groups of participants**

MAIN RESULTS	Groups				statistics		
	Pharmacists n=113 score in % (±SD)	Pharmacist trainees n=61 score in % (±SD)	GPs n=67 score in % (±SD)	GP trainees n=53 score in % (±SD)	p-value ANOVA	Effect size ANOVA *r*	Effect size high vs low Cohen d
Basic pharmacology knowledge	**76.5 (9.6)**	**74.7 (9.2)**	**69.3 (6.5)**	**71.8 (10.7)**	**p<.001†**	**0.28**	**0.88**
- pharmacodynamics	61.0 (16.4)	60.5 (14.7)	53.0 (17.9)	60.9 (21.9)	p=0.02	0.40	0.47
- pharmacokinetics	82.6 (15.5)	79.9 (15.8)	77.6 (16.3)	75.9 (16.6)	p=0.05	0.18	0.42
- interactions & side effects	80.6 (14.7)	80.0 (13.7)	71.5 (14.0)	72.2 (16.9)	p<.001	0.16	0.63
- ATC groups*	84.3 (14.9)	81.1 (13.3)	76.0 (16.9)	78.9 (15.6)	p<0.01	0.28	0.52
Clinical pharmacology or applied knowledge	**79.7 (8.4)**	**73.7 (8.7)**	**70.3 (10.8)**	**71.5 (9.7)**	**p<.001‡**	**0.40**	**0.97**
- prescribing	70.3 (15.8)	59.1 (16.7)	65.2 (18.6)	61.4 (15.6)	p<.001	0.26	0.69
- prescribing for special groups	82.8 (12.0)	76.5(14.8)	67.2 (16.1)	74.6 (13.2)	p<.001	0.40	1.10
- drug information, regulation & laws	83.0 (12.5)	81.0 (12.9)	76.1 (14.7)	76.5 (17.4)	p<0.01	0.22	0.51
- interactions & side effects	80.6 (14.7)	80.0 (13.7)	71.5 (14.0)	72.2 (16.9)	p<.001	0.16	0.63
Skills /prescription writing	**84.7 (20.7)**	**81.6 (18.0)**	**66.3 (21.1)**	**78.3 (18.2)**	**p<.001§**	**0.12**	**0.88**

Effect sizes are given for the ANOVA (r) and between the highest and the lowest group within this comparison (Cohen d).

** Drug groups by Anatomical Therapeutic Chemical Classification*

ANOVA with Hochberg's GT2 as post hoc test, only for the main domains the post hoc com parisons are specified in detail below

† *Pharmacists outperformed GPs (p<0.001) and GP trainees (p=0.024) but not pharmacist trainees (p=0.825). Pharmacist trainees outperformed GPs (p=0.012), but not GP trainees (p=0.500). GPs and GP trainees had comparable scores (p=0.173)*

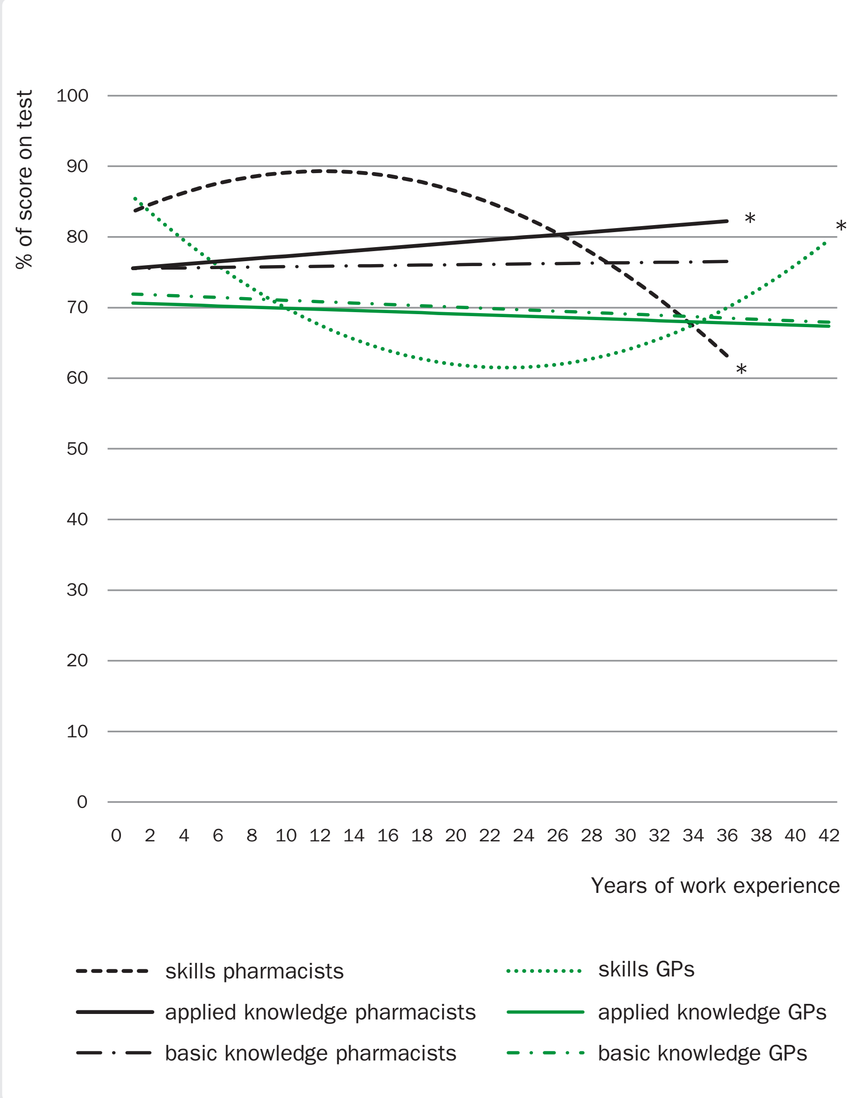
‡ *Pharmacists outperformed all other participants (all p<0.001); no other differences were found.*

§ *Pharmacists outperformed GPs (p<0.001), but not GP trainees or pharmacist trainees. Pharmacist trainees outperformed GPs (p<0.001), but not GP trainees (p=0.937). GP trainees outperformed GPs (p<0.01)*

TABLE 4. **linear regression with years of work experience as independent variable and assessment scores on the three domains as dependent variables for pharmacists and physicians separately**

RESULTS OF WORK EXPERIENCE ON ASSESSMENT SCORES				
Health Professional	**Domain**	**Constant (SE)**	**Unstand. beta (SE)**	**p-value**
General Practitioners (GPs)	Basic pharmacology knowledge	72.0 (1.57)	-0.10 (0.09)	0.26
	Clinical and applied pharmacology	70.7 (1.60)	0.09 (0.08)	0.93
	Prescription skills	77.5 (3.15)	-0.41 (0.17)	**<.05**
Pharmacists	Basic pharmacology knowledge	75.5 (1.14)	0.03 (0.07)	0.70
	Clinical and applied pharmacology	75.4 (1.05)	0.19 (0.07)	**<.01**
	Prescription skills	87.9 (2.29)	-0.31 (0.15)	**<.05**

FIGURE 2. **changes in knowledge and skills scores on the assessment (y-axis) by work experience (x-axis) for the combined groups of health professionals and trainees**



** Significant results (p<.05)*
provided for ±2 SD of the mean work experience to prevent the influence of outliers.

DISCUSSION

This study shows that pharmacists outperformed General Practitioners (GPs) on all domains of pharmacology and pharmacotherapy knowledge and skills. They also outperformed pharmacist trainees on most domains. In contrast, GP trainees generally performed slightly better than GPs. Pharmacy trainees and GP trainees had rather similar scores for the different (sub)domains. The between-group differences for the (sub)domain scores had medium to large effect sizes. For example, the absolute scores for pharmacists' and GPs' knowledge of prescribing for special groups were 82.8% (SD±12.0) and 67.2% (SD±16.1), respectively. If corrected for chance on the three-option multiple-choice question, the absolute difference was 23.4%. This represents the improvement in prescribing that could be achieved with interdisciplinary collaboration between pharmacists and physicians. We also found work experience to be associated with a better knowledge of clinical pharmacology on the part of pharmacists, with an estimated 2% improvement in assessment score per 10 years of work experience, whereas pharmacotherapy (prescribing) skills deteriorated with work experience, by 3% for pharmacists and 4% for GPs per 10 work years, respectively. All other knowledge domains remained the same over time. Generally speaking, the differences between pharmacists and GPs were most pronounced among the more experienced professionals. Taken together, the medium to large effect sizes detected in this study might be clinically relevant.

There are several potential explanations for this difference in performance, such as differences in undergraduate curriculum, work tasks and environment, postgraduate education, knowledge retention, and educational changes over time. An earlier study showed that differences in the undergraduate curricula of medical and pharmacy students led to differences between these students in basic knowledge (pharmacy students outperformed medical students) and pharmacotherapy skills (medical students outperformed pharmacy students); clinical or applied pharmacology knowledge did not differ between the groups.[9] Direct comparisons with the results of the current study cannot be made because the questions used in the former study were easier. In the current study, we did not find differences between GP trainees and pharmacist trainees, which suggests that the first few years of work experience have a major influence on knowledge and skills and reduce potential differences between the two professional groups. Unfortunately, it is not clear whether this is due to the loss of knowledge in one group or the gain of knowledge in the other. The observation that pharmacists with more years of work experience had higher scores for applied knowledge suggests that pharmacists tend to learn by doing during their career. It might be that the work tasks and environment lead to implicit "learning by doing" even without explicit education,[13] as a result of spontaneous and non-organized peer learning or quality improvement measures,[13, 19, 20] or postgraduate education.[21] In the Netherlands, all physicians and pharmacists must follow continuing education programmes. However, while physicians must follow a number of programmes on different topics, pharmacists 'only' have to follow programmes on pharmacology and pharmacotherapy. The same is true for postgraduate specialization programmes in pharmacy and GP medicine. These differences in postgraduate education could underlie the differences we found, with pharmacists outperforming pharmacy trainees whereas the opposite was true for GPs. We considered work experience to include not only actual work experience, but also other factors such as time since graduation. It is recognized that knowledge is not easily retained over time,[11] and that knowledge and skills have to be put to use or rehearsed in order to be retained. Whether this is the case here depends on the type of work tasks, work environment, and education.[10, 11, 20] Given that the average half-life of un-rehearsed knowledge is about 2 years, the decline in knowledge we found was rather small,[11] but still potentially of clinical relevance. In addition, undergraduate education and training has undergone a number of changes in the past decades, with emphasis being increasingly shifted away from basic knowledge such as pharmacology and pharmacotherapy.[3, 22] This means that the older and more experienced health professionals might have had a more thorough grounding in these topics during their undergraduate education resulting in higher test scores in the more experienced professionals, both for pharmacists as GPs. However, prescribing practice has also changed over the years, and the introduction of electronic prescribing may have led to a decline in prescribing skills over time, although we did not find evidence for this in the literature. As exposure to electronic prescribing is the probably same in all groups, it cannot explain the differences we found. The differences we found might be of importance to interprofessional education and collaboration,[7, 8] and recognition of these differences might improve patient care. Studies of interprofessional education and workplace learning often mention differences in attitude towards learning and cultural differences.[7, 8, 23] Although it is still unclear how this education should be designed,[24, 25] it is generally believed that previous education and knowledge should be taken into account when designing educational programmes.[8, 26]

We found clear differences in several knowledge and skills domains, measured with a formative assessment, between pharmacists and physicians and that work experience influenced these differences. However, the results should be interpreted in the light of some study limitations. First, the study was performed in the Netherlands, and it is not clear to what extent findings can be extrapolated to other countries. Participants came from all regions and the response rate was high, so selection bias within the Netherlands is not likely. Work experience was studied as a potential explanation for the assessment results, but it should be borne in mind that it was not studied longitudinally. The associations we found between work experience and knowledge and skills might be causal, but causality cannot be concluded given our study design. Perhaps the most optimal way to study the causality between work experience and knowledge and skills would be in a longitudinal study, however this also means several assessments over time within one person, with high change of test-driven learning. Lastly, only one pharmacotherapy skill was measured, namely, writing a prescription. More skills are needed to achieve optimal pharmacotherapy, such as communication skills.[23, 27] While it can be debated whether it is important that pharmacists should be able to write a prescription, it is recognized that they should be able to check a prescription for completeness. In this study, only the necessary elements were scored, not the order in which they were mentioned. It seems logical that pharmacists should be able actively recall the knowledge necessary to check a prescription, which is in fact identical to writing a prescription.

CONCLUSIONS

This study shows that relevant differences in knowledge of pharmacology and pharmacotherapy exist between pharmacists and physicians. While the level of knowledge and skills is similar shortly after graduation, differences emerge during the working life of pharmacists and physicians. These findings could form a basis for interdisciplinary collaboration and education and emphasize the need for life-long learning to keep knowledge and skills up-to-date. Reasons for these differences should be studied in more detail and international replication studies are needed.

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4

EDUCATIONAL INTERVENTIONS

> *What we have to learn to do, we learn by doing*
>
> **Aristotle**

4

4.1

Implementation of the WHO-6-step method in the medical curriculum by a learning programme to improve medical students' pharmacology knowledge and pharmacotherapy skills

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ABSTRACT

Aim Insufficient knowledge of pharmacology and pharmacotherapy is a predictor of prescribing errors, which can lead to serious clinical problems. It is therefore important that medical students receive high-quality education in pharmacology and pharmacotherapy. The only validated educational tool for pharmacology and pharmacotherapy is the 6-step method of the World Health Organizations (WHO) guide to good prescribing (WHO-6-step). Several experimental studies with short-term interventions have proven its effectiveness. The aim of this study was to investigate the generalizability of this effect after implementation of the WHO-6-step in a contextual-rich medical curriculum.

Methods The pharmacology and pharmacotherapy knowledge and skills of cohorts of students, from the years before, during, and after implementation of a WHO-6-step-based integrated learning programme were tested using a standardized assessment containing 50 items covering knowledge of basic and clinical pharmacology, and pharmacotherapy skills.

Results In total, 1652 students were included between September 2010 and July 2014, a participation rate of 89%. The WHO-6-step-based learning programme improved students' knowledge of basic pharmacology (60.6(SD±10.5) vs 63.4%(SD±10.9), p .009), clinical or applied pharmacology (63.7(SD±10.4) vs 67.4%(SD±10.3), p <.001) and improved their pharmacotherapy skills (68.8(SD±26.1) vs 74.6%(SD±22.9), p 0.019). Moreover, satisfaction with education increased (5.7(SD±1.3) vs 6.3 (SD±1.0) on 10-point scale, p <.001) and as did students' confidence in daily practice (-0.81(SD±0.72) to -0.50(SD±0.79) on a -2 to +2 scale, p <.001).

Conclusions The WHO 6-step method can be successfully implemented in a medical curriculum. The integrated learning programme had positive effects on students' knowledge of basic and applied pharmacology and improved their pharmacotherapy skills. It also increased students' satisfaction with their education and confidence in prescribing. Whether this training method leads to better patient care remains to be established.

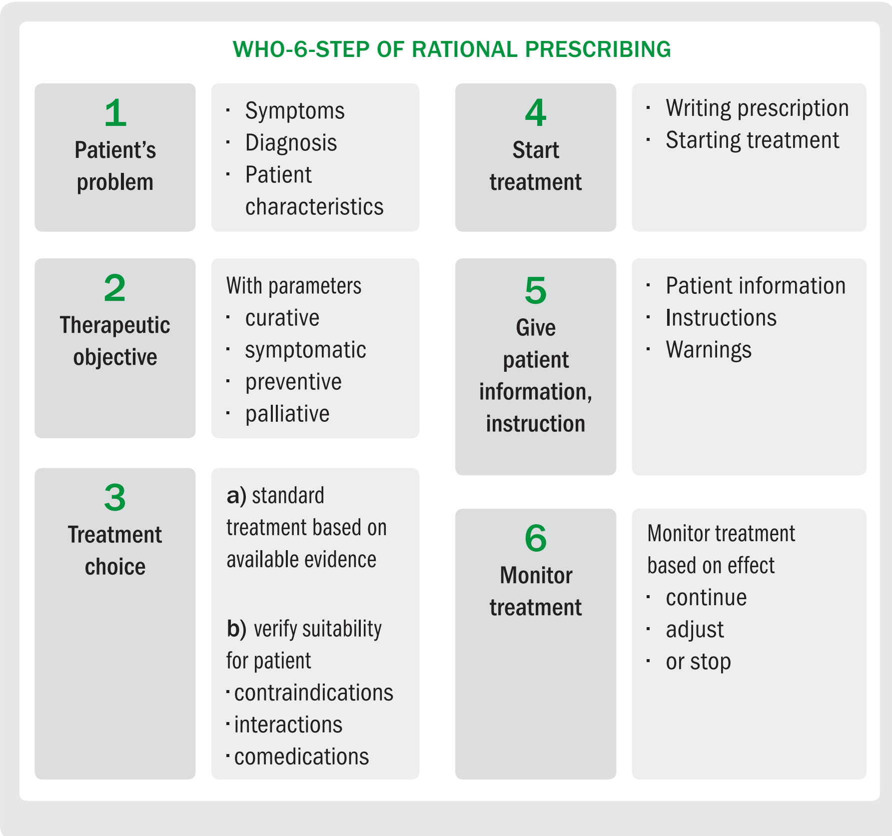
INTRODUCTION

Prescribing medication is an important component of patient care.[1] Although medications are beneficial to patient health and wellbeing, their incorrect prescription can have harmful effects.[2, 3] Half of all prescribing errors are potentially preventable, and recent studies indicate that these errors are often caused by prescribing physicians' limited knowledge of pharmacology and pharmacotherapy.[4, 5] This means that such errors might be avoided in the future, if the pharmacology education given to medical students is improved.[6-8] Indeed, medical students often feel unprepared for their prescribing task when they graduate and have expressed a wish to have more opportunities to acquire these skills in practice.[8] One possible reason why students feel unprepared is that they usually copy their supervisors' medication choices, without thinking autonomously about potential choices.[9] Hence, in order to improve prescribing in clinical practice, it is important that this autonomous thinking process is stimulated during medical training.

The only validated pharmacology and pharmacotherapy education tool is the WHO-6-step method of the World Health Organization's guide to good prescribing (WHO-6-step). This method specifically aims to improve the prescriber's thinking process,[10-13] (Figure 1) and seems to be a valuable prescribing tool for trainees. Ultimately, it focuses on rational pharmacotherapy, but in order to achieve this, relevant underlying basic knowledge has to be accurately applied to specific patient characteristics (Step 3b in Figure 1), e.g., changed pharmacokinetics.[10, 11] Several studies have addressed the effectiveness of the WHO-6-step, and short-term educational interventions based on the WHO-6-step have shown robust improvements in students' pharmacotherapy skills, measured at each of the six steps.[14-20] One study reported an increase in basic pharmacology knowledge,[20] and other studies reported the transfer of knowledge to unrehearsed patient cases and improved long-term results.[14, 16, 19] However, as mentioned, these studies involved short-term interventions, and results achieved in experimental studies may not always generalize to true curriculum effects after implementation of the programme in the contextual rich environment of medical education.[21, 22] Two studies investigated the long-term effects of implementation of the WHO-6-step in a medical curriculum and found positive effects on WHO-6-step skills and a transfer effect. However, only a small selection of students participated in the studies and outcomes other than treatment decisions measured on the steps of the WHO-6-step were not investigated.[23, 24]

To date, the WHO-6-step has not been studied thoroughly after its implementation in the contextual rich environment of a medical curriculum. This means that the generalizability of previous experimental findings is uncertain. We hypothesized that an integrated learning programme incorporating the WHO-6-step and given throughout the curriculum would increase students' knowledge of basic and applied pharmacology and improve their prescribing skills.

FIGURE 1. **WHO-6-step of rational prescribing from the Guide to Good Prescribing**



METHODS

Medical students from different entry years, representing cohorts before, during, and after curriculum reorganization, were compared with each other in terms of their pharmacology and pharmacotherapy knowledge and skills at fixed points in their educational careers, in our case halfway and at the end of their study. Knowledge of basic pharmacology and clinical or applied pharmacology, and pharmacotherapy skills were assessed using a formative standardized assessment. The specific educational interventions, the assessment, the study samples, and analyses are described in more detail below.

Educational intervention

Dutch medical curricula offer a 6-year two-phase Bachelor (3 years) and Master (3 years) programme, with secondary school diplomas as entry requirement. After curricular changes were made at Utrecht Medical School, the WHO-6-step was implemented in the curriculum as part of an integrated, longitudinal learning programme in pharmacology and pharmacotherapy. The WHO-6-step was the content of the education whereas the integrated and longitudinal learning program was the teaching strategy. The WHO-6-step was used during large (interactive) lectures, small group tutorials, and small group practical lessons (see Figure 1), in order to increase the patient context of education. The total number of contact hours was also increased, by 58 hours, mainly in the Bachelor phase (Table 1). In addition to these changes regarding the content, teaching strategy, and number of scheduled contact hours, other elements were added to the curriculum: the e-learning programme Pscribe, which is based on the WHO-6-step, was made obligatory for some tutorials;[25] some lectures and tutorials were interdisciplinary and were for medical and pharmacy students; and an additional elective course was introduced during the third year, but was poorly attended.

TABLE 1. **scheduled contact hours of pharmacology and pharmacotherapy education before and after implementation of WHO-6-step**

SCHEDULED CONTACT HOURS BEFORE AND AFTER IMPELEMENTATION										
		Before implementation WHO-6-step				*After* implementation WHO-6-step				
Study phase	**Study year**	**Lectures**	**Tutorials**	**Practical lessons**	**Total/ year**	**Lectures**	**Tutorial**	**Practical lessons**	**Total/year**	**Change**
Bachelor	Year 1	8	6	4	18	39	16	2	57	+39
	Year 2	0	0	0	0	7	5	0	12	+12
	Year 3	0	0	0	0	4	2	0	6	+6
	Total 1-3	**8**	**6**	**4**	**18**	**50**	**23**	**2**	**75**	**+57**
Master	Year 4	5	8	4	17	6	2	0	8	-9
	Year 5	0	0	0	0	0	8	0	8	+8
	Year 6	0	0	0	0	2	0	0	2	+2
	Total 4-6	**5**	**8**	**4**	**17**	**8**	**10**	**0**	**18**	**+1**
Both phases	**Total 1-6**	**13**	**14**	**8**	**35**	**58**	**33**	**2**	**93**	**+58**

Assessment

Students' knowledge and skills were measured with a formative written assessment based on the available literature on core curricula.[1, 26, 27] A formative assessment was chosen to eliminate the confounding variable of students' learning prior to the assessment.[28] The assessment was designed with a test matrix and covered three domains: basic pharmacology knowledge, clinical or applied pharmacology knowledge, and pharmacotherapy skills. The basic pharmacology knowledge questions tested factual knowledge from study books (canonical knowledge) with short questions e.g. "what is a first pass effect?", and the clinical pharmacology knowledge questions involved short case vignettes that required students to apply their knowledge to a specific patient e.g. "an 80-year-old woman with renal failure comes to the general practitioner with a complicated urinary tract infection (UTI). What is the best treatment for the UTI in this woman?" To assess pharmacotherapy skills, students had to write a drug prescription based on a case description.

Six parallel assessments from a database of 270 questions were formed, using a test matrix and drawing on the advice of an expert panel of ten pharmacists and clinical pharmacologists. Three versions of the assessment were used for the Bachelor medical students, with easier questions, on which an expert panel scored an average of 91.2% (SD±6.1). This assessment was also used in a previous study.[29] To prevent a ceiling effect, Master students were given a more difficult assessment, on which the expert panel scored an average of 80.8% (SD±6.1). This means that the performance of Bachelor and Master students could not be compared because different assessments were used. All assessments were used alternately during data collection to prevent distribution of the assessment among medical students during the 4-year study period.

The psychometric properties of the six assessments were adequate. The construct validity was supported by the fact that experts scored much higher than the Bachelor students on the easier assessment 91.2% (± 6.1) vs 71.5% (± 8.9) (unpaired t-test samples $p<0.001$) and higher than the Master students on the more difficult assessment 80.8% (± 6.1) vs 63.4% (± 8.1) (unpaired t-test $p< 0.01$). The content validity was ensured by the use of a test matrix. The reliability of the assessments was acceptable with an internal consistency (Guttman Lambda 2) ranging from 0.56 to 0.68 for the easier assessments and from 0.50 to 0.63 for the more difficult assessments, which is acceptable for formative assessments.[30, 31] The reliability of individual questions, expressed as the item-rest correlation (*rir)* scores for the different questions, was good: no questions had to be excluded from the analyses. The questions had a good spread of difficulty, expressed as p-values for each question (% of correctly answered question), namely, for the three easier assessments 0.18-0.97, 0.16-0.98, 0.18-0.97, and for the three more difficult assessments 0.23-0.97, 0.14-0.96, 0.10-0.97, respectively, indicating a variation in the difficulty of the questions and the presence of some easy questions with very high p-values.

Additionally, in order to establish population characteristics, all participating students filled out a short questionnaire prior to the written formative assessment regarding their age, sex, entry year of the study, and previous relevant studies. Five additional questions concerned pharmacology education, namely, average hours of self-study, interest in the subject, importance of pharmacology knowledge, and confidence in own pharmacology and pharmacotherapy knowledge and skills in clinical practice. Lastly, students were asked to grade the pharmacology and pharmacotherapy education on a 10-point scale (1–10).

Study samples and data collection procedure

Students from Utrecht Medical School, Utrecht, the Netherlands, were included. Bachelor students were assessed after completion of the first 3 years of medical training, at the start of their 4^{th} study year; Master students were assessed after completion of all compulsory courses, at the start of the 6^{th} study year (subsequent education entails elective courses only). Table 2 displays the background characteristics.

Students were asked to participate during voluntary, scheduled study activities in four academic years between 2010–2011 and 2013–22014. The assessment was formative and did not count towards students' study results.

Ethical considerations

This study with medical students falls outside the scope of the Dutch Law on Medical Research (WMO). The Dutch Ethics Review Board for medical educational research (NVMO-ERB) was not operational at start of the study. The students, all 18 years or older, were informed about the study in advance in the written study materials. They gave active verbal consent and participated on a voluntary basis. All data were collected anonymously.

Data analysis

To prepare data for analyses, assessments were scored by a researcher (CK). The multiple choice questions were scored as right or wrong (0-1); each correct item included in the prescription written by a student was awarded by 1 point: 1) name patient and date of birth, 2) name physician and signature, 3) drug and dose, 4) number, 5) label instruction. All scores are expressed as a percentage of the maximum score possible per (sub)domain. The students were asked whether they had previously studied a biomedical subject, e.g. biomedical sciences; other studies, such as law, were not considered as relevant prior studies. Response rates were calculated by comparing the number of participants to the number of number of medical students recorded in the University digital registration system.

To test the effectiveness of WHO-6-step implementation, the mean scores of students from different cohorts for knowledge of basic and applied or clinical pharmacology knowledge, pharmacotherapy skills, and the subdomains, satisfaction, and motivational factors were compared using ANOVAs and ANCOVAs to correct for the possible confounding effect of age, sex, and study duration. More specifically, to assess the effectiveness of implementing the WHO-6-step in the Bachelor phase, students' knowledge and skills before implementation (entry year 2007 or before, for the first time assessed in 2010) were compared with students' knowledge and skills after implementation of the WHO-6-step (entry year 2008, 2009, 2010; assessed in 2011, 2012, 2013). To assess the effects in final-year Master students, three groups were formed: students who had not received WHO-6-step training (entry year 2006 or before, assessed in 2011), students who received WHO-6-step training in the Master phase only (entry year 2007, assessed in 2012), and students who had received WHO-6-step training in both the Bachelor and Master phases (from entry year 2008 on, assessed in 2013).

First, to assess the effect of the complete WHO-6-step programme, final-year students without WHO-6-step training were compared with students who had received training in both the Bachelor and Master phases. Second, to determine whether the overall effect has its origin in the Bachelor or Master phase, students who had received training in either the Bachelor phase or the Master phase were compared with the control groups of students who had not received training in either phase. Thirdly, analyses were performed to determine whether the effect of training in the Bachelor phase carries over to students in the Master phase. In other words, do medical students retain knowledge gained in the Bachelor phase years after this training or is knowledge present in the Master phase acquired during the Master phase. To analyse this, Master students who received WHO-6-step in the Master phase only were compared with Master students who had received the training in both the Bachelor and Master phases.

It should be mentioned that the assessment points were for students without a study delay. If students had a study delay, they were included in later assessments. Since a study delay might influence study results, it was taken into account as a covariate in the models. In all models, effect sizes (Cohen's d) were calculated to magnify the significant differences. Effect sizes < 0.5 were considered small, 0.5-0.8 medium, and > 0.8 large.[32] A p-value of <.05 was considered significant. Data of the assessments were collected and analysed using Excel and IBM SPSS version 22.0 (IBM).

RESULTS

In total, 1652 medical students were enrolled in this study, 942 Bachelor students (response rate 87%) and 710 Master students (response rate 92%) in the study period September 2010 to July 2014 (Table 2). One student withdrew consent after inclusion without giving a reason; data for this participant were deleted. The cohorts of Bachelor and Master students differed in terms of age, sex, and proportion of students without a study delay.

Main results

The main results are given in Table 3. Master students who received the full WHO-6-step programme (in the Bachelor and Master phases) significantly outscored the control Master students who did not receive the WHO-6-step programme in the following domains: basic pharmacology knowledge, applied pharmacology knowledge, and pharmacotherapy skills, and the subdomains pharmacodynamics and prescribing. After correction for possible confounding variables, most effects remained significant, except for the domain pharmacotherapy skills and the subdomain pharmacodynamics.

Bachelor students who received the Bachelor part of the WHO-6-step programme had a significantly better basic pharmacology knowledge and knowledge of pharmacodynamics and ATC groups than did control Bachelor students who did not receive the WHO-6-step programme. These differences remained significant after correcting for potential confounders. Similarly, Master students who only received the Master part of the WHO-6-step programme had a better knowledge of basic and applied knowledge pharmacology than did the control Master students who did not receive the WHO-6-step programme. The difference in applied pharmacology knowledge was no longer significant after correction for confounders.

In summary, the WHO-6-step intervention was effective when used in either the Bachelor or the Master phase and improved students' knowledge of basic pharmacology, and in the Master phase it led to better knowledge of applied pharmacology. When used in both phases, students had a better knowledge of basic and applied pharmacology, and better skills in the subdomains prescribing and pharmacodynamics. The significant results had small effect sizes ranging from 0.17 to 0.35 (Cohen d).

Compared with students who received WHO-6-step training in the Master phase only, students who received the WHO-6-step training during both the Bachelor and Master phases had a better knowledge of applied pharmacology (Mean±SD 65.6 (10.5) vs 67.4 (10.3), p 0.035) and better prescribing skills (Mean±SD 62.9 (16.4) vs 59.0 (17.2), p 0.028); the latter was no longer significant after correcting for confounders in the ANCOVA (p 0.065). Thus introduction of the WHO-6-step programme in the Bachelor phase improved students' knowledge and skills slightly more than when the intervention was introduced in the Master phase.

TABLE 2. baseline characteristics of the cohorts before and after implementation of the WHO-6-step programme

BASELINE CHARACTERISTICS							
	Bachelor Students (n=942)			*Master* Students (n=710)			
Characteristic	Before	After change in Bachelortraining	p-value	Before	After change in Master training only	After full intervention	p-value
Entry year (n)§			n.a.				n.a.
<2006	22	-		90	-	-	
2006	81	-		233		-	
2007	226	-			235	-	
2008	-	217		-	-	148	
2009	-	229		-	-	1	
2010	-	160		-	-	-	
Total n	329	606		323	235	149	
Age (Mean±SD)	22.7 (±2.2)	22.1 (±1.4)	<.001†	24.9 (±2.5)	24.0 (±1.2)	23.7 (±1.7)	<.001‡
Sex (Female,%)	66%	76%	<.01*	68%	72%	85%	<.01*
Previous study Δ			.315				.186*
None (n)	266	481		256	192	132	
Yes, not relevant (n)	29	71		41	24	10	
Yes, relevant (n)	34	53		26	16	7	
Missing data (n)	-	1		-	3	-	
No study delay (%)	47%	76%	<.001*	40%	66%	100%	<.001*

*p-value calculated by * Pearson's chi-squared tests,*
† *t-test for independent samples,*
‡ *ANOVA, n.a.: comparison not applicable*
§ *Missing variables on entry year and therefore some students could not be categorised into cohorts for further analyses: Bachelor students n=7, Master students n=3; 1 Master student had exemptions due to previous studies, resulting in very fast study progress*
Δ *all biomedical studies e.g. biomedical sciences were considered as relevant previous studies, other studies e.g. law school were considered non-relevant previous studies*

TABLE 3. **main results: percentage of maximal assessment scores before and after implementation of the WHO-6-step programme for Bachelor and Master students**

MAIN RESULTS: ASSESSMENT SCORES BEFORE AND AFTER IMPLEMENTATION				
	Bachelor Students		Statistics	
	Before	After change in Bachelor-training	Before vs After	Effect size*
Domain	Mean ±SD	Mean ±SD	p-values/adj†	Cohen d
Basic knowledge	67.8 (9.9)	70.1 (10.0)	**0.001/0.008**	0.23
Pharmacodynamics	68.8 (14.9)	71.3 (14.9)	**0.014/0.031**	0.17
Pharmacokinetics	67.9 (16.6)	69.3 (16.2)	0.219/0.567	
Interactions and side effects	65.9 (15.6)	67.7 (17.0)	0.104/0.175	
ATC groups	65.3 (18.5)	68.1 (18.3)	**0.028/0.049**	0.17
Applied knowledge	71.5 (10.6)	72.2 (11.4)	0.380/0.854	
Prescribing	63.8 (16.1)	64.4 (16.2)	0.596/0.833	
Prescribing in special groups	72.7 (19.2)	74.2 (19.8)	0.272/0.554	
Drug information, regulations and law	78.8 (17.9)	78.0 (19.8)	0.517/0.495	
Interactions and side effects	65.9 (15.6)	67.7 (17.0)	0.104/0.175	
Skills	67.3 (26.1)	69.6 (28.7)	0.226/0.410	

** effect sizes only given for significant differences*
† p-values adjusted by ANCOVA with covariates: age, gender, study delay

MAIN RESULTS: ASSESSMENT SCORES BEFORE AND AFTER IMPLEMENTATION						
Master Students			Statistics			
Before	After change in Master training only	After full intervention	Before vs After Master training only	Effect size*	Before vs After full intervention	Effect size*
Mean ±SD	Mean ±SD	Mean ±SD	p-values/adj†	Cohen d	p-values/adj†	Cohen d
60.6 (10.5)	63.1 (9.8)	63.4 (10.9)	**0.004/0.008**	**0.25**	**0.009/0.0026**	0.26
57.3 (16.4)	60.0 (16.2)	60.6 (17.5)	0.051/0.058		**0.047**/0.052	0.19
66.0 (20.4)	66.1 (20.2)	67.1 (18.8)	0.963/0.928		0.585/0.950	
66.9 (19.9)	67.8 (20.4)	69.8 (18.6)	0.575/0.714		0.137/0.142	
54.6 (21.3)	57.9 (19.6)	56.4 (18.6)	0.059/0.067		0.386/0.208	
63.8 (10.5)	65.6 (10.5)	67.4 (10.3)	0.036/0.101	0.17	**<.001/0.001**	0.35
57.1 (17.8)	59.0 (17.2)	62.9 (16.4)	0.209/0.232		**0.001/0.001**	0.18
66.6 (18.7)	68.3 (18.1)	69.9 (17.3)	0.291/0.854		**0.070**/0.592	
64.4 (21.1)	66.3 (21.7)	65.6 (22.6)	0.288/0.246		0.581/0.297	
66.7 (19.9)	67.7 (20.3)	69.8 (18.6)	0.575/0.714		0.137/0.142	
68.8 (26.1)	72.7 (24.3)	74.6 (23.0)	0.072/0.346		**0.019**/0.114	0.24

TABLE 4. **secondary results after implementation of the WHO-6-stepfor Bachelor and Master students**

SECONDARY RESULTS: BEFORE AND AFTER IMPLEMENTATION											
	Bachelor Students		Statistics		*Master* Students			Statistics			
	Before	After change in Bachelor-training	Before vs After	Effect size‡	Before	After change in Master training only	After full intervention	Before vs After Master training only	Effect size‡	Before vs After full intervention	Effect size‡
Domain	Mean±SD	Mean±SD	p-values/adj†	Cohen d	Mean±SD	Mean±SD	Mean±SD	p-values/adj†	Cohen d	p-values/adj†	Cohen d
Interest in topic*	0.24 (0.92)	0.13 (0.89)	0.085/**0.028**	0.12	0.29 (0.85)	0.31 (.82)	0.44 1.84)	0.840/0.814		0.248/0.402	
Recognized importance*	1.16 (0.86)	1.07 (1.55)	0.321/0.267		1.25 (0.98)	1.21 (.87)	1.22 (.87)	0.679/0.814		0.787/0.718	
Confidence in clinical practice*	-0.89 (0.74)	-0.60 (0.78)	**<.001/<.001**	0.38	-0.81 (0.72)	-0.69 (.81)	-0.50 (.79)	0.066/0.131		**<.001/0.009**	0.41
Self-study hours (h/wk)	0.89 (1.60)	1.24 (2.23)	**0.014/0.006**	0.18	0.54 (0.82)	0.49 (.91)	0.48 (.83)	0.440/0.575		0.403/0.972	
Appreciation education (1-10 scale)	5.7 (1.5)	6.5 (0.90)	**<.001/<.001**	0.65	5.7 (1.3)	6.0 (1.2)	6.3 (1.0)	**0.015/0.040**	0.24	**<.001/<.001**	0.52

** Measured on a Likert scale: -2: very disagree, -1 disagree, 0 neutral, 1 agree, 2 very agree*
† p-values adjusted by ANCOVA with covariates: age, sex, study delay
‡ effect sizes only given for significant differences

Students' satisfaction, study behaviour, and motivation

Master students who had received the intervention in both the Bachelor and Master phases had a greater appreciation of their education and were more confident in clinical practice (although on average still unconfident) than the control group of Master students who did not receive WHO-6-step training (Table 4). These results were still significant after correction for possible confounding variables.

Students who had received the intervention in the Master phase only expressed a greater appreciation of the education received than did students who did not receive the intervention in the Master phase. Students who received the intervention in the Bachelor phase only were more interested in the topic, were more confident (although on average still unconfident), had a greater appreciation of the education provided, and made more self-study hours per week than the control students who had not received the intervention in the Bachelor phase.

Students who received WHO-6-step training in both phases were more satisfied with their education than students who received the training in the Master phase alone (6.3 (±1.0) compared to 6.0 (±1.2), ANOVA p = 0.006; after correction for confounders p = 0.011). Introduction of the WHO-6-step training increased students' confidence scores from very unconfident (-0.69±0.81) to mildly unconfident (-0.50±0.80) on -2 to +2 scale (ANOVA p = 0.026, after correction for confounders p = 0.003). Other factors did not differ between these two cohorts. The effect sizes of the differences in confidence and self-study hours were small (Cohen d range 0.18-0.41), whereas the differences in appreciation showed medium-sized effect sizes (Cohen d up to 0.65)

The WHO-6-step programme hardly effected intrinsic motivational study factors such as students' interest in pharmacology and pharmacotherapy and the recognized importance of the topic (Table 4). In all groups of students the recognized importance was higher than interest in the topic (all p<0.001 on paired t-test), although the recognized importance did not increase in any of the groups.

DISCUSSION

This study shows that the WHO-6-step based learning programme is effective in increasing students' pharmacology knowledge and pharmacotherapy skills and is appreciated by both Bachelor and Master medical students. In cohorts of students who received the full training (in both the Bachelor and Master phases), there was improvement on all pharmacology knowledge and pharmacotherapy skills domains, relative to earlier cohorts that had not received the WHO-6-step training. Training in the WHO-6-step method improved knowledge of basic pharmacology in students that received the intervention in the Bachelor phase only and improved knowledge of basic and applied pharmacology in students that received it in the Master phase only. Additionally, with more training students reported greater appreciation of their education and more confidence in prescribing, although the latter was still rather low. Bachelor students with the Bachelor training only reported more self-study hours. Unfortunately, other factors, such as recognized importance of and interest in pharmacology and pharmacotherapy, did hardly differ between groups with and without training. To quantify these significant improvements: the effects on students' appreciation of education were the largest with medium-sizes effect sizes, whereas the differences in the other domain such as knowledge, skills, and self-confidence showed small effect sizes.

Earlier studies have already shown positive effects of the WHO-6-step on the performance of medical students.[14-20, 23, 24] However most of these studies were randomized controlled trials.[14-17, 19, 20, 24] Although this study design is considered the best possible, in medical education the results from randomized controlled trials are not always generalizable to other settings, such as the contextual rich environment of the medical curriculum. As in earlier studies, this study shows that the WHO-6-step is suitable for Bachelor and Master medical students. This study used a different outcome measure than most other studies, namely, pharmacology knowledge and pharmacotherapy skills rather than students' decisions on the different steps of the WHO-6-step. Only one other study showed positive results on basic knowledge after a short-term intervention, as measured directly after the intervention.[20] While this might seem a strange endpoint, studies of medication-related errors have mentioned knowledge deficits, not a lack of skills in the WHO-6-step, as being a concern.[4, 5] Moreover, if the skills learned with the WHO-6-step can be transferred to other non-rehearsed patient cases,[16, 24] then the WHO-6-step might contribute to a broader knowledge of pharmacology and better pharmacotherapy skills. The WHO-6-step method might stimulate a deeper understanding of, and more active engagement in, pharmacology and pharmacotherapy by showing students the clinical relevance of these subjects. Although the WHO-6-step method improved pharmacology knowledge and pharmacotherapy skills, effect sizes were small, possibly due to an indirect learning effect. The clinical relevance of these small differences can be debated, but it should be borne in mind that small or even non-significant results are very common in educational implementation studies.[21] The effect sizes for appreciation of education were medium. Interestingly, although writing a prescription is an explicit part of the WHO-6-step, there was hardly any improvement in this skill. Why this is the case is unclear, but possibly the increased use of electronic prescribing diminishes the prescription writing skills of later cohorts of students, although no evidence could be found in literature for this.

Surprisingly, findings also suggest that the improved performance of the Master students was mainly due to training in the Master phase: students who received the WHO-6-step training in the Master phase only had scores nearly comparable to those of students who had received the training in both Bachelor and Master phases of their study plus an additional 57 hours of education during the Bachelor phase. Only applied knowledge improved significantly in this comparison. Knowledge retention might be a problem, as suggested in earlier studies.[33] This raises questions about the described positive effects of repeated and integrated education over the years.[34] However, it should also be noted that although hardly any significant difference was found by a head-to-head comparison, the group with the full intervention did have the highest scores on all domains. Next to that, these extra hours of education at least had other significant positive effects, namely on satisfaction, which is an important outcome measure in medical educational research.[35] Unfortunately, other outcomes, such as interest in the topic and recognized importance of the topic, were hardly affected by the method. And as it is stated: "education is not filling the bucket, but lighting a fire",[36] we probably failed to light a fire for the students and to increase their intrinsic motivation to study pharmacology and pharmacotherapy. Students recognize the importance of the subject, but are not interested in it, and the educational intervention did not make any difference to this. It might be worthwhile to study intrinsic motivation in future research on pharmacology and pharmacotherapy education.

How robust are the positive effects of the WHO-6-step on students' knowledge and skills? And does the WHO-6-step itself actually influence pharmacology knowledge and pharmacotherapy skills? Owing to the design with two assessment points, for both the Bachelor and Master students, it is very likely that the results are robust because they were replicated within the study. The crucial question remains, to what extent can these results be attributed to the WHO-6-step method (educational content), rather than the additional hours of education provided (quantity of education) or the introduction of a longitudinal learning programme (teaching strategy). Our results showed that it was the WHO-6-step method in the learning program that was responsible for the improvement in knowledge and skills, because students who received the training in the Master phase only, performed better than the students who did not receive this training, even though the number of contact hours and self-reported self-study hours were similar (17 h vs 18 h of offered education). In the Bachelor phase, the improvement in students' knowledge may have been due to the four-fold increase in contact hours. It is difficult to determine to whether the teaching content (the WHO-6-step method) or the teaching strategy (integrated, longitudinal programme) had the largest influence on the improvement in knowledge and skills in this study. This would need to be investigated in a study in which different teaching strategies, with the same educational content, are compared.

Strengths and limitations

This study is the first to show that a WHO-6-step based learning programme incorporated into the medical curriculum improves students' pharmacology knowledge, pharmacotherapy skills, and satisfaction. Selection bias is unlikely given the large number of students that participated and the high response rate. Moreover, the programme was effective in both the Bachelor and Master phases of the curriculum. However, the study had some limitations. It was carried out in a single centre, and therefore the generalizability of the results to medical students of universities in other countries is uncertain. Given that Dutch medical curricula are very similar (e.g., same entry requirements), it is very likely that the same results would be obtained for students from other Dutch medical schools. Still, the WHO-6-step based learning programme cannot necessarily be directly duplicated in other curricula, because of differences in teacher skills, curricular content, etc. These factors are multifactorial and not static and may even change depending on student group dynamics during medical education. That said, there is no reason to believe that the WHO-6-step programme cannot be implemented in other medical schools. Another potential limitation is that the study had an

observational and practice based design and was not a randomized controlled trial.[37] However, randomized controlled trials are very difficult to perform with a real curriculum, and, given its effectiveness, it might be unethical to withhold the WHO-6-step method from half of the students. As a result of our design, a long inclusion period was necessary, which has its disadvantages. As shown in the population characteristics in Table 2, changes in study regulations can affect baseline characteristics. In the Netherlands, the costs of studying are increasing rapidly and this might have resulted in differences in the population characteristics: the intervention group was relatively younger, with less study delay. Moreover, the number of female students has increased steadily over the years – these differences were used as covariates in the analyses. Lastly, some comments can be made about the assessment. It had a rather low internal consistency. While it is normal to assess scores for an individual, we assessed group means, for which an internal consistency higher than 0.5 is acceptable.[30,31] A low internal consistency is mainly a problem if there are non-significant results, because it is difficult to detect group differences if the variation in scores is large. The assessment required students to write a prescription, but it can be queried whether this task is useful, given the increase in electronic prescribing. In addition, while it is recognized that there are more pharmacotherapy skills than writing a prescription, these other skills, such as pharmacotherapy communication skills, are hard to assess with a written assessment. [38]

CONCLUSIONS

The WHO-6-step method can be successfully implemented into a medical curriculum by an integrated learning programme and has positive effects on students' knowledge of basic and applied pharmacology, pharmacotherapy skills, and satisfaction and confidence in prescribing. Both Bachelor and Master students can benefit from the method. As prescribing is a high-risk task, the availability of evidence-based training is important. Further studies are needed to establish whether patients benefit from being treated by doctors trained with this method.

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4.2

Structured pharmaceutical analysis of the STRIP is an effective method for final-year medical students to improve polypharmacy skills: a randomised controlled trial

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ABSTRACT

Aim Medical students may not be adequately trained to prescribe appropriately to older patients with polypharmacy. This study addresses how to teach students to minimize inappropriate polypharmacy.

Methods This study was designed as a randomised controlled trial with a pre-test and post-test. The Systematic Tool to Reduce Inappropriate Prescribing (STRIP) was used as the intervention. This medication review tool consists of five steps and is part of the Dutch multidisciplinary guideline on polypharmacy. Step two is a structured pharmaceutical analysis of drug use, assessed by means of six questions regarding: 1) undertreatment; 2) ineffective treatment; 3) overtreatment; 4) potential adverse effects; 5) contraindications or interactions; 6) dose adjustments. It is used in combination with the START and STOPP checklists. Students were asked to optimize the medication lists of real patients, making use, or not, of the STRIP. Half of the students used E-learning as additional intervention. The number of correct or potentially harmful decisions made by the students when revising the lists was determined by comparison with expert consensus.

Results One hundred and six final-year medical students from two Dutch schools of medicine participated. Students who used the STRIP had better scores than the control students: they made more correct decisions (+34% (9.3 vs. 7.0); $p < 0.001$; r 0.365) and fewer potentially harmful decisions (-30% (3.9 vs. 5.6); $p < 0.001$; r 0.386). E-learning did not differ from non-E-learning methods on effect.Students were satisfied with the method.

Conclusions The STRIP method is effective in helping final-year medical students improve their polypharmacy skills and is well appreciated by the students.

INTRODUCTION

Polypharmacy is a potential risk factor for drug-related problems caused by inappropriate prescribing and can lead to hospital admission and death.[1,2] However, inappropriate prescribing to patients on polypharmacy can also lead to undertreatment, a situation known as the polypharmacy paradox.[3,4] For these reasons, patients usually benefit from a regular clinical medication review.[3,5,6] Although the risks of, and problems associated with, polypharmacy are well known, medical training fails to provide medical students with the knowledge and skills needed to prescribe appropriately to patients who use multiple medications.[7,8] As a result, physicians may inadvertently cause drug-related problems, and especially in older patients on polypharmacy, because of the complexity of prescribing multiple medications and an inadequate understanding of pharmacology.[7,9,10] Generally spoken, junior physicians lack the skills needed to perform a medication review to optimize polypharmacy.

Few studies have addressed how geriatric pharmacology and therapy should be taught.[11]Several methods are available to help clinicians and pharmacists to optimize polypharmacy in clinical practice, such as technical prescription review, a technical review of the prescribed drugs, and clinical medication review, which explicitly involves the patient.[5,6] Technical prescription reviews can be divided into explicit (such as the Beers list and START/STOPP criteria) and implicit or judgmental reviews (such as the Prescribing Optimizing Method).[12-15] The Systematic Tool to Reduce Inappropriate Prescribing (STRIP) is a new method for performing a clinical medication review. It is considered a best practice method and is incorporated in the national Dutch guideline on polypharmacy.[16] One of the steps is the structured pharmaceutical analysis, based on the Prescribing Optimizing Method and the START and STOPP criteria. The structured analysis has proven effective among general practitioners after an introductory lecture on the topic.[15] However, it has not been studied in a simulation of clinical practice in which users have access to resources such as guidelines available on Internet. Moreover, it is not known whether clinical experience, which medical students do not have, is a prerequisite for using the STRIP.

The aim of this randomised controlled study was to investigate the effect of the STRIP in combination, or not, with E-learning on undergraduate medical students' skills in optimizing polypharmacy.

METHODS

For this study the CONSORT statement was used as a guide.[17]

Trial design

This multicentre randomised controlled trial with a pre-test/post-test design investigated whether the STRIP improves the medication review skills of final-year medical students when dealing with patients on polypharmacy. This study investigated the technical prescription review step, which involves cognitive or problem-solving skills.[18] All students reviewed the prescriptions of two real-life cases consecutively: the first (pre-test) without the STRIP, and the second (post-test) with or without the method (see Figure 1).

Students were randomised 1:1 to the control and intervention groups. The intervention group, which used the STRIP, was subdivided 1:1 into an E-learning group and a non-E-learning group, to study the effect of an E-learning environment on the results of the medication review. Students from centre A were already familiar with the E-learning program Pscribe, which had been used for non-polypharmacy cases, and therefore they received the non-E-learning environment, in contrast to students from centre B, who were naive to Pscribe. Therefore, students were randomised to the main intervention, the STRIP, and allocated by location to the E-learning or non-E-learning environment.

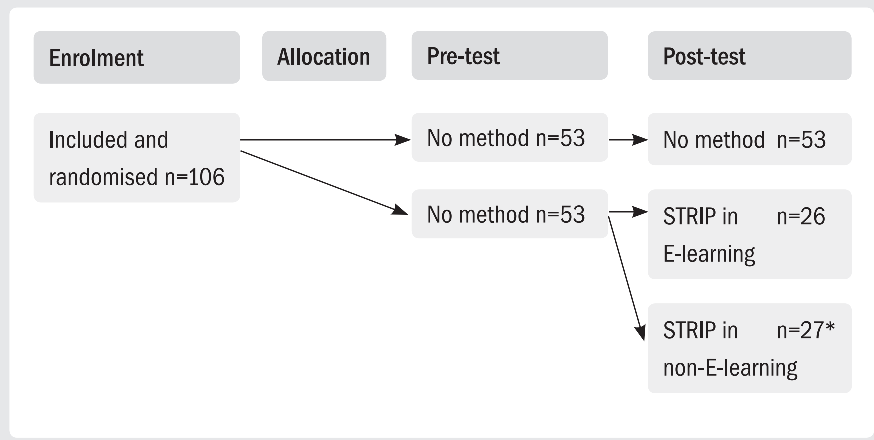
All students were asked to review the prescriptions of the same two patient cases of similar complexity and number of drugs prescribed.[15] Both cases contained information about the medical history, a medication list, and the results of physical examination and laboratory testing. All cases were presented on-screen, accompanied by the instruction to optimize the medications. For the first case, both the intervention and control groups had to optimize the medications without guidance, but for the second case the intervention group had access to the STRIP, either implemented in the user friendly designed E-learning environment Pscribe or in a non-E-learning environment. The students were not taught how to use the STRIP or the E-learning program because both were assumed to be self-directing. All students had access to resources available on Internet.

Interventions

Systematic Tool to Reduce Inappropriate Prescribing

The STRIP consists of five steps: 1) structured history of medication use; 2) structured pharmaceutical analysis; 3) decision making for medication choice by

FIGURE 1. **study design and flow chart**



** n=3 were lost due to technical problems and not analysed, resulting in n=24 in STRIP non-E-learning group*

physician and pharmacist; 4) definite choice by shared decision making with the patient; and 5) follow-up and monitoring.[16] The second step of the STRIP is an implicit method for prescription review with the explicit methods the START and STOPP added as aids.[12,14] It is a validated tool for doctors to optimize the prescribing of multiple medications and consists of six questions about the medication list regarding: 1) undertreatment; 2) ineffective treatment; 3) overtreatment; 4) (potential) adverse effects; 5) contraindications or interactions; and 6) dose adjustments.[15] The START criteria were added to the 1st question on undertreatment, and the STOPP criteria were added as a guide for the 3rd, 4th and 5th questions.

E-learning with Pscribe

Pscribe is an E-learning program for medical and pharmacy students, to guide the prescribing process.[19] It is incorporated into a computer-assisted instruction program to optimize knowledge and skills in pharmacotherapeutic reasoning. The system includes a Learning Content Management System with several assessment modules as well as a data-tracking module that automatically registers data during the drug-choice process in order to assess knowledge and skills in drug prescribing. Teachers can add their own patient cases to Pscribe. In our E-Learning environment, the STRIP guides students step-by-step through a patient case report. All decisions made in one step are taken to the next step until the case is "solved". Links to various useful resources are available, such as the START and STOPP checklist. It is considered a self-directed program. The program is available online at www.pscribe.nl; there is a subscription fee.

Setting and participants

Final-year medical students who had completed all mandatory courses and rotations at Centre A (School of Medicine, University of Utrecht, Utrecht) and Centre B (School of Medicine, University of Amsterdam, Amsterdam) were eligible for participation. All students present on a certain study day during their clerkships were asked to volunteer to optimise two medication lists. These sessions were supervised by two researchers. All students had access to Internet resource that they would use in clinical practice. At the end of the session, students were asked to fill in a questionnaire with Likert scales (running from 1, completely disagree, to 5, completely agree) on satisfaction with the method and the E-learning program Pscribe. All participants received a voucher worth €10 for participating.

Outcomes

The main outcome was the accuracy of the revised medication list, evaluated by calculating the number of correct, indifferent, or potentially harmful decisions made by comparison with a medication list prepared by consensus by an expert panel of two geriatricians/clinical pharmacologists and two clinical pharmacists (i.e. the gold standard). Those decisions that the expert panel considered open to discussion were rated as correct if the decisions were followed but were not rated as potentially harmful if ignored. For example, whether it is appropriate to start an 82-year-old man on statin therapy when life expectancy might be an issue. So if a student did start a statin, it was a correct decision, but it was not a harmful decision if the student did not prescribe a statin. Secondary endpoints were student–expert agreement and satisfaction with the method and E-learning program.

Randomisation

Students were randomised 1:1 to the intervention and control groups using an automatically generated randomisation scheme. Students were given inlog codes that had previously been attached in advance to the control or intervention group. While students were blinded to group allocation when they revised the medication list of the first case, this was not the case for the medication list of the second case, as they either did or did not use the STRIP. The researchers were blinded when evaluating the students' performance.

Power calculation

The power calculation was based on the results of a previous study, using the number of potentially harmful prescriptions as input for the power calculation.[15] A study population of at least 100 (n=50 + n=50) participants was needed. Because E-learning is considered as effective as non-E-learning, this was not included in the power calculation.[20, 21]

Data collection

The medication lists generated by the students were made anonymous and transferred by an independent researcher to an Excel file (version Office 2010). Then investigators (HK, CK) rated the choice of each medicine made by each student. The data were then transferred to SPSS 20 and analysed.

Statistical analyses

Baseline characteristics were compared in order to check whether randomisation was successful, using a t-test, chi-square, Mann-Whitney or Kruskal-Wallis. For the E-Learning and non-E-Learning subgroups, separate chi-squares or ANOVAs (with three groups E-Learning, non-E-Learning, and control) were performed at baseline. The main analysis was performed with a repeated measurement ANOVA since this takes potential differences in baseline measures between the control and intervention groups into account. When comparing the control, E-learning, and non-E-learning groups, post-hoc tests were used, namely, LSD or t-tests. Differences at baseline were added to the model with a cut-off of $p<0.1$. Paired and unpaired t-tests were used to compare the effect of "learning by doing" on a repeated task, the agreement with the drugs chosen by the experts, and student satisfaction with the method and the E-learning program.[22] Effect sizes were calculated: $r > 0.1$ was considered a small effect, >0.3 a medium effect, and >0.5 a large effect.[23]

Ethics

The national Ethics Review Board of Medical Education (ERB-NVMO) gave their approval for the study. Informed consent was obtained from all participants.

RESULTS

Populations' characteristics

In total 106 medical students (54 from Centre A and 52 from Centre B) took part in the study during the period June 2012 to January 2013. Three students from the intervention group were excluded because their data were lost due to technical problems, leaving the data for 103 medical students available for analysis (53 in the control group and 50 in the intervention group). Figure 1 shows the flow chart of the study.

The pre-test scores of the students in the control and intervention groups were similar, indicating that randomisation was successful (Table 1); however, the age and sex distribution of students in the E-learning group and the non-E-Learning group were different. The baseline characteristics of the three excluded students did not differ significantly from those of students in the other groups.

Main results

In a repeated measures model, in which the initial differences between groups and between the complexity of the tasks were taken into account, the intervention group significantly outperformed the control group on the post-test case, as shown in table 2. Otherwise said, the appropriateness of prescribing by the students in the intervention group improved significantly between the first and the second cases, whereas that of the students in the control group (not being assisted by intervention in the second case) did not. The two groups did not differ in the number of indifferent answers.

The number of correct decisions increased and the number of potentially harmful decisions decreased in the intervention group relative to the control group. Most improvement was seen at the level of undertreatment and adverse effects. The students in the intervention group correctly discontinued medications because of adverse effects more often than did the students in the control group (16 medications discontinued in the control group vs 24 in the intervention group, +50%) and correctly added medications in the case of undertreatment (74 medications added in the control group vs 134 in the intervention group, +81%). The students in the intervention group made fewer potentially harmful decisions, such as continuing medications that caused adverse effects (40 potentially harmful decisions in the control group vs 23 in the intervention group, -43%) and not correcting undertreatment (191 potentially harmful decisions in the control group vs 123 in the intervention group, -36%). Both groups made the most errors when it came to not correcting undertreatment.

TABLE 1. **baseline characteristics of students randomised to the control and intervention groups with intervention subgroups E-learn and non-E-learn**

BASELINE CHARACTERISTICS								
		Control	Intervention					
			All		non-E-learn	E-learn		
		n=53	n=50	p-value	n=24	n=26	p-value	
Age	**Years, median** *(range)*	25 *(23-32)*	25 *(23-40)*	0.38*	25 *(23-40)*	28 *(23-40)*	**<.001¶**[a]	
Gender	**Female (n)** **Male (n)**	40 13	29 21	0.06†	7 17	14 12	**0.03** †	
Location	**Centre A (n)** **Centre B (n)**	27 26	24 26	0.77†	24 -	- 26	n.a.	
Previous study§	**Not or not relevant (n)** **Relevent (n)**	44 9	41 9	0.89†	21 3	20 6	0.61 †	
Weeks until graduation	**Median** *(range)*	12 *(6-42)*	12 *(6-40)*	0.98*	18 *(6-36)*	12 *(10-40)*	0.95 ¶	
Pre-test score	**Correct decisions** *(mean (SD))*	5.8 *(1.7)*	5.2 *(1.5)*	0.11‡	5.7 *(1.6)*	4.9 *(1.4)*	0.06	
	Indifferent decisions *(mean (SD))*	0.9 *(0.9)*	1.1 *(0.9)*	0.23‡	1.0 *(0.9)*	1.2 *(1.0)*	0.34	
	Harmful decisions *(mean (SD))*	3.4 *(1.5)*	3.4 *(1.0)*	0.99‡	3.1 *(1.1)*	3.7 *(0.9)*	0.45	

All groups (all, non-E-learn, E-learn) were compared with the control group. n.a. not applicable
** Mann-Whitney U, †Chi-square, ‡ unpaired t-test, § all biomedical studies were considered relevant e.g. pharmacy, ¶ ANOVA with LSD as posthoc-test*
[a] *non-Elearning compared with Elearning p .001, Elearning compared with control p .001, non-Elearn compared to control n.s.*

TABLE 2. **main results: effect of the structured pharmaceutical analysis of the STRIP, the control group versus the intervention group in the post-test**

MAIN RESULTS					
	Control group Mean (SD) n=53	Intervention group Mean (SD) n = 50	Difference in post-test between groups %	Effect size r	p-value
Correct decisions (n)	6.98 (1.79)	9.34 (1.90)	+34%	0.36	**<.001***
Indifferent decisions (n)	1.09 (1.11)	1.26 (1.35)	+15%	0.12	0.204*
Harmful decisions (n)	5.64 (1.78)	3.92 (1.98)	-30%	0.39	**<.001***

** repeated measures ANOVA*

E-learning and non-E-learning

There were no significant differences between the non-E-learning and E-learning groups: both groups similarly outperformed the control group in a repeated measures model with age and sex as covariates. Both groups (E-learning and non-E-learning) made significantly more correct decisions than the control group in the repeated measurement ANOVAs: the difference between the control group and non-E-learning group was 2.35 (mean 9.33-6.98; t(75)=-5.25; p<.001; r 0.407) and the difference between the control group and the E-learning group was 2.37 (mean 9.35 – 6.98; t(77) = -5.35; p <.001; r 0.270). They also made significantly fewer potentially harmful decisions: the difference between the control group and non-E-learning group and between the control group and the E-learning group was – 1.73 (mean 3.92 – 5.64); t(75) = 3.86; p <.001; r 0.289 and – 1.72 (mean 3.92 – 5.64); t(77) = 3,83; p < .001; r 0.429 respectively. There was no significant difference between the three groups concerning the number of indifferent decisions (F (2,98) = 2.24; p 0.11).

'Learning' by doing

Although the control group made 21% more correct decisions about the second case than about the first case (mean 7.0 (std. dev. 1.8) versus mean 5.8 (std. dev. 1.7), respectively; t -3.581; df 52; p 0.001), they also made 66% more harmful decisions (mean 5.6 (std. dev. 1.8) versus mean 3.4 (std. dev. 1.5), respectively; t -6.654; df 52; p < 0.001) when revising the medications of the second case. Thus the students did not appear to learn by doing, as the students in the control group made more additional errors than correct decisions when they evaluated the second case, in contrast to the students in the intervention group, whose performance improved with the second case. This potential effect of "learning by doing" was incorporated in the model for the main outcome.

Optimisation of drug use

When optimizing the medications of the second case, the students in the intervention group added more drugs to the medication list than did the students in the control group (+1.6 drugs, mean 9.9 (std. dev. 2.1) versus mean 8.3 (std. dev. 1.7), respectively; t -4.20, df 101, p < 0.001). The expert medication list contained 12–15 drugs (some changes were indifferent and therefore drugs could be added or omitted, resulting in a range in the optimal number of drugs in the final medication list). The medication lists of the students in the control group showed 55–69% agreement with those of the experts, whereas this proportion was 66–82% for the lists of the students in the intervention group. The E-learning and non-E-learning groups did not differ from each other, and there was no difference between the number of drugs prescribed in the first case between the intervention and control groups: mean 7.8 (stddev 1.3) versus mean 7.4 (std. dev. 1.3), respectively (t 1.43, df 101, p 0.15).

Satisfaction with STRIP and Pscribe

The students thought the STRIP was useful (mean 3.3 (std. dev. 0.9)/5) and suitable for teaching (mean 4.0 (std. dev. 0.8)/5) and probably beneficial for patients (mean 3.6 (std. dev. 0.9)/5). The opinions of students from Centres A and B did not differ. The students thought that the E-learning program Pscribe was suitable for teaching (mean 4.0 (std. dev. 0.8)/5) and a good E-learning program (mean 3.6 (std. dev. 0.6)/5), but they thought it could be made visually more attractive (mean 2.9 (std. dev. 1.0)/5).

DISCUSSION

Overall, this randomised controlled trial in an educational setting showed that the structured pharmaceutical analysis of the STRIP is an effective method to help students to minimize harmful polypharmacy in older people: students who used the method to review the medication lists of real-life cases made better decisions (34% more correct decisions) and fewer (by 30%) potentially harmful decisions than the control group did, who did not use this method. The improvement was mainly seen in less undertreatment and more attention being paid to adverse effects. The effect was moderate: 0.37 and 0.39 for the increase in correct decisions and for the decrease in harmful decisions, respectively.[23] Furthermore, there was no apparent difference between the E-learning and non-E-learning groups. Although the study probably did not have sufficient power to detect such differences, this finding was in line with our expectations.[20] Students were positive about the new learning method. Perhaps, more importantly, the revised medication lists of the students who used the STRIP were largely in agreement with those of the panel of experts in the field of polypharmacy.

Implications in theory and practice

Given the potential adverse effects of inaccurate prescribing of multiple medications, such as preventable hospital admissions, undertreatment, and overtreatment, it is crucial that students acquire the necessary prescribing skills before they enter clinical practice.[24] It is recognized that young professionals often struggle with this complex task in real life.[7] An earlier study demonstrated that the structured pharmaceutical analysis of the STRIP improves general practitioners' ability to detect and avoid inappropriate medication,[15] and this study showed that this method is appropriate for educational purposes, even when used without prior instruction. Therefore the results can most likely be generalised to other medical schools. Medical curricula pay relatively little attention to geriatric pharmacology and pharmacotherapy,[11] but this method, which can be used without prior instruction and does not require an E-learning environment, can probably be easily integrated into existing curricula.

The structured pharmaceutical analysis of the STRIP improved medical students' ability to optimize polypharmacy.[25] While it is not known whether this educational intervention will impact on students' future skills as doctors reviewing patients on polypharmacy, several studies suggest that improving education can lead to better patient care.[10,26,27] Unlike the WHO 6-step method for rational prescribing, the STRIP analysis focuses on polypharmacy instead of a single prescription;[26] both methods seem effective in educational environments, although the WHO 6-step method is hardly applicable to polypharmacy. A secondary outcome was that optimisation of the medication list with this method led to more drugs on the medication list (almost three additional drugs when compared to the number of drugs on the medication list of the first case; 41% extra); however, it should be borne in mind that only one medication list was optimised. Moreover, as concern about the dangers of polypharmacy often leads to undertreatment, increasing the number of drugs might, in fact, be appropriate.[4] The students in this study thought that the STRIP method would be a useful tool to teach polypharmacy in medical curricula. This is promising, since students' satisfaction can be seen as a basis for good education.[25]

Strengths and weaknesses

While this two-centre study involving more than 100 students demonstrated that the STRIP is an effective method for teaching medical students how to manage polypharmacy, the results should be interpreted in the light of some limitations. Although it would seem that these results can be generalised to other medical curricula, it should be remembered that the cases, checklists, and recommendations of the experts came from one country. Although it can be assumed that guidelines that are based on the international literature will differ only slightly per country, the effect of the STRIP method on the skills of medical students in other countries was not studied. The students optimized the medication lists without contact with patients and thus had no direct feedback on their skills. However, both cases were based on real patients, and in daily practice the technical prescription review is usually performed without the patient, but with information on paper. The study did not have enough power to demonstrate whether E-learning and non-E-learning have a different effect, but it is generally accepted that the methods are similarly effective.[20,21] Although the two test cases were selected because of their similarity, based on the answers of general practitioners,[15] the second case might have been marginally more difficult because the control group's performance was slightly worse than with the first case. However, we corrected for this potential difference in difficulty and also for potential differences in baseline measures between the control and intervention groups, using repeated measures models. The next step in research is to determine whether patients benefit from physicians and students using the STRIP in real-life clinical practice.

CONCLUSIONS

This randomised controlled trial showed that the structured pharmaceutical analysis of the STRIP is an effective tool for helping medical students learn how to minimize inappropriate polypharmacy: it facilitates good prescribing practice and can lead to fewer potentially harmful adverse drug effects. Since no prior instruction is needed, the method can easily be integrated into medical curricula worldwide, enabling more medical students to benefit from this effective tool.

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5

SUMMARY AND GENERAL DISCUSSION

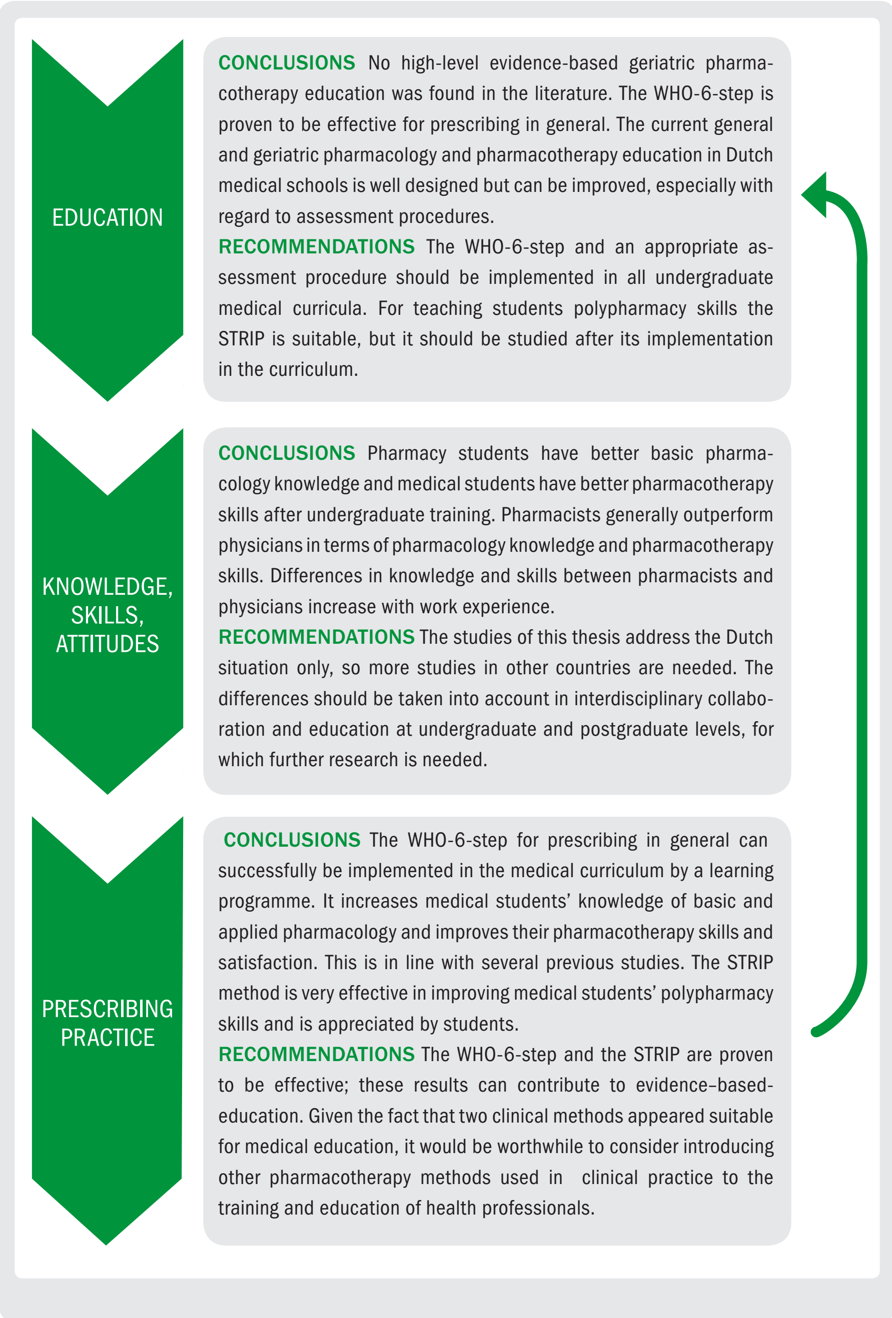
The whole of science is nothing more than a refinement of everyday thinking

Albert Einstein

5.1

Summary and General Discussion in English

FIGURE 1. **summary of conclusions and recommendations of this thesis**



SUMMARY AND GENERAL DISCUSSION

Appropriate pharmacotherapy in older patients is of increasing importance. Advances in medicine and pharmacotherapy mean that people with health problems live longer.[1] The longer life expectancy means that health professionals, but particularly physicians, pharmacists, and nurses, will have to meet the challenge of providing pharmaceutical care to older vulnerable patients. Older patients often have more than one medical problem. This makes appropriate prescribing for curative, preventive and symptomatic treatment goals essential, with polypharmacy as a result.[1,2] However, there is currently concern about the large number of drug-related problems reported, which appear to especially affect older patients.[3-5] These problems are thought to be because health professionals lack sufficient knowledge and skills in pharmacology and pharmacotherapy, possibly because of shortcomings in their education and training. Indeed, it has been suggested that improving education in geriatric pharmacotherapy might improve the knowledge and skills of health professionals in complex pharmacotherapy, thereby preventing or reducing the number of drug-related problems.[1, 5-10] This was the main reason to initiate the studies described in this thesis, with a view to answering the following questions:

1 **Does a lack of education and training in general and geriatric pharmacology and pharmacotherapy contribute to the suggested deficit in health professionals' knowledge and skills?**

2 **How much knowledge and skills of pharmacology and pharmacotherapy do health professionals have? Does work experience influence their knowledge and skills?**

3 **Can clinical methods, such as the WHO-6-step and the STRIP, improve students' knowledge, skills, and satisfaction, and can these methods be implemented in medical curricula?**

This chapter summarizes and discusses the answers to these questions, placing them in a broader perspective. Recommendations for future studies are given. Figure 1 shows the main findings and recommendations.

1 Does a lack of education and training in general and geriatric pharmacology and pharmacotherapy contribute to the suggested deficit in health professionals' knowledge and skills?

Findings

Two strategies were used to evaluate the educational quantity and quality. In the study reported in **Chapter 2.1,** the literature was searched for 'evidence-based education' in general and geriatric pharmacology and pharmacotherapy, but no high-quality studies of evidence-based education in geriatric pharmacology and pharmacotherapy for different health professionals were identified. Although several studies addressed this topic, the level of evidence was rather low and replication studies were not found. The only effective method so far is the WHO-6-step method from the Guide to Good Prescribing. This method is for prescribing in general and is not always directly appropriate for geriatric patients on polypharmacy. Although it can be used for a single prescription in the case of co-medication, the WHO-6-step is not suitable for optimizing polypharmacy, e.g., by medication review. The next strategy was to perform a detailed curriculum mapping of general and geriatric pharmacology and pharmacotherapy education in Dutch medical curricula, to evaluate daily educational practice (**Chapter 2.2**). Extensive structured interviews were carried out with coordinating teachers at all Dutch medical schools, thereby enabling a detailed overview of the educational programmes provided. Results showed that while Dutch medical curricula are generally well constructed in terms of general and geriatric pharmacology and pharmacotherapy, differences and shortcomings were identified that could serve as starting points for curricular improvement. The number of contact hours for pharmacological education differed by a factor three between medical schools, ranging from 39 to 107 hours. The credit points (1 ECTS=28 student study hours, including self-study) assigned to the topic were rather low relative to the number of contact hours, ranging from 0 to 3 ECTS. Education coordinators estimated that, overall, 79% of the educational goals identified in the published literature would be met with the curriculum offered by their medical school: 85% for knowledge, 76% for skills, and 66% for attitudes. With regard to geriatric pharmacology and pharmacotherapy, 87% of knowledge learning goals would be met and 65% of skills learning goals. Interestingly, all geriatric learning goals were met when a geriatrician was a member of the education coordination team. Only in half of the medical schools were pharmacology and/or pharmacotherapy knowledge and skills evaluated with a summative assessment. Summative means that the assessment is designed so that students either pass or fail; it is not merely to provide feedback on students' performance. Given that only half of the medical schools had such a summative assessment, students could theoretically graduate from the other medical schools without any proof that they had acquired the necessary pharmacology knowledge or pharmacotherapy skills to enable them to prescribe safely. The reported level of students' preparation for daily practice was mostly mediocre.

Considerations and limitations

The studies described in this chapter investigated the teaching and education provided in general and geriatric pharmacology and pharmacotherapy. Whereas the WHO-6-step is available for prescribing in the general population, it appears that there is an urgent need for evidence-based education in geriatric pharmacotherapy, since no high-quality educational programmes in this subject were identified in a literature search. This in turn requires high-quality studies, but medical educational research does not always yield robust results because medical education is given in a contextually complex environment in which there is, e.g., social interaction.[11] This will be discussed from a broader perspective later. The main points for improvement, as shown in our national overview, are to provide education in pharmacotherapy skills and attitudes, rather than focusing solely on knowledge of basic pharmacology. This is the case for both general and geriatric pharmacology and pharmacotherapy. Next, assessment procedures should be rigorously overhauled, taking into consideration that assessment drives students' learning.[12] Although ideally students should learn from purely intrinsic motivation, the truth is that extrinsic motivation, such as assessments, can be a useful tool to increase students' knowledge.[13, 14] With a rather complex and high-risk task such as prescribing, it is strange that the assessment of relevant knowledge and skills does not have a higher priority. It is like driving a car without a driver's license. A driving test was introduced in 1927 in the Netherlands to prevent mortality among, and caused by, drivers.[15] Perhaps, almost hundred years later, the time is ripe for a prescribing examination to prevent the harmful effect of errors, which mostly affect older and vulnerable patients. If prescribing in general is like driving a car, then prescribing for older patients is like driving a bus – the task is more complex and the risks are greater. Therefore, assessments in medical education should explicitly address prescribing including prescribing for older patients, by means of clinical observation of prescribing in practice or by simulation of clinical practice. Theoretical examinations of knowledge of basic and applied pharmacology could be a useful counterpart to these practical examinations.

Before the above question can be answered properly, some methodological issues need to be addressed. Perhaps the most important limitation is the fact that it could not be concluded, on the basis of the study design, that education and knowledge are actually related. We primarily studied education, rather than the knowledge obtained from the curriculum. To study this properly, a study would have to fulfil the following criteria:

1) uniform measurement of knowledge and skills of graduated students and detailed description of the education provided,
2) a multicentre and preferably international study, and
3) uniform approach to educational strategies, e.g. small-group learning at one medical school should be comparable to that of another medical school.

The feasibility of this approach is a major problem, and for this reason the best available evidence will probably come from smaller studies. Another limitation is that there is a certain element of subjectivity to curriculum mapping that should be taken into account when interpreting the results. We hoped to minimize this by using a highly structured interview. A potential limitation is that the planned and delivered curriculum is not always the same as the experienced curriculum, and it is the experienced curriculum that is ultimately responsible for students' gaining knowledge.[16] Future research could compare the two 'types' of curricula. The content of education in geriatric pharmacotherapy is still debated and guidelines for the general population are not always applicable to vulnerable older patients and may even have harmful effects.[17] How guidelines should be applied to the older population still needs to be clarified. Information from drug registration studies, which is needed to enable appropriate prescribing for older patients, is often not incorporated into clinicians' pharmacotherapy handbooks.[18] More needs to be learned about geriatric pharmacotherapy, and this knowledge should be used to provide meaningful education for future generations of health professionals.[19, 20] The curriculum mapping performed in this study needs to be replicated for other, international, medical curricula, so that results can be generalized. To date, only two other detailed curriculum-mapping studies have been reported, but educational changes over the years might have rendered their findings out of date.[21, 22]

As a final note, it should be pointed out that although the literature review covered various health professionals, only the medical curriculum was studied in detail.

Conclusions and recommendations

To answer the research question, insufficient education might contribute to the lack of health professionals' knowledge of geriatric pharmacology and pharmacotherapy. Currently there is no evidence-based education in geriatric pharmacotherapy. More needs to be learned about geriatric pharmacotherapy education in order to provide students with meaningful and evidence-based learning programmes. For education on prescribing in the general population the WHO-6-step can be used. Suggestions for curricular improvements are made, with the most important being the need to improve assessment procedures. Medical students should take a 'prescribing examination', just as motorists have to take a driving test.

2 How much knowledge and skills of pharmacology and pharmacotherapy do health professionals have? Does work experience influence their knowledge and skills?

Findings

The knowledge and skills of Dutch medical students, general practitioners (GP), GP trainees, pharmacy students, pharmacists, and pharmacist trainees were assessed, using a standardized formative assessment addressing knowledge of basic pharmacology, clinical or applied pharmacology, and pharmacotherapy skills. In the study reported in Chapter 3.1, medical and pharmacy students were compared. Although pharmacy students received six times more scheduled education in pharmacology and pharmacotherapy, the knowledge of clinical or applied pharmacology of the two groups of students was similar. Pharmacy students had a largely better knowledge of basic pharmacology than the medical students, whereas the medical students had better pharmacotherapy skills. In the study reported in Chapter 3.2, the knowledge and skills of pharmacists, pharmacist trainees, GPs, and GP trainees were compared and the role of work experience in potential differences was investigated. The differences found in students were not replicated in the health professionals. GP trainees and pharmacist trainees had a similar knowledge of basic and clinical or applied pharmacology and had similar pharmacotherapy skills. The pharmacists outperformed all other groups, including the pharmacy trainees. In contrast, the GP trainees outperformed their supervisors, the GPs. For pharmacists, more work experience was associated with more (higher scores) knowledge of applied pharmacology. Surprisingly, for both physicians and pharmacists, pharmacotherapy skills decreased with more work experience. The absolute difference between pharmacists and GPs was maximally 23% after correction for chance, so rather large differences exist between the two professional groups. The greatest difference was seen in the subdomain prescribing for special groups, among others older patients. The causes for these differences were not studied, but might be explained by learning by doing, differences in postgraduate education, educational changes over decades, and problems with knowledge retention.

An additional comparison was made between the above groups of participants, the medical students that participated in the study described in **Chapter 4.1** and the expert-panel of clinical pharmacologists who validated the assessments. Experts scored the highest, although pharmacists had virtually the same overall scores for knowledge and skills (mean 80.8% (SD 6.1) vs mean 77.8% (SD 8.0), p=0.599). Final-year medical students had the lowest scores (mean 63.4% (SD 8.1), lower than those for GPs (69.0% (SD 8.6), p <0.001) and GP trainees (71.4% (SD 8.9), p<0.001).

Considerations and limitations

There were rather clear differences in the pharmacology knowledge and pharmacotherapy skills of the different health professionals. This might be important, given that interdisciplinary collaboration is increasingly being seen as a component of undergraduate and postgraduate education, at least in the literature, and that interdisciplinary pharmaceutical care has proven promising in terms of patient care.[23] The differences in knowledge and skills between different professions perhaps are of added value to multidisciplinary collaborations relative to a monodisciplinary approach. The field of inter-professional pharmacotherapy education is still largely unexplored.[24] Can different professionals learn from another? The inter-professional differences in knowledge and skills we found suggest this is possible, but further research is needed. Previous studies mainly addressed the simultaneous education of different health professionals (also referred to as inter-professional education). However, peer-teaching and peer-learning also exist.

Peer-teaching is teaching between professionals and can be a part of informal inter-professional learning in the workplace.[24-26] Interdisciplinary education and collaboration might lead to peer-teaching and might become essential to the acquisition and retention of knowledge after medical and pharmacy students graduate.[24] So how knowledgeable are Dutch health professionals? As mentioned in the Introduction, there is no clear norm of knowledge. This means that participants cannot be termed highly or poorly knowledgeable. As the pharmacists had scores near to those of the expert panel, there might be little room for improvement among pharmacists, compared with the other groups of students/professionals. Knowledge of basic and applied pharmacology and pharmacotherapy skills were studied using a formative assessment, which enabled us to exclude as possible confounder learning behaviour or knowledge gained by learning prior to the assessment.[12] We thought that this would be the most authentic way to measure knowledge and skills, since most health professionals do not rehearse their knowledge and skills in pharmacology and pharmacotherapy before patient consultations.

Some methodological issues need to be addressed before conclusions can be drawn. The assessment, which was designed and validated for these studies, had some problems with reliability, specifically the internal consistency varied considerably in the different populations, ranging from mediocre for the studied populations (internal consistency by Guttman lambda-2=0.5-0.7) to rather good for the expert panels (internal consistency by Guttman lambda-2=0.7-0.8).[27] Does this make our results less robust? A low internal consistency can cause non-significant results because the assessment variance is large compared with the group variance in between-group comparisons. However, as most of our studies showed significant differences, the low internal consistency probably did not have a great effect on our results. Another limitation is the way pharmacotherapy skills were measured, namely, with writing a prescription. Certainly there are more skills than writing a prescription, such as pharmacotherapeutic communication skills and taking a good drug history.[28, 29]However, prescription writing is the only skill that can be authentically evaluated with a written assessment. Thus we assessed only one of the many pharmacotherapy skills that physicians should possess. Another potential limitation is the cross-sectional design. This means that only associations could be found, not causal relations between work experience and knowledge and skills. Another important limitation is certainly our national approach, as not only does undergraduate education differ in other countries, but also the professional tasks of pharmacist and GPs are different. This means that the generalizability of study findings cannot be guaranteed. This first structured comparison of the pharmacology knowledge and pharmacotherapy skills of physicians and pharmacists might be a starting point for replication studies in other countries.

Conclusions and recommendations

Differences in the knowledge and skills of pharmacists and physicians probably have their origins in undergraduate education, at least in the Netherlands. Moreover, postgraduate experiences probably have an even greater influence on knowledge and skills. Pharmacy students outperformed medical students in terms of knowledge of basic pharmacology, whereas medical students had better pharmacotherapy skills. The two groups of students had a comparable knowledge of clinical or applied pharmacology. After graduation, these differences between pharmacists and GPs became more pronounced. Whereas pharmacists outperformed their trainees and had scores comparable to those of experts, GP trainees outperformed their supervisors, the GPs. The largest differences were seen in the subdomain prescribing for special groups, among them older patients. The bright sight of these differences is that they could form the basis for peer-learning in interdisciplinary education and collaboration. Our results should be replicated in medical schools in other countries, to enable generalization of our findings. Further research is needed to clarify the causes of the differences found, especially the post-graduation variables, such as learning by doing, postgraduate education, educational changes over decades, and problems with knowledge retention.

3 Can clinical methods, such as the WHO-6-step and the STRIP, improve students' knowledge, skills, and satisfaction, and can these methods be implemented in medical curricula?

Findings

The WHO-6-step method for rational prescribing in the general population was investigated in the study reported in Chapter 4.1. This method has already proven effective as short-term educational intervention for medical students in several international randomized controlled trials.[30-33] In this thesis, its effectiveness was studied after it was implemented in the different study years of a medical curriculum. This is important because results obtained in experimental studies cannot always be generalized to an educational setting.[11] The WHO-6-step method improved students' knowledge of basic and applied pharmacology and marginally improved students' pharmacotherapy skills, namely, the ability to write a prescription. Moreover, students appreciated the method and reported greater confidence in clinical practice; they also increased their number of self-study hours. The method was effective for both Bachelor and Master students. Yet, the WHO-6-step was designed to facilitate the rational prescription of a single drug, whereas older patients often use more than one medicine (typically five or more prescriptions). Optimizing polypharmacy is a skill required in geriatric pharmacotherapy and cannot be achieved with the WHO-6-step method. Instead, medication review methods, e.g. the Systematic Tool to Reduce Inappropriate Prescribing (STRIP), are available to achieve a balanced approach to polypharmacy.[34] The randomized controlled trial reported in Chapter 4.2 investigated whether use of the STRIP improved students' prescribing skills. It did – students made more (34%) correct decisions and fewer (30%) harmful decisions. Moreover, students who used the method had 66–82% concordance with the prescribing decisions of experts in the field, whereas the control group had only 55–69% concordance. The students appeared not to 'learn by doing' polypharmacy skills without the STRIP and an E-learning environment was not of additional benefit.[35] The students were satisfied with the method and found the STRIP suitable for educational goals.

Considerations and limitations

The WHO-6-step has been studied previously.[36] Its effectiveness (e.g., can students come to a treatment goal in step 1) has been established in randomized controlled trials.[30-33] The transfer effect to other patient cases has been specifically proven,[37] and the method was effective in improving students' knowledge of basic pharmacology.[38] Two studies investigated the effectiveness of the WHO-6-step method after its implementation in the different study years of a medical curriculum.[37, 39] However, one study included only 30 students per study year,[37] and the other compared students who did not show up to scheduled education with those who attended planned classes,[39] so selection bias cannot be excluded, which may affect the robustness of results. However, evidence supporting the effectiveness of the WHO-6-step is quite robust, but our studies provided further evidence in that our studies: 1) were the first to obtain positive results with the WHO-6-step without possible selection bias (large numbers of students participated and the response rate was high, 89%); 2) the WHO-6-step improved students' knowledge of basic and clinical or applied pharmacology; 3) the WHO-6-step method was suitable for Bachelor and Master students; and 4) implementation of the method increased students' satisfaction with the education, improved their confidence in clinical practice and self-reported self-study hours. The transfer effect of the WHO-6-step to new patient cases has already been demonstrated,[37] but the transfer effect with regard to the more general knowledge domains, such as knowledge of basic and applied pharmacology, is new, even though the method only implicitly addresses these topics. Taken together, evidence supports the effectiveness of the WHO-6-step method, also when it is incorporated into a medical curriculum, and there is a transfer of knowledge and skills to new patient problems and other related knowledge domains.

The study had some limitations. The study investigated the WHO-6-step method (educational content) implemented in an integrated learning programme given over the different study years (teaching strategy). This means that it is not possible to draw conclusions about whether the content or the teaching strategy had the greatest influence on the results, and whether the content (the WHO-6-step method) will be equally effective when implemented with a different teaching strategy. We compared students from study years before and after introduction of the WHO 6-step method, a design with both advantages and disadvantages. The rather long inclusion period of 4 years means that other confounders could have influenced the results. For example, in the past few years study regulations have changed, such as the decentralized selection of students and study finance. Moreover, the study was performed in one medical school in the Netherlands, which potentially limits the generalizability of our findings. And, although the effectiveness and suitability of this method was thoroughly investigated for medical students, it was not investigated for other prescribers, such as physician assistants and prescribing nurses.

The STRIP (previously called the Prescribing Optimizing Method) has been studied by Drenth-van Maanen et al and is included in the Dutch Multidisciplinary Guideline on Polypharmacy for older patients.[34, 40] In the earlier studies, GPs received a lecture on the method, and polypharmacy skills were evaluated before and after the lecture. In our study, medical students used the STRIP without having received any information about it beforehand and we included a control group. The STRIP appeared to be very effective for medical students, and E-learning with Pscribe[35] did not influence the results, which shows that the results could be explained by use of the STRIP – the possible effects of learning by doing or the effect of a lecture were excluded by the study design. We believe that the method is effective when applied to medical education. With regard to whether the educational content and/or the teaching strategy is more important, our findings suggest that the content, namely the STRIP, is more important than the teaching strategy. For instance, there were not large differences in outcomes between e-learning and non-E-learning environments.[41] In fact, the concept known as the Dr. Fox effect, shows the opposite, namely, that education presented in an attractive and seductive way improves students' test performance.[42] This study was performed as a randomized controlled multicentre study, and therefore the results can probably be generalized, at least in the Netherlands. As the method can be translated into other languages, it will probably be effective in medical schools in other countries, but this needs to be investigated.

Conclusions and recommendations

To conclude, the clinical methods we studied were suitable for medical students' education, having positive effects on knowledge, skills, and student satisfaction. The WHO-6-step was consistently shown to be effective and should therefore be incorporated in medical curricula worldwide, to teach students how to prescribe in the general population. In addition, this was the first time that the STRIP method was used by medical students. The lack of other methods to teach students geriatric pharmacotherapy means that this method is currently the best option for educating students in this subject. It also means that it is worthwhile to study whether other methods commonly used in clinical practice can be used in medical education.

THE BROADER PERSPECTIVE

As mentioned in the Introduction, the field of geriatric pharmacotherapy education is largely unexplored. As a consequence, the studies of this thesis could only address some pieces of a much larger puzzle. A shortcoming in health professionals' knowledge and skills, caused by shortcomings in pharmacological education, is probably one explanation for the high number of drug-related problems, especially in vulnerable old patients.[3-5] However, while this cannot be firmly concluded from the available evidence or from our studies, this is not a reason not to improve education, as has also been suggested by others.[1, 5-10]

There is room for improvement in the undergraduate medical curriculum. The detailed curriculum mapping shows that the largest room for improvement probably lies in the assessment procedures. Two clinical methods appeared to be suitable for undergraduate education, the WHO-6-step for prescribing in general and the STRIP for polypharmacy, in particular the structured pharmaceutical analysis of the STRIP. Both could be adopted as a start to curriculum improvement. Another point of potential concern is the retention of knowledge and skills after graduation. The fact that GPs were outperformed by their trainees underlines the need for postgraduate training in pharmacology and pharmacotherapy for physicians. But does this work? It apparently does for pharmacists: their knowledge of clinical pharmacology increases after graduation. This may be due to pharmacists' postgraduate education, which primarily focuses on pharmacology and pharmacotherapy. However, the workplace and tasks of pharmacists can also provide more implicit learning opportunities than those of GPs. As it can be said of muscles or the brain, the same is true for knowledge and skills: 'use it or lose it'.[43] Given the fact that peer-teaching and peer-learning are very common, physicians could also learn from pharmacists in daily practice.[24] This means that interdisciplinary collaboration is not only beneficial to patients but in potential also for health professionals. We did not study whether pharmacists can also learn from physicians. It might be that other skills, such as clinical reasoning, could be peer-taught in the opposite direction. In peer-learning, a clear understanding of each other's knowledge and skills is very useful, and our studies could contribute to this understanding.[44] Even if undergraduate training and postgraduate learning are optimized, there is probably still a gap to bridge in the transition between medical school and clinical practice. Indeed, both medical students and their teachers believed that today's medical students are not fully prepared for clinical practice after graduation. Two aspects could be considered when trying to bridge this gap between medical school and clinical practice:

1) Involvement of patients and the work setting in undergraduate education.[45] The WHO-6-step addresses patients. Innovations in assessments with regard to patients are the 'patient letter' and the 'Objective Structured Clinical Examination (OSCE) for prescribing', as shown in the curriculum mapping study. The STRIP is already part of clinical guidelines and is suitable for educational purposes. Other clinical guidelines and methods should be considered for educational goals.

2) Involvement of education in the work setting, e.g. by formalizing workplace learning with regard to prescribing. This can be achieved by making it a part of a lifelong learning portfolio or by making it a part of re-registration regulations.[24, 46]

In the context of our findings and pharmaceutical care, one major piece of the puzzle is missing. Nurses were not studied in this thesis, but they have an important role in pharmaceutical care. However, we had to make choices. It also should be noted that all of our studies were performed in the Netherlands, and further studies are needed to establish the generalizability of our findings to the international context.

Some comments about medical education research should be made in the light of future research. It is stated of educational research that 'it's not rocket science'.[11] The variables and outcomes are often more difficult to control and measure than in patient studies. For example, blood pressure or renal function are often rather similar between patients from different countries and can be measured relatively easily compared with the measurement of intrinsic motivation to learn, pharmacology knowledge, or pharmacotherapy-related attitudes. A central problem in educational research is the friction between proof-of-concept studies and applied research. Proof-of-concept studies often generate more robust results but frequently have limited generalizability, whereas applied research often fails to generate significant results because of the contextual rich environment of medical education, such as social interactions, which are difficult to measure.[11, 47] Educational theory, rather than applied research, is still the main focus of medical educational research and publications.[48] In applied research, the effectiveness of education can be measured at different levels, as described by Kirkpatrick in a four-level model:[49] 1) reaction of the learner, such as satisfaction, 2) learning outcomes, such as knowledge or skills, 3) behaviour in real situations, and 4) results, such as patient outcomes (e.g. fewer medication errors). Although these levels appear to be hierarchical in nature, this is still being discussed, as is whether research at all levels has additional value.[50] In this thesis, outcomes were measured at the different levels of Kirkpatrick's model, with the exception of patient care, although the STRIP study did involve real patient cases.

Studies need a solid design in order to be able to answer research questions, e.g., a randomized controlled trial.[51] However, again, it is uncertain whether the results of a randomized controlled trial will be the same when a method or intervention is implemented in a real-life setting (as opposed to a study setting);

critics have called this phenomenon ‘context stripping’.[47] A comparison with pharmaceutical research can be made. It starts with ‘in vitro’ research in a laboratory and animal studies for the proof of concept, then ‘in vivo’ phase III randomized controlled trials in relatively young patients with few comorbidities for proof of effectiveness on measurable endpoints, and ultimately research after prescribing in clinical practice in relatively older and more vulnerable patients. The generalizability from one point to the next is often not guaranteed. In fact, pharmaceutical study populations and the population in which a drug is actually prescribed are often very different.[18] This shows that problems with generalizability are certainly not unique to medical education research, and that different research approaches are needed to come to solid conclusions. A major difference between drug research and medical education research is the financial support available.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, geriatric pharmacotherapy education is needed to teach health professionals how to provide appropriate pharmaceutical care to their older patients. The general and geriatric pharmacology and pharmacotherapy education at Dutch medical schools is already constructed quite well. However medical schools need to pay attention to assessment procedures – prescribing without a ‘prescribing examination’ is like driving without a driver’s license, given that it is a high risk task with potentially negative patient outcomes. For prescribing in general, the WHO-6-step should be adopted by medical schools worldwide, given the robust evidence supporting its effectiveness. This thesis shows that the effectiveness remains after implementation in a real medical curriculum by a longitudinal learning programme. The STRIP could be adopted for polypharmacy skills, given the lack of other evidence-based strategies. It might be worth considering using other clinical methods to achieve educational goals. A start was made to studying interdisciplinary learning between pharmacists and physicians, by identifying the actual knowledge of both professions. Nurses should be included in future research. It is important to realize that the absence of evidence is not evidence for the absence of effect.[52] In the field of geriatric pharmacotherapy education, there is a major absence of evidence, which means that teachers and curriculum designers should use the best evidence available.[53] The studies of this thesis provide pieces of evidence that can be used to optimize education in appropriate pharmacotherapy in older patients.

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5.2

Samenvatting in het Nederlands

SAMENVATTING

Goede farmacotherapie bij ouderen is in toenemende mate een belangrijk thema door de expansieve groei van de groep ouderen in de westerse samenleving. Zowel de levensverwachting als de therapeutische mogelijkheden zijn in de afgelopen jaren aanzienlijk toegenomen. Door gelijktijdig aanwezige curatieve, preventieve en symptomatische behandeldoelen is het voorschrijven van meerdere geneesmiddelen geïndiceerd en komt polyfarmacie veel voor. Daarom moeten artsen, apothekers en verpleegkundigen adequaat zijn opgeleid om te kunnen omgaan met de uitdagingen van voorschrijven bij ouderen. Echter, er worden vraagtekens geplaatst bij de kwaliteit van het onderwijs voor de verschillende zorgverleners over farmacotherapie voor de oudere patiënt. Geneesmiddel gerelateerde problemen treden frequent op bij ouderen. Er wordt gepostuleerd dat het verbeteren van dit onderwijs leidt tot meer kennis en kunde en daardoor tot minder medicatie fouten. In dit domein wordt nog weinig onderzoek gedaan. Dit proefschrift toont resultaten die kunnen bijdragen tot het verbeteren van het farmacotherapie onderwijs en uiteindelijk tot betere farmacotherapie voor oude patiënten.

In **hoofdstuk 2** wordt het farmacotherapie onderwijs bestudeerd. Door een literatuurstudie in **hoofdstuk 2.1** werd gezocht naar 'evidence-based onderwijs'. Dit bleek wel aanwezig te zijn voor voorschrijven in het algemeen, namelijk de WHO-6-step methode van de Vries et al. Deze methode kan ook bij oudere patiënten worden toegepast, maar volstaat vaak niet in het geval van polyfarmacie. Een bewezen effectieve onderwijsmethode specifiek over farmacotherapie bij de oudere patiënt werd voor geen van de verschillende zorgverleners gevonden. Voor medisch studenten werd in **hoofdstuk 2.2** een gedetailleerd overzicht van het huidige onderwijs verkregen door middel van het in kaart brengen van het curriculum aan de medische faculteiten in Nederland. De coördinerende docenten zijn op een gestructureerde manier geïnterviewd over het curriculum aan hun medische faculteit. Over het algemeen is het onderwijs vrij goed vorm gegeven, maar er zijn ook verschillen en verbeterpunten gevonden. Het valt op dat het aantal uren dat wordt besteed aan het farmacologie en farmacotherapieonderwijs sterk varieert, namelijk met een factor drie (39-107 h). Alle universiteiten hebben de WHO-6-step opgenomen in het curriculum. Docenten konden aangeven welke leerdoelen kunnen worden behaald met het aangeboden onderwijs in vergelijking met belangrijke leerdoelen uit een literatuur overzicht. 79% van de leerdoelen konden worden gehaald. Leerdoelen over farmacologie en farmacotherapie bij oudere patiënten scoorde vergelijkbaar met leerdoelen over algemene farmacologie en farmacotherapie. Met name op het niveau van toetsing is verbetering mogelijk: op de helft van de faculteiten werd farmacologie en farmacotherapie niet separaat getoetst. Dit geldt voor zowel de algemene farmacologie en farmacotherapie als voor farmacologie en farmacotherapie voor de oudere patiënt. Dit betekent dat deze studenten kunnen afstuderen zonder aangetoonde kennis en kunde hierin. Voorschrijven zonder 'voorschrijf-examen' kan men vergelijken met autorijden zonder rijbewijs, het zijn immers beiden hoog risico verrichtingen. Als voorschrijven bij volwassenen als autorijden is, is voorschrijven bij ouderen als het rijden van een bus. De taak is immers complexer en de risico's zijn groter.

Samenvattend zijn er geen bewezen effectieve onderwijsmethoden over farmacotherapie voor de oudere patiënt voor de diverse zorgverleners. De WHO-6-step methode voor voorschrijven in het algemeen kan ook worden gebruikt bij ouderen en heeft al bewezen effectiviteit in het medische onderwijs. Het huidige farmacologie en farmacotherapie onderwijs aan de geneeskunde faculteiten is al redelijk goed vormgegeven, maar kan verbeterd worden. Voornamelijk op het niveau van toetsing lijkt dit dringend gewenst.

In **hoofdstuk 3** zijn de kennis en vaardigheden van de verschillende zorgverleners bestudeerd door middel van de kennistoets die is ontwikkeld voor dit proefschrift om te onderzoeken in hoeverre de benodigde kennis aanwezig is en in hoeverre die verschilt tussen zorgverleners. Dit laatste is relevant in interdisciplinaire samenwerking bijvoorbeeld bij gezamenlijke medicatie beoordelingen en/of gezamenlijk onderwijs. In **hoofdstuk 3.1** zijn geneeskunde en farmacie studenten vergeleken. De universitaire scholing geeft een verschil in kennis en vaardigheden: farmacie studenten hadden meer basis farmacologie kennis, geneeskunde studenten meer vaardigheid in het schrijven van een recept. Opvallend genoeg was er nauwelijks verschil in toegepaste farmacologie kennis. Dit terwijl farmacie studenten zesmaal meer onderwijs kregen over het onderwerp. In **hoofdstuk 3.2** werden huisartsen en huisartsen in opleiding vergeleken met openbare apothekers en apothekers in opleiding tot openbaar apotheker. Opvallenderwijs bleken huisartsen in opleiding en openbaar apothekers in opleiding niet veel van elkaar te verschillen op de verschillende kennis domeinen. De verschillen tussen artsen en apothekers namen toe naarmate er meer werkervaring was: openbaar apothekers scoorden hoger dan hun kandidaten in opleiding, maar bij huisartsen was het omgekeerde het geval. Overal scoorden openbaar apothekers het

hoogst op alle domeinen die gemeten werden. Dat de verschillen toenemen met werkervaring kan liggen aan een andere werkomgeving, andere werktaken en/of ander postacademisch onderwijs waardoor kennisretentie verschillend kan zijn. Dit moet nog verder worden onderzocht.

De gevonden verschillen zouden kunnen bijdragen aan beschreven positieve resultaten van een multidisciplinaire aanpak in vergelijking met een monodisciplinaire medicatie beoordeling. De gevonden verschillen kunnen een goede basis zijn voor interdisciplinair onderwijs en samenwerking.

In **hoofdstuk 4** is gekeken of methoden die gebruikt worden in de praktijk, kunnen worden geïmplementeerd in medisch onderwijs. Voor voorschrijven in het algemeen is in **hoofdstuk 4.1** het onderzoek naar de WHO-6-step beschreven. Hiervoor was al bewijs van effectiviteit, maar bij de meeste onderzoeken betrof het een korte onderwijsinterventie. De literatuur is niet eensluidend of de methode werkzaam is na implementatie in de contextuele rijke omgeving van het geneeskunde onderwijs. Dit hoofdstuk toont dat de WHO-6-step succesvol kan worden geïmplementeerd in een medisch curriculum. Aan de medische faculteit in Utrecht is de WHO-6-step geïmplementeerd door middel van een leerlijn. Er is gekozen voor een longitudinale opbouw door alle jaren heen, zowel de bachelor als de masterfase van het geneeskunde curriculum, met een terugkerend karakter van de lesstof in alle blokken. De WHO-6-step is een vast element daarin. De jaargangen voor, tijdens en na de invoering van de leerlijn met WHO-6-step zijn met elkaar vergeleken. De leerlijn met de WHO-6-step leidde tot hogere basiskennis, hogere toegepaste kennis en mogelijk meer recept-schrijfvaardigheden. Daarnaast waren de studenten tevredener, was hun zelfvertrouwen om voor te schrijven in de praktijk beter en namen de zelfgerapporteerde zelfstudie-uren toe. Deze methode was zowel werkzaam bij bachelor en master studenten. Of het resultaat vooral door de WHO-6-step (inhoud), de onderwijsstrategie (leerlijn), of het toegenomen aantal uren onderwijs veroorzaakt wordt is moeilijk te differentiëren. Echter, in de masterfase is de WHO-6-step de grootste verandering in het onderwijs en nam het aantal contacturen niet toe. Dit suggereert dat de WHO-6-step op zichzelf op zijn minst in de masterfase bijdragend is geweest aan de positieve resultaten. Omdat de WHO-6-step niet zo bruikbaar is bij polyfarmacie werd in **hoofdstuk 4.2** de medicatiebeoordeling van de Structured Tool to Reduce Inappropriate Prescribing (STRIP), die in de multidisciplinaire richtlijn polyfarmacie bij ouderen als methode is opgenomen, bestudeerd bij geneeskunde studenten. Door deze methode namen de vaardigheden voor het optimaliseren van polyfarmacie sterk toe: er werden 34% meer juiste keuzes en 30% minder potentieel schadelijke keuzes gemaakt in vergelijking met de controle groep die de methode niet kreeg. Het gebruik van de methode in een E-learning omgeving liet vergelijkbare resultaten zien. De studenten vonden het een goede methode die geschikt is voor het geneeskunde onderwijs.

Dit betekent dat zowel de WHO-6-step geschikt is voor het onderwijs als de STRIP methode. De WHO-6-step methode is geschikt voor voorschrijven in het algemeen en kan ook bij ouderen worden toegepast. Gezien de uitgebreidheid van de bewijskracht over de WHO-6-step zou dit in elk geneeskunde curriculum moeten worden ingevoerd. De STRIP methode is zeer geschikt voor het aanleren van farmacotherapeutische vaardigheden specifiek voor de oudere patiënt met polyfarmacie. Voor de STRIP methode zijn nog replicatie studies nodig. Echter, gezien het feit dat andere bewezen effectieve onderwijsmethoden over farmacologie en/of farmacotherapie bij de oudere patiënt ontbreken is het te overwegen deze ook te gaan gebruiken in de geneeskunde opleidingen. De twee methoden uit de klinische praktijk die werden onderzocht in dit proefschrift bleken effectief in een onderwijssetting. Voor de toekomst zou het de moeite waard kunnen zijn om overige klinische methoden te overwegen voor onderwijsdoeleinden. Effectiviteit dient dan te worden onderzocht.

In **hoofdstuk 5** is de samenhang tussen de verschillende studies bediscussieerd en worden aanbevelingen geformuleerd. Literatuur suggereert dat het verbeteren van het farmacologie en farmacotherapie onderwijs leidt tot meer kennis en kunde met als gevolg minder medicatie fouten. Het zou waar kunnen zijn, maar kan niet worden aangetoond met dit proefschrift. Wel toont dit proefschrift dat er in de basisopleiding geneeskunde verbeteringen nodig zijn: geadviseerd wordt de WHO-6-step aan alle geneeskunde faculteiten te gebruiken en het toetssysteem zou moeten worden aangepast. De STRIP is een goede methode om de studenten het optimaliseren van polyfarmacie aan te leren. Door zowel medisch studenten als docenten is aangeven dat de studenten maar matig zijn voorbereid op hun toekomstige taken als voorschrijvend dokter. Er moet er blijkbaar nog een brug worden geslagen tussen de basisopleiding en de dagelijkse praktijk. Dit zou kunnen door enerzijds de praktijk naar de basisopleiding te brengen bijvoorbeeld door klinische methodes aan de studenten te onderwijzen. Anderzijds kan ook het levenslang leren geformaliseerd worden bijvoorbeeld door beoordelingen

van de farmacotherapie vaardigheden in de dagelijkse praktijk. In de dagelijkse praktijk verschillen huisartsen en apothekers van elkaar qua kennis en vaardigheden. Dit komt onder andere door de verschillen in de basisopleiding, maar ook factoren na deze basisopleiding spelen waarschijnlijk een rol. Deze verschillen betekenen enerzijds dat samenwerking een rationele keuze is aangezien beide disciplines elkaar kunnen aanvullen in de gezamenlijke farmaceutische patiëntenzorg, maar anderzijds kunnen ze in potentie van elkaar leren hetgeen tot een betere samenwerking en betere kennisretentie zou kunnen leiden. Waarom apothekers meer kennis krijgen met meer jaren werkervaring maar bij artsen het omgekeerde wordt gezien moet verder worden onderzocht.

CONCLUSIES EN AANBEVELINGEN

Goed onderwijs over farmacotherapie bij de oudere patiënt is nodig om zorgverleners te leren hoe optimaal voor te schrijven bij kwetsbare oudere patiënten. Echter, het onderzoeksveld van onderwijs over farmacotherapie bij de oude patiënten is een nog grotendeels onontgonnen gebied zoals ook blijkt uit de literatuurstudie. Dit proefschrift toont een eerste aanzet tot ontginning ervan. De geneeskunde opleiding is qua farmacologie en farmacotherapie redelijk goed vormgegeven, zowel voor de algemene farmacologie en farmacotherapie als voor farmacologie en farmacotherapie voor de oude patiënt. Met name de toetsingscyclus moet geoptimaliseerd worden. Voorschrijven zonder ‘voorschrijf-examen’ kan men vergelijken met autorijden zonder rijbewijs, het zijn immers beiden hoog risico verrichtingen. De WHO-6-step methode is een effectieve methode voor voorschrijven in het algemeen en kan ook bij ouderen worden toegepast. Dat de effectiviteit van de methode overeind blijft na implementatie in een geneeskunde curriculum in de vorm van een leerlijn blijkt uit dit proefschrift. De WHO-6-step zou in elk geneeskunde curriculum moeten worden ingevoerd als “evidence-based-education” om studenten voorschrijven in het algemeen aan te leren. De STRIP methode die gericht is op het optimaliseren van polyfarmacie is voor het eerst bestudeerd bij geneeskunde studenten en toont zeer positieve resultaten. Andere bewezen effectieve methoden voor het optimaliseren van polyfarmacie werden niet gevonden in de literatuurstudie. Daarom is het advies met behulp van de STRIP methode geneeskundestudenten het optimaliseren van polyfarmacie bij oudere patiënten te leren. Artsen en apothekers verschillen aantoonbaar van elkaar qua kennis en vaardigheden. Dit komt voort uit zowel de basisopleiding als door het werken in de praktijk. In interdisciplinaire samenwerkingen, bijvoorbeeld bij een gezamenlijke medicatiebeoordeling, en interdisciplinair onderwijs kunnen artsen en apothekers elkaar waarschijnlijk aanvullen en mogelijk ook van elkaar leren. De resultaten uit dit proefschrift kunnen worden gebruikt om het onderwijs over optimaal voorschrijven bij oudere patiënten te verbeteren.

Figuur 1 toont de conclusies en aanbevelingen grafisch weergegeven.

FIGUUR 1. **Samenvatting van conclusies en aanbevelingen van dit proefschrift**

6

APPENDICES

> *met wat proate en gedeuld*
> *en wat geluk komde 'n end*
>
> **Rowwen Hèze**

6.1

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List of coauthors

Coauthors of manuscripts presented in this thesis and their affiliations during conductance of the research

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6.2

List of publications

List of publications

Publications related to this thesis

Keijsers CJPW, van Doorn AB, van Kalles A, de Wildt DJ, Brouwers JR, van de Kamp HJ, Jansen PA. Structured Pharmaceutical Analysis of the Systematic Tool to Reduce Inappropriate Prescribing Is an Effective Method for Final-Year Medical Students to Improve Polypharmacy Skills: A Randomized Controlled Trial.
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6.3

Curriculum Vitae in het Nederlands and in English

Curriculum Vitae

Carolina JPW (Karen) Keijsers werd geboren op 27 oktober 1982 in Venray en groeide op in Horst. Zij behaalde in 2000 cum laude haar VWO diploma op het Dendron college te Horst, waarna ze geneeskunde ging studeren in Utrecht. Enkele keuzestages in het Jeroen Bosch Ziekenhuis en in het UMC Utrecht leidden tot de keuze voor het vak klinische geriatrie. In 2006 begon ze aansluitend aan de geneeskundeopleiding aan de opleiding tot klinisch geriater.

Tijdens haar opleiding werkte ze twee jaar bij de interne geneeskunde in Ziekenhuis Gelderse Vallei te Ede, een jaar bij de ouderenpsychiatrie bij Pro Persona te Ede en voor de klinische geriatrie in het Jeroen Bosch ziekenhuis en het UMC Utrecht. Tijdens haar opleiding werd haar promotieonderzoek opgestart waarvoor ze een jaar haar opleiding onderbrak in 2011. Tijdens dit onderzoeksjaar werd tevens de opleiding tot klinisch farmacoloog gevolgd, de basiskwalificatie onderwijs (BKO) en later de senior kwalificatie onderwijs (SKO) behaald.
Sinds juni 2013 werkt ze als klinisch geriater, klinisch farmacoloog in het Jeroen Bosch ziekenhuis en werden onderzoek werkzaamheden gecombineerd met patiëntenzorg en onderwijs.
Ze is getrouwd met Jorrit Donkervoort en trotse mama van Bastiaan.

Carolina JPW (Karen) Keijsers was born on 27 october 1982 in Venray the Netherlands, and grew up in Horst. In 2000 she graduated cum laude from her secondary school “Dendron College” in Horst. She subsequently graduated her medical school in 2006. After a few elective courses in geriatrics in the “Jeroen Bosch ziekenhuis” and “UMC Utrecht” during her study she started her residency in geriatric medicine.
During her residency (2006-2013) she worked at the internal department of hospital Gelderse Vallei in Ede, at the old age psychiatry of Pro Persona in Ede and for the geriatric medicine she worked at the Jeroen Bosch Ziekenhuis and the UMC Utrecht. During her residency the PhD was started and for one year her geriatric training was interrupted for research. During this year a fellowship program in clinical pharmacology was followed and the Basic Teaching Qualification and afterwards the Senior Teaching Qualification was obtained.
Since June 2013 she works as a geriatrician and clinical pharmacologist in the Jeroen Bosch Hospital in Den Bosch. Research and patient care activities were combined from that time on.
She is married to Jorrit Donkervoort and the proud mother of Bastiaan.

6.4

Dankwoord

Friendship redoubleth joys,
and cutteth griefs in half

Francis Bacon

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> *Education is the most powerful weapon which you can use to change the world*
>
> **Nelson Mandela**