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Smartphone apps to support hospital prescribing and pharmacology education: a review of current provision

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Junior doctors write the majority of hospital prescriptions but many indicate they feel underprepared to assume this responsibility and around 10% of prescriptions contain errors. Medical smartphone apps are now widely used in clinical practice and present an opportunity to provide support to inexperienced prescribers. This study assesses the contemporary range of smartphone apps with prescribing or related content. Six smartphone app stores were searched for apps aimed at the healthcare professional with drug, pharmacology or prescribing content. Three hundred and six apps were identified. 34% appeared to be for use within the clinical environment in order to aid prescribing, 14% out with the clinical setting and 51% of apps were deemed appropriate for both clinical and non-clinical use. Apps with drug reference material, such as textbooks, manuals or medical apps with drug information were the commonest apps found (51%), followed by apps offering drug or infusion rate dose calculation (26%). 68% of apps charged for download, with a mean price of £14.25 per app and a range of £0.62–101.90. A diverse range of pharmacology-themed apps are available and there is further potential for the development of contemporary apps to improve prescribing performance. Personalized app stores may help universities/healthcare organizations offer high quality apps to students to aid in pharmacology education. Users of prescribing apps must be aware of the lack of information regarding the medical expertise of app developers. This will enable them to make informed choices about the use of such apps in their clinical practice.

Introduction

Prescribing is one of the commonest tasks undertaken by junior doctors and is often critical to the success of medical therapy. However it may also give rise to potential compromise to patient safety. Recent studies have shown that the rate of prescribing errors by doctors in their first 2 years of practice varies between 7 and 10% [1, 2]. The causes are multifactorial but include lack of knowledge and training in relation to prescribing [1, 3, 4], lack of support in the workplace and pressure of work. Root cause analysis has identified common themes including inadequate knowledge of the drug or the patient [5], failure to select appropriate drug dosages [1, 6] and lack of knowledge of a relevant rule, for example how to adjust a drug dose for a patient in renal failure [7]. Although most of these errors are perpetrated by junior staff, it is clear that the error rate is also significant amongst more senior doctors [1].

Although prescribing will always be a challenging and complex task there appears to be room for improvement based on better training and support of prescribers, particularly in their early years of training. The increasing availability of modern computer-based technology offers potential solutions. The emergence of electronic prescribing with decision support systems has been shown to produce significant reductions in error rates [8]. Although these are extremely expensive and are not widely implemented, the availability of handheld computing means that it might still be possible to harness many of these gains in the absence of an e-prescribing system.

More than 85% of clinicians are now owners of smartphones, with approximately 50% using smartphone applications, or 'apps', in their clinical practice [9]. There are a diverse range of medical smartphone apps, providing a wealth of information and resource to support clinical decision making [10]. Studies have described apps for pain management [11], microbiology [12], orthopaedics [13],

dermatology [14] and colorectal surgery [15] to name a few. It has already been demonstrated that medical smartphone apps have positive results over standard textbooks in dose calculation [16] whilst also serving as potentially valuable educational tools in resource-limited settings [17, 18].

The aims of this study were to: (i) review the current availability of smartphone apps that directly assist healthcare workers in writing and administering safe and effective drug prescriptions and (ii) review the availability of apps aimed at healthcare professionals which offer drug reference information or provide pharmacology educational support.

Methods

We conducted a search on the six main smartphone app stores (Google Android 'Play Store', iOS 'Appstore', Windows Phone 'Marketplace', BlackBerry 'App World', Symbian 'Nokia Ovi' Store and Bada 'Samsung Apps' store) between 26 January 2013 to 1 February 2013 for apps which provided drug reference and prescribing material for the healthcare professional. Search terms were 'prescribing', 'drug safety', 'drug dose', 'drug calculation' and 'formulary', which were based on keywords from the publication *'Outcomes from the Medical Schools Council Safe Prescribing Working Group'* [19] which outlines core prescribing competencies for junior doctors in the UK. Apps were included if they contained information or tools concerned with prescribing, drugs, intravenous infusions or pharmacology and if they were specifically aimed at the healthcare professional rather than the lay person (for example, apps aimed at patients to serve as medication reminders or to record their medication lists were not included in the results). Data on apps were sourced from individual app descriptions or associated webpage links on app stores prior to download. Apps were subsequently categorized according to principal function. Those priced in US dollars were converted to pounds sterling as per the exchange rate on 2 February 2013 (1 US$ = 0.636963 GB£) and where apps were available on more than one app store average of price was taken. Information on app user rating was taken from app store pages. Apps were rated out of a score of 5 (1 = low, 5 = high). Data on app release date or most recent update were also collected. For apps with a release date as well as date of update, the latter was used for data analysis since this was deemed to be the most recent time point at which the app was reviewed and modified by its developers. For those without details of update, release date was taken to be the date of most recent review. For apps which were available on more than one store, averages of user rating, number of raters, date of last update and price were taken for the purposes of data analysis.

Results

Three hundred and six apps were identified meeting our search criteria. Two hundred and seventy-five (90%) were available on single app stores, whilst 31 (10%) apps were available on multiple stores. 70% of apps were available on Android's 'Google Play' store. Table 1 outlines apps per store.

Intended environment for app use

Apps were categorized according to their intended area of use. One hundred and four (34%) apps were identified which would be of use in directly supporting prescribing within the clinical environment. These included apps with drug calculation capabilities (n = 31), intravenous drip or dilution calculators (n = 20), apps which were able to calculate both drug doses and drip infusion rates (n = 5), medical or drug reference apps which included drug dose or infusion calculator functions (n = 25), drug interaction checkers (n = 4), e-prescribing apps (n = 3) and drug formularies (n = 14). Other apps included a drug reference resource which also allowed healthcare workers to log clinical events and medications given in 'real time', and an app permitting pharmacists to monitor their patients controlled drug usage (Table 2). Forty-seven (15%) apps were identified as for use predominantly out with the clinical environment. These were exam revision aids (n = 6), journals (n = 6), flashcards, quizzes, tutorials and other interactive learning aids (n = 26), news, drug information and

Table 1
Apps by store

	App store (operating system)					
	Appstore (iOS)	Play Store (Android)	BlackBerry App World (Blackberry)	Marketplace (Windows Phone)	Ovi (Nokia) store (Symbian)	Samsung Apps (Bada)
Number of unique apps (n = 275)	43	215	0	4	7	6
Number of duplicated apps (n = 31)	21	31	4	7	1	5

Table 2

Apps for use within the clinical environment

Drug calculators	Medical or drug reference app with drug dose/infusion calculator function	Drip/infusion rate calculators
Gentamicin	Medcalc 3000 Complete	IV drip rate
Dosage Calc	Chemotherapy CS	Emergency Drugs
Paeds ED	MedCalc 3000 Kidney	Drip calculator
Dose Calc	MedCalc 3000 Neurology	Infusion Rate
Drug Doses	Medcalc 3000 Endocrine	Dosage calc
Kid-eCalc	Medcalc 3000 GI	NurseCalcs
InfusiCalc	Tarascon Pharmacopoeia	Infusion rate
Paramedic Dosage	PEPID	Infusion therapy
Pediatric Epinephrine	EP Mobile	IV Drip Rate Professional
Stat Meds Lite	EM Suite	Medication infusion
Medical Abacus	Fraser EMS	Drips and pumps
Thrombate III Calculator	Adult Anesthesia	InfusionCalc
Kids Drug Dosage Calc – PaedRx	Medical Tools Aurora for android	Nursing Tool & IV Drips Pharmacy Technician Toolkit
IRCALC-Drug Dosage in RF	Medical Calculators	Anesthesia Infusion
Anesthesiologist	IV Drips	OmniMedix Medical Calculator
Kid Dose	EMS Notes	IV Drip Rate Calculator
Antibiotic Kinetics	Critical Medical Guide	IV Infusion Calc
Medcalc 3000 Pharmcaology	Calculate by QxMD	BS3 Drip Calculator
Pediatric Anesthesia	AvidNurse	Infusion Nurse
Speedy Dose	CheckMate PDA	
RSI Calculator Digoxin Calculator	PICA BS3 Basic Tools Pack	**Drug dose and infusion calculators**
Accutane Calculator	Emergency Drugs Pocket	Vasopressors
NeoDose	Skyscape Rx drugs	Neonatal Infusion Therapy
AneIV Lite – Anesthesia Aid		Anesthesia Calc
Pharmacy Calculator Child Dose	**Drug formularies**	Nursing Calculators Anesthesia Calculator
Flush Calculator	NICEBNF	
IV-MedCalc DentalSTAT	NHS Lanarkshire Formulary BNF for Children	**e-Prescribers**
Opioid Converter	NHS Forth Valley Formulary British National Formulary	MTBC iRx RxNT eRx
Interaction checkers	NHS Highland Formulary BNF for Children 2012–2013	RxPad
Prescription checker Drug interactions	Custom Paramedic Formulary NFI 2011	**Others**
HEPi Chart Adverse drug interactions tool	Drug Formulary – Cancer Care Ontario NHS Tayside Neonatal Formulary NICEBNFC IA PDF	Safe Dose PMPreport Drug Monitoring

research update apps from the US Federal Drug Agency (n = 7), a pharmaceutical company drug guide and an app accessing an online medical news, reviews and educational website (Table 3). One hundred and fifty-five (51%) apps appeared suitable for use both in and outside of the clinical environment. Thirty of these were drug handbooks or textbooks converted into app format, 56 were other types of drug reference app, 46 medical reference apps with drug information and 16 medical textbooks or handbooks with drug information. Six apps offered purely antibiotic related material. Another app provided information for doctors on where their patients can acquire discount prescription drugs (Table 4).

Details of app price, update, and user rating

Two hundred and eight (68%) apps charged for download, with a mean price of £14.25 per app and a range of £0.62–101.90. Ninety (29%) apps were free to download. The remaining eight apps (3%) were free to download for those working with the National Health Service (n = 1), to doctors working within the United States (n = 1) or after payment of an online subscription (n = 6). Of charged apps, 110

Table 3

Apps for use out with the clinical environment

Flashcards, quizzes, tutorials and other interactive learning aids	Exam revision aids
Nursing Pharmacology	Pharmacy Tech Certification
Nursing Pharmacology – quiz	NCLEX Medication Flashcards
Pharmacology by WAGmob	PTCB Exam Review
Medical Prescription Abbr Quiz	NPS Exam Flashcards
265+Rx Abbreviation Quiz	NPS Exam Secrets
Prescription Trivia	PharmPrep: NAPLEX Exam Preparation
Top 200 Drugs Quiz and Card	
Pharmacy Technician	**Journals**
Medical Drug Quiz	
Top 200 Treatment Drugs Brand/Generic	Pharmacist's Letter
Diabetes Mellitus apc	HPJ Now
Warfarin Doser	Oncology Nurse Advisor
Symptom to Diagnosis	Pharmacy Technician's Letter
Anesthesiology a-pocketcards	The Medical Letter
Chief Resident Pearls Free	Formulary
Acute Coronary Syndrome a-pocketcards	
Drug Information Flashcards	**Federal Drug Association (FDA) resources**
Pharmacy 101 by WAGmob	
Antibiotics a-pocketcards	Mobile PDR Prescribers Edition
Pediatrics apocketcards	Mobile PDR
Heart Failure a-pocketcards	FDA News Reader (food and drug administration)
PTCB Prep	Drug Checker (pregnancy and lactation)
Davis Mobile Pharm Phlash	FDA Drugs Free
irx	Mobile PDR
Dose Coach	Medwatcher Drug/Device/Vaccine
Adult Drug Calculations	
	Others
	onMedica
	iPharm: Discount Drug Plans

(53%) cost less than £5 for purchase. Three hundred apps (98%) provided information about most recent update or app release date. One hundred and thirty-six of these (45%) had either been released or updated within the last 6 months, a further 74 within 1 year, 67 within 2 years, 19 within 3 years and four within 4 years. Five apps made no mention of a date of release or update (Figure 1). One hundred and ninety-six apps (64%) were rated by users on online app stores out of a score of 5. Average rating was 3.8 with a median number of six raters per app and a range of 1–15 533 raters.

Details of medical involvement in app creation

Medical input into app creation or design was estimated to be present in 206 apps (67%), whereas in the remaining 33% there was no evidence from app description or associated webpages that there had been medical or professional involvement in app development. Apps were assumed to include medical input if they were either medical textbooks, guidelines or protocols converted into app format, apps produced by eHealth or mobile medical app developers, a University department, health trust, Federal Drug Agency, nursing, allied or other health professional, a recognized medical society or association, or developed by a medical publishing company. Table 5 outlines the input of medical or associated healthcare professionals in app creation and development. Six apps provided medical references for the information they contained within their apps (one of which was an app with unknown developer qualification), and 18% of apps had disclaimers assuming no liability for patient harm made through app use.

Discussion

Our search has demonstrated that there are currently a large and diverse number of smartphone apps available to support prescribing practice. The majority of these are apps that offer the potential to improve ease and accuracy of drug dose calculation and intravenous drug delivery. In addition, a wealth of educational resources for pharmacology are also now widely available in mobile app format, allowing users greater ease of access to and portability of popular textbooks and journals, as well as mobile pharmacy exam preparation resources. The majority of apps are either free or cost less than £5. However apps costing up to £101.90 for a full app version of a textbook may be prohibitively expensive to some users.

Smartphone apps are rapidly expanding into the medical sphere both on a national and international level [10]. Software developers, doctors and other healthcare sector workers are being encouraged to develop ideas for medical apps and supported in the development process [20]. Within the UK, the Department of Health has recently encouraged GPs to recommend apps to patients, providing a means to empower patients with the information needed to make health-related choices and encouraging individual responsibility for health [21]. However, clinicians need to be familiar with the technology and have awareness of what medical apps are available. Educating doctors regarding mobile health at an undergraduate, 'grass-roots' level may be what is needed in order to promote this change.

Given the multitude and diversity of medical apps available, the need for quality control is vital. Indeed, current concerns surrounding the reliability of content offered by some contemporary medical apps have been reported [12, 14, 15, 22]. In our own study of opioid convertors, there was a wide range in the conversion doses of several opioids between apps (for example, 1 mg of oral morphine to oral codeine demonstrated a range of 3.3–12 mg) and a significant difference was found in the conversion doses of one opioid between apps with and without medical involvement in their design and

Table 4

Apps for use both within and out with the clinical environment

Drug textbooks and handbooks	Drug references (other)	Medical reference apps with drug information
OAPN Statin Prescribing Guide	Monthly Prescribing Reference	Complete Nurse
Davis Drug Guide	MIMS	Pediatric Support
Nurses Drug Handbook	Maudsley Prescribing Guide in Psychiatry	Epocrates
IV Drug Handbook		Anesthesia
Drugs in Emergency and ICU	Drug and Prescription Medication	West Midlands Paediatric Palliative Care Network
Drugs for Pregnant and Lactating	Janssen HIV	
Psychiatric Drug Therapy	Professional Mobile Resource	Emergency
AHFS Drug Information	AAeARx	Poisoning and Drug Overdose
Nurse's Pocket Drug Guide 2011	Infant Risk Center Healthcare Reference Guide	ERres
Drug Index and Guide		Medscape
LWW Nursing Drugs Handbook	PediDoser	Clinical Advisor
Clinician's Drug Reference 2011	ChemoDosing	iGeriatrics
Davis's Drug Guide for Nurses	ICU Critical Care Drips Drugs	DiAppBetes
Davis's Drug Guide – Physicians	EMS Pocket Drug Guide	AF-STROKE
Sota Amoigui's Anesthesia Drugs	iPharmacy – Pill Identifier and Drug Guide	10 Second EM
2013 Nursing Drugs Handbook		Pediatric Oncall
ANZ Drug Guide	Drug Monograph	Medicine Central
Nurse's Drug Handbook	Mbook 4.0 Drug Indication	CCS Atrial Fibrillation Guidelines
Omoigui's Pain Drugs Handbook	Mbook 4.0 Drug and Dose	Pediatric Care Online
Medications and Mothers' Milk	Mbook 5.0 Medical Toxicology	Nursing Essentials
Intravenous Medications	Mbook 2.0 Pharmacology 2	Nurse's Toolbox
Essential Cancer Pharmacology	Merriam-Webster's Medical Dictionary	Skyscape Oncology Suite
Clinical Psychopharmacology		Skyscape Primary Care Suite
Mosby's Nursing Drug Reference	Mbook 1.0 Mobile Pharmacology	Skyscape Dermatology Suite
Manual of IV Therapeutics	Mbook 2.0 Mobile Pharmacology 2	MedCalc 3000 Pediatrics
Lippinicots Nursing Drug Guide	Prescription Adviser	BS3 Cardiology Pack
Physicians Cancer Chemotherapy	Chemotherapy Advisor	Hepatitis C Guidelines
Nursing 2012 Drug Handbook	VIDAL Monographs 2012	CRRT-Extrarenal Purification
Pearson Nurse's Drug Guide	Drug Doses	BS3 Nephrology Pack
Handbook of Combination Drugs	Dental Prescriber	Practical Urology
	Lactation Doctor	Eres – Emergency Medicine
Medical textbooks or handbooks with drug information	NPC Opioid Guidelines	Perioperative Care
	Drug Information System	Urology for Gynecologists
	Cardiology Drug Guide	Skyscape Medical Resources
On Call Principles and Protocols	Micromedex Drug Information	Sepsis Clinical Guide
Patient Safety Manual	Generic Drugs Encyclopedia	Boka's Notes
Harriet Lane Handbook	Paramedic Meds	MedCalc 3000 Cardiac
EMS BLS guide	Pedi STAT	Clinical Constellation
Oxford Handbook of Psychiatry	Drug Guide for Paramedics	NurseTabs: Fundamentals
EMS ACLS Guide	Drugs Guide	ADHD Psychopharmaoclogy
Critical Care ACLS guide	Vademecum	Psych Notes: Clinical Guide
Nursing Central	smartMecum	Clinical Anesthesia Procedures
Emergency Medicine Handbook	STAT intubation: anesthesia	Nurse Tabs: Complete
AAP Red Book	Diabetes Pharma	AACN Critical Care Nursing
Manual of Childhood Infections	Pharmacology Study Guide	Pocket Reference for ALS
Hopkins Gynaecology and Obstetric	Emergency Medications EMS	Schizophrenia Pharmacology
	Pediatric Dosing Made Easy	
Rnotes	Critical Care Drips	Practical Urology for Primary Care
Oxford Handbook of Anesthesia	Pedi Safe Medications	
Manual of Critical Care	Pharmacotherapy Handbook 8th ed	
Emergencies in Anesthesia	Pedi Anesthesia	**Others**
	Practical Analgesia	
Antibiotic resources	Medicines Compendium UK	Medical Information
	Study Notes for EMT's	
Drugs and Bugs	NurseTabs: Pharmacology	
Nelson's Pediatric Abx Therapy	Washington Manual: Therapeutic	
Microguide	CPS Essentials by CPhA	
Sepsis Antibiotic Guideline	Lexicomp	
Sanford Guide	Epilepsy Treatment	
Tap On The Bugs	Drug interactions (A-Z)	

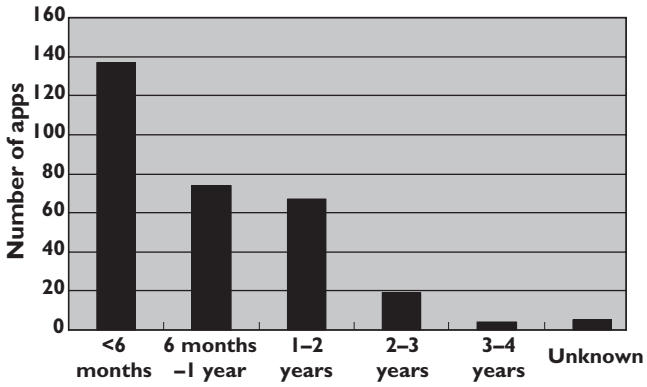

Figure 1

Time since most recent app release or update

Table 5

Involvement of medical or associated healthcare professionals in app development

Apps with suggested medical involvement (*n* = 206)	
Medical/nursing/allied health professional textbook, journal, or manual	64
Medical app/eHealth software developer	46
University department	5
Physician involvement in app creation or app company	30
Pharmacology or M.D. degree	7
Federal Drug Agency (United States)	7
Nursing/allied or other health professional (dentist, paramedic) or association	17
Health trust	11
Medical guidelines/protocols	3
Recognized medical association or society	7
Medical publisher (not in format of textbook etc.)	9
Apps without evidence of medical involvement (*n* = 100)	
Test preparation resource developer	2
Non-medical app/software developer	41
Pharmaceutical company	4
Others	4
Unknown	49

content [23]. The results of this study also suggest that some apps have not been updated for several years, further calling into question the accuracy and reliability of content.

The Medical Device Directive (MDD) oversees regulation of medical apps within the European Union. However there is current debate regarding which apps fall into the category of a 'medical device'. Definitions of a 'medical device' vary between countries. This results in a lack of consistent regulation across Europe over which, and to what extent, apps must conform to the legislation set out by the directive. In the United States, the Food and Drug Administration has set out proposals regarding its intentions to regulate apps falling under the definition of a medical device. However these recommendations are not as yet legal requirements. The current situation regarding medical app regulation globally is under rapid development and it is likely that as the medical app market expands, more thorough and consistent regulation in this area will emerge.

In light of current deficits in medical app screening or peer review prior to marketing, individual organizations (such as *Happtique* [24] or the *Medical App Journal* [25]) aim to provide some element of 'blue-ribbon' approval. This process could be expanded into undergraduate medical education, with universities or healthcare organizations creating their own apps or app repositories for peer reviewed apps deemed suitable for use by their medical undergraduates. The development of 'in house' apps may also help to target the current shortfall in the prescribing competencies of medical undergraduates. In doing so, private repositories could provide institutions with the means of ensuring that only high quality, peer reviewed apps are recommended to students or healthcare workers. Setting this precedent early on in a medical students' education and equipping them with the skills to identify such apps, would hopefully encourage students to adopt the principles of app appraisal in their medical career.

Given the popularity of e-learning in clinical pharmacology and therapeutics teaching, educational smartphone apps have the potential to improve the prescribing performance of junior doctors. Current pharmacology e-learning resources may lend themselves well to a smartphone app version by offering greater portability and accessibility within clinical environments. They may also offer the potential to combine self-directed teaching with simulated prescribing scenarios, and offer easier access to personalized student formularies. However, more research is needed into the type and format of apps which could help to improve prescribing performance.

Whilst there are limitations to our study ((i) our search criteria, although broad, may not have picked up every app with pharmacology content that is currently available through the app stores, (ii) details on app content and function were based on sometimes limited app store information and (iii) app rating does not necessarily reflect the quality of individual apps), there is nevertheless evidence that a wealth of useful apps exist and there is great potential for further development. There are many apps which facilitate drug dose calculation, including those which educate the user on adjustments to doses for patient-specific factors. It is possible that such apps could help to broach the current deficits in the prescribing knowledge and competencies of medical trainees. It is also evident that medical undergraduate education needs to reflect the current trends towards mobile healthcare delivery. Given the rapid development in the medical app field, it is important that the new generation of doctors are equipped with the knowledge and skills to assess the

benefits and risks of the use of such apps in their clinical practice.

At present, with a distinct lack of information on app stores, as well as inconsistent regulatory oversight, clinical prescribers cannot confidently assess the reliability of apps available. For this reason, users of such apps must be wary of the inherent dangers in basing clinical decisions on apps available in online stores. This is particularly relevant to the field of prescribing where patient safety can be easily compromised by inaccurate drug information or dose calculation.

Competing Interests

All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author). SM and FH declare no support from any organization for the submitted work, no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years and no other relationships or activities that could appear to have influenced the submitted work. RB declares no support from any organization for the submitted work, RB is the owner of ResearchActive.com, a company which develops medical apps and provides mHealth solutions and has no other relationships or activities that could appear to have influenced the submitted work.

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