

University of Groningen

Healthcare professionals' level of medication knowledge in Africa

Berhe, Derbew Fikadu; Taxis, Katja; Haaijer-Ruskamp, Flora M.; Mol, Peter G. M.

Published in:
British Journal of Clinical Pharmacology

DOI:
[10.1111/bcp.13746](https://doi.org/10.1111/bcp.13746)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2018

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Berhe, D. F., Taxis, K., Haaijer-Ruskamp, F. M., & Mol, P. G. M. (2018). Healthcare professionals' level of medication knowledge in Africa: A systematic review. *British Journal of Clinical Pharmacology*, *84*(12), 2729-2746. <https://doi.org/10.1111/bcp.13746>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

SYSTEMATIC REVIEW AND META-ANALYSIS

Healthcare professionals' level of medication knowledge in Africa: a systematic review

Correspondence Peter G.M. Mol, University Medical Center Groningen, UMCG, Department of Clinical Pharmacy and Pharmacology, EB70, Hanzeplein 1, PO Box 30001, 9700 RB Groningen, The Netherlands. Tel.: +31 (0)50 363 8313; Fax: +31 (0)50 363 2812; E-mail: p.g.m.mol@umcg.nl

Received 12 November 2017; **Revised** 14 July 2018; **Accepted** 17 August 2018

Derbew Fikadu Berhe^{1,2} , Katja Taxis³ , Flora M. Haaijer-Ruskamp¹ and Peter G. M. Mol¹ 

¹Department of Clinical Pharmacy and Pharmacology, University of Groningen, University Medical Center Groningen, The Netherlands, ²School of Pharmacy, College of Health Sciences, Mekelle University, Mekelle, Ethiopia, and ³Department of Pharmacy, Unit Pharmacotherapy, -epidemiology and -economics, University of Groningen, Groningen, The Netherlands

Keywords Africa, healthcare professionals, medication knowledge

AIMS

Understanding how much healthcare professionals (HCPs) know about medication can help in devising strategies to improve rational medication use. This study aimed to synthesize information on the level of medication knowledge of HCPs in Africa.

METHOD

We performed a systematic literature study in *Embase* and *PubMed*. We included original studies quantifying HCPs' medication knowledge, published between 2012 and 2016. We extracted disease focus, country, number and type of HCPs included and all medication-related knowledge questions and scored the quality of papers. The outcome measure was the percentage of HCPs who correctly answered medication knowledge questions.

RESULTS

We identified 64 studies from 12 African countries, comprising 13 911 HCPs, mostly nurses/midwives and physicians. We extracted 306 medication-related knowledge questions, and only 52% (SD 28) of HCPs correctly answered them. Knowledge questions were mainly about medication prescribed for communicable diseases (70%), followed by non-communicable diseases (11%), and family planning/gynaecology (10%). Most papers concluded that there was a considerable medication knowledge gap among HCPs.

CONCLUSION

We found a low level of medication knowledge across different disease areas, countries and HCPs. This underlines the continuous need to strengthen the undergraduate and postgraduate education in (clinical) pharmacology and therapeutics in Africa.

Introduction

Medication knowledge encompasses the understanding of (clinical) pharmacology and therapeutics and the skills to apply that knowledge in daily practice [1–3]. According to the European Association of Clinical Pharmacology and Therapeutics, the basic elements are ‘sufficient knowledge of commonly prescribed medications, the ability to adequately treat the most common diseases, a rational approach to medication selection, and the ability to write a prescription safely and unambiguously’ [4]. In a conceptual framework model for knowledge, attitude and practice [5], rational prescribing is determined by attitude to apply specific medication knowledge to a clinical situation and the healthcare professional’s prescribing skills. An adequate level of knowledge is the starting point for rational medication use. There is, however, no universally accepted level of medication knowledge physicians and other healthcare professionals responsible for prescribing, dispensing and administering medication need to have. In Norway, Simonsen *et al.* used a 60% of correct answers as the pass mark for nurses with regard to medication knowledge [3, 6], and a higher threshold (80–90%) was used in a study that involved final year medical students from 15 European countries [4].

In Africa, there is a strong need for appropriate and efficient use of scarcely available medicines; over 50% of the population in the region does not have access to essential medicines [7, 8]. Healthcare professionals (HCPs) are the principal source of information for patients. Other sources of information (patient information leaflet, drug information centres and internet) are much less accessible or affordable, and many patients are illiterate [7, 9]. The medication knowledge source for HCPs in Africa is mainly through (clinical) pharmacology courses during their under- and postgraduate training. Often a single course is given to non-pharmacy professionals, and delivered before the start of major professional courses. This situation emphasizes an important need for good medication knowledge of HCPs in Africa, but also the need for rational prescribing skills and attitudes. Understanding the level of medication knowledge can help to identify gaps and serve as the basis for focused knowledge improvement plans by policy makers and training institutes. Studies on medication knowledge in Africa are mostly limited in size and the scope of papers is usually on overall disease management not just medication [8, 10–12]. However, many studies seem to indicate that there is a lack of medication knowledge among HCPs. We performed a systematic literature review to provide a comprehensive overview of the level of medication knowledge among HCPs in Africa and to identify specific gaps in medication knowledge. We explored medication knowledge across subgroups of special interest, such as HCP specialism, and disease group.

Method

Search strategy

Following the PRISMA guidelines [13], we performed a systematic literature search in *Embase* and *PubMed* that collectively cover a wide range of journals covering the relevant

literature. Search terms were grouped into four queries, using the Boolean operators, ‘or’ [within a query], ‘and’ [between the four main queries]; Africa with list of countries, type of HCPs, knowledge and medication terms (Table S1). Studies published in a five-year time span from January 1, 2012 to December 31, 2016 were included to capture studies reflecting the current level of HCPs’ medication knowledge. Studies were included without language restrictions.

Eligibility criteria

We included original research articles that evaluated HCPs’ medication knowledge using a quantitative survey/score in Africa. Medication knowledge was defined as outlined in the introduction [1–3]. We excluded reviews, opinion pieces, letter to editors, conference abstracts and commentaries. We also excluded papers on traditional medicine and substance abuse.

Study selection and data extraction

Embase and *PubMed* search results were combined and duplicates removed. Titles were independently screened by D.F.B. and P.G.M. and all potentially relevant papers were selected for abstract review. These abstracts were screened by D.F.B. and double-checked by P.G.M. Full text screening was performed by D.F.B. and P.G.M. D.F.B. abstracted data using a customized electronic case report form. P.G.M. independently cross-checked the abstraction. Any differences in article screening, selection and data abstraction (specifically also in the identification of medication-related knowledge questions) were resolved in consensus between P.M., D.F.B. and, where needed, K.T. From each article, we extracted the following study characteristics: type (profession) of HCPs, sample size, country where the study was performed, the main disease focus, if the questions focused on benefits and/or harms of medications, and finally we assessed the quality of the included papers. Differences were resolved by consensus (D.F.B., P.G.M., K.T.).

We included HCPs who have had formal professional training in any healthcare field, and classified them into physicians, pharmacists, nurses/midwives, and ‘other HCPs’. The ‘other HCPs’ group consisted of druggists/pharmacy technicians, nurse assistants/vocational nurses, or physiotherapists. For studies that also involved patients or non-HCPs, such as community healthcare workers, we extracted medication knowledge only for the HCPs. Based on the medication knowledge questions, papers were classified into four main disease categories, namely communicable diseases (CDs), non-communicable diseases (NCDs), family planning or gynaecological indications (FP/Gyn), or ‘no specific disease focus’. Papers in the group ‘no specific disease focus’ included studies on knowledge of, for example, dose calculation and prescribing errors. We excluded, however, knowledge questions related to the healthcare system; such as whether the HCP knew how to report adverse drug reactions. We excluded vaguely presented knowledge questions with terms like ‘heard of’, as hearing about medication does not suggest knowledge was retained, but suggests a passive recall of knowledge. Attitude questions like ‘how much do you agree that medicine X is safe’ were also excluded. We classified medication knowledge questions as testing knowledge about medication benefits, harms, both or

on basic medication-knowledge issues (See Supporting information Table S2). Examples are knowledge on indications of emergency contraceptives (medication benefit), knowledge/awareness of safe period for artemether-lumefantrine use during pregnancy (medication harm), knowledge on the correct dose of specific medication (both medication benefit and harm), knowledge of different types of emergency contraceptive (basic medication knowledge).

We also extracted an excerpt of the conclusion and recommendations provided by the authors themselves.

Assessment of the quality of the included studies

We developed and pretested a nine-item tool to score the quality of the studies (See Supporting information Table S3). The tool contained items on representativeness of the HCP population included in the studies (sampling method, sample size, response rate and demographics), the methods used to test the HCPs' medication knowledge (clarity of the knowledge questions, definition of appropriate answers and validation of knowledge questionnaires) and finally on the presentation of results (descriptive statistics and missing data). This score was based on a modified version of the STROBE checklist [14]. The sum score of all nine items was set at 10 with a maximum score of two for one item and one point for all others. We grouped the quality into low (0 to 5), medium (>5 to 8) and high (>8) scores. These cut off values are arbitrary but commonly used limits in different scoring issues.

Outcome measure

Medication knowledge questions were extracted from each study. We computed the 'knowledge score' by dividing the sum of HCPs with a correct answer by all HCPs who completed the question. This was defined as

$$\text{Knowledge score (per question)} = \frac{\sum \text{HCPs with correct answer to the question}}{\sum \text{HCPs who completed the question}} * 100\%$$

We followed the definitions for a correct answer as indicated in the papers and/or cited references. We dichotomized all answers into correct or incorrect answers. If papers used a dichotomous answer (correct/incorrect, yes/no), this meant we could use the knowledge score as reported in the paper. In studies, where the numbers of respondents with a wrong answer were presented, we calculated the number of respondents with a correct answer. If answers to questions were presented on a three or more point Likert scale (e.g. low, medium or high knowledge score), we dichotomized these answers by grouping medium and high scores as correct answers. Finally, if respondents had to choose between multiple answers and there could be more than one correct answer, each answer was counted separately. In intervention studies with several measurement points, e.g. a pre- and post-training score, we extracted the pre-intervention score. In randomized controlled trials (RCT), we used the pre-intervention medication knowledge score of the control group. We assumed the pre-intervention or control group reflects daily practice.

Statistical analysis

This study focused on evidence synthesis on HCPs' medication knowledge in Africa. The questions within and between papers were very heterogeneous in terms of answer categories (see above) and complexity. We therefore used descriptive statistics to explore knowledge across extracted study characteristics (Table 1). We hypothesized that medication knowledge may be determined by the disease focus and type (profession) of HCPs due to differences attached to relevance of drugs in a particular field of medicine. Additionally, we considered that sample size and quality of the study may affect the trust in study results. Finally, we considered that emphasis in treatment is placed on efficacy not safety and thus this could affect medication knowledge on harms caused by drugs.

Results

Study characteristics

Of 2379 potentially relevant publications, 64 papers met our inclusion criteria, based on respectively screening of the title ($n = 2379$), abstract ($n = 447$) and full text ($n = 185$) (Figure 1). Three papers identified for full-text screening had to be excluded as we could not get hold of these papers even after repeated attempts to reach the authors. Overall, 13 911 HCPs – ranging from 16 to 2386 (median 176) HCPs per paper – answered a total of 306 medication-related knowledge questions. In total, 5011 nurses/midwives, 4892 physicians, 1455 pharmacists and 1721 other HCPs were included in respectively 37 (58%), 38 (59%), 20 (31%) and 26 (41%) papers. Three papers mentioned the type of HCPs, but did not provide group specific numbers and two papers did not specify the type of HCPs involved in the study. The studies have been performed in 12 African countries, but 75% originated from four countries: Nigeria ($n = 29$ papers), Tanzania ($n = 9$), Kenya ($n = 6$) and Cameroon ($n = 4$) (Tables 1 and 2).

Most knowledge questions ($n = 215$; 70%, 45 papers) were on communicable diseases, followed by 33 (11%, eight papers) questions on non-communicable diseases, 31 (10%, five papers) questions on family planning and gynaecology, and 27 (10%, 6 papers) questions with no specific disease focus. The majority ($n = 116$; 38%) of knowledge questions were on medication benefit, the remainder of the questions were equally on medication harm (20%), both benefit and harm (24%), or related to basic medication knowledge (19%) (see Table 1).

Study quality

All but three of the studies were descriptive cross-sectional surveys. Two studies assessed the impact of training or a workshop and had pre- and post-intervention knowledge scores [15, 16] and one study was a randomized controlled trial [17].

The mean quality score of the papers was 7.5 (SD 1.8, range 3–10). The included papers scored poorly with regard to sample size calculation (item 1), sampling methods (item 2) and tool validation (item 7 of our quality score tool). In all papers, information was collected via interviews or self-

Table 1

Knowledge score per question and sub group

	Paper, n (%)	Question, n (%)	Knowledge score, mean (SD) ^a
Overall	64 (100)	306 (100)	52 (28)
Type of HCPs^b			
Physicians (n = 4892)	38 (59)	107 (35)	56 (31)
Nurses/Midwife (n = 5011)	37 (58)	89 (29)	55 (32)
Pharmacists (n = 1455)	20 (31)	55 (18)	49 (31)
Other HCPs (n = 1721)	26 (41)	39 (13)	53 (32)
Sample size in papers (tertiles)^c			
≤ 120	26 (41)	127 (42)	58 (29)
121–253	19 (30)	82 (27)	43 (27)
≥ 254	19 (30)	97 (32)	51 (27)
Medication for			
Communicable disease	45 (70)	215 (70)	54 (27)
Non-communicable diseases	8 (13)	33 (11)	47 (29)
Family planning/gynaecology	5 (8)	31 (10)	44 (28)
No specific disease focus	6 (9)	27 (9)	50 (30)
Question type			
Benefit		116 (38)	49 (28)
Harm		60 (20)	41 (27)
Both (benefit-harm)		73 (24)	59 (27)
Basic medication issues		57 (19)	59 (27)
Quality score			
Low (0 to 5)	8 (13)	27 (9)	60 (28)
Medium (>5 to 8)	30 (48)	145(47)	47 (28)
High (>8 to 10)	26 (41)	134 (44)	54 (28)

^aKnowledge score is calculated based on average knowledge score per question

^bNumber (percentage) of questions for which knowledge scores were reported separately per type of professional. This was only done for 290 questions; for a number of questions sometimes results were reported for mixed groups of HCPs. For example, physicians answered 175 questions but only 107 of these results were reported separately for this group of professionals

^cWe split (equal tertiles) papers based on their sample size

Other HCPs, druggists/pharmacy technicians, nurse assistants/vocational nurses, or physiotherapists; Others (for disease), did not have a specific disease focus, including dose calculation and prescribing errors; HCP, healthcare professional

administered questionnaires. Two papers [18, 19] used mystery client surveys, in addition to interviews. In most papers ($n = 53$), questionnaires were newly developed by the authors, of which four followed a 'formal' validation procedure, 28 conducted only a pre-test, and 21 papers did not explain if or how the questionnaire was validated. The remaining 11 papers adapted a tool previously used by others; five used an adapted tool and six made some modifications (Table 2). Most papers defined how the medication knowledge score was measured (item 5, $n = 60$) (see Table 3).

Medication knowledge questions and scores

Overall, 306 medication-related knowledge questions were identified; a median of four (range 13 and interquartile range

6) questions per paper. Fifty-two percent (SD 28) of HCPs answered the 306 questions correctly. Physicians answered a mean of 56% (SD 31) out of 107 questions correctly, nurses/midwives 55% (SD 32) out of 89 questions, pharmacists 49% (SD 31) out of 55 questions, and other HCPs 52% (SD 35) out of 39 questions (Table 1).

The highest proportion of correct answers (68%, SD 23) was reported in South African studies and the lowest in Zimbabwean studies with (37%, SD 7) correct answers; more detailed results are presented below and in Table 2.

The highest knowledge scores were observed for questions on basic medication knowledge (59%, SD 27) and questions on both benefit-harm issues (59%, SD 27), which were higher than questions on benefits (49%, SD 28) and harm (41%, SD 27) only.

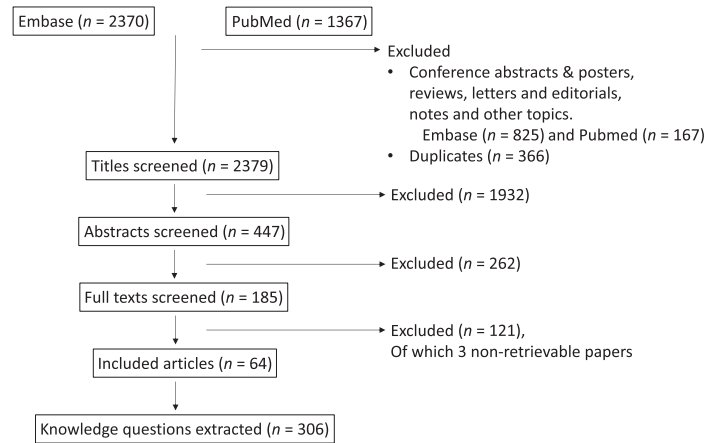


Figure 1

Review process

Table 2

Summary of study characteristics and knowledge score

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
Communicable diseases/malaria							
Bruvoort <i>et al.</i> 2014 [17] Tanzania	NS	37	10 ^b	8	66 (27)	Dispenser knowledge of correct advice on artemisinin lumefantrine.	Dispenser knowledge could be increased somewhat by using text messages, but patient adherence was not affected in this cluster randomized trial.
Kamuhabwa <i>et al.</i> 2013 [20] Tanzania	Pm, N, O	32	7 ^e	4	42 (21)	ACT [absorption, safety/pregnancy, dose/patient weight for dispensing and prescribing]	Lack of sufficient knowledge on dosage, drug–drug (food) interactions, and contraindications for ACT, and the need for on-the-job training and continuing education.
Mangham <i>et al.</i> 2012 [21] Cameroon	NS	447	7.5 ^b	1	61 (–)	Malaria prevalence and treatment of febrile patients with malaria [ACT for uncomplicated malaria]	Febrile patients may not necessarily have malaria. Rational use of ACT should be promoted with appropriate testing, also updated guideline for negative test results.
Mbachu <i>et al.</i> 2013 [22] Nigeria	N/M	213	8 ^e	1	31 (–)	Monitoring and evaluation of malaria control interventions [ACT grouping]	Knowledge gaps on understanding of data management, perception of efficient data transmission and practice of malaria monitoring and evaluation.
Mbonye <i>et al.</i> 2013 [23] Uganda	N/M, O	65	9.5 ^b	1	43 (–)	Treatment of fever [1st line drug ACT]	Lack of knowledge on Coartem (ACT) resulted in a low proportion of malaria patients receiving appropriate ACT. Interventions should address the inadequate training on malaria management.
Watsierah <i>et al.</i> 2012 [24] Kenya	PM, O	288	8.5 ^b	8	69 (19)	Malaria treatment policy and dosing regimen with ACT, quinine and other drugs [drug choice, age-based dosing, other issues]	Better knowledge on treatment policy and dosing regimen by public-sector providers in private.

(continues)

Table 2

(Continued)

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
Rabiu et al. 2015 [25] Nigeria	P	394	9.5 ^b	3	17 (8)	Malaria treatment in pregnancy	Private medical practitioners have poor knowledge of malaria prophylaxis and treatment in pregnancy, and the practice of most does not conform to guideline recommendations.
Mannan et al. 2015 [26] Sudan	P, PM	119	9 ^e	13	63 (27)	Knowledge of HCPs on ACT	ACT knowledge is very poor. There is need for improving knowledge via provider-oriented training programmes.
Onwujekwe et al 2012 [27] Nigeria	P, PM, N	52	8.5 ^b	3	83 (11)	Management/chemoprevention for malaria-in-pregnancy [IPTp general, timing, usefulness, and definition]	Overall, knowledge on management of malaria-in-pregnancy is sub-optimal. However, medication-specific knowledge is in acceptable range. There is need for interventions.
Rusk et al. 2012 [28] Kenya	P, N/M, O	117	7 ^c	1	65 (-)	Anti-malarial medication	Majority could identify the first-line treatment for uncomplicated malaria but this still needs improvement.
Minyaliwa et al. 2012 [29] Malawi	P, N, O	16	6 ^e	5	30 (34)	New malaria treatment guidelines	Dispensers have inadequate knowledge of the new malaria treatment guidelines. Involving dispensers in all stages of guideline preparation, training, and continuing professional education is needed.
Communicable diseases/HIV							
Etokidem et al. 2014 [30] Kenya	P, PM, N, O	350	9 ^e	1	29 (-)	Microbicides [preventing spread of STIs/HIV]	There is a general knowledge gap on the use of microbicides, and there is a need for capacity building.
Mathewos et al. 2013 [31] Ethiopia	P, PM, N/M, O	195	8.5 ^b	5	62 (11)	Post-exposure prophylaxis/HIV [initiate, duration of therapy, and effectiveness]	Inadequate knowledge and practice of HIV PEP. Recommended interventions: training and set up a 24-hour accessible formal PEP center with guideline.
Mponela et al. 2015 [32] Tanzania	P, N, O	291	7 ^e	1	41 (-)	Post-exposure prophylaxis/HIV	PEP specific knowledge is low. Also, low PEP usage, low level of knowledge on occupational exposure and reporting rate. There is a need for reporting exposure on time so that the provider can receive PEP.
Owolabi et al. 2012 [33] Nigeria	P, N, O	230	8.5 ^b	9	58 (20)	Post-exposure prophylaxis/HIV [medications used, duration of therapy and indication]	PEP knowledge and practice were very poor. The authors report a need to scale up PEP services.
Ruud et al. 2014 [34] South Africa	N, O	102	6.5 ^b	12	79 (11)	HIV and treatment [awareness and specific medication knowledge]	Knowledge of HIV medications is fairly high. However, HCPs lack the ability to manage ADRs and have little knowledge of barriers to patient adherence. There is a need for training on management of antiretroviral therapy.

(continues)

Table 2

(Continued)

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
Ajibola et al. 2014 [35] Nigeria	P, N	300	7.5 ^b	4	46 (30)	HIV PEP [time to take, duration of use and medication]	Despite reasonable knowledge score, PEP usage was low. There is a need for PEP management programs to increase reporting professional/accidental exposure, improve counselling, follow up and access to PEP.
Ogbonna et al. 2016 [36] South Africa	P, N	102	4.5 ^b	3	46 (32)	Prevention of mother-to-child HIV transmission (PMTCT)	Physician and nurses' knowledge of HIV counselling was better than their medication knowledge (e.g. on dosages and combination of drugs to be used for PMTCT). Over two-thirds reported following PMTCT guideline recommendations, but as their knowledge was limited, their practice may be substandard.
Musa et al. 2012 [37] Nigeria	P	74	9.5 ^b	2	13 (17)	HIV prevention strategy/vaginal microbicides	Gynaecologist knowledge on vaginal microbicides is poor. There is a need to create awareness on recent HIV prevention technologies, including the role of vaginal microbicides.
Aminde et al. 2015 [38] Cameroon	N	85	10 ^d	10	50 (19)	HIV PEP knowledge and practices of nurses	The knowledge and practice of nurses on PEP for HIV is low. There is a need for training and workshops to increase awareness, improve practice and reduce the risk of HIV acquisition from work-related activities among HCPs.
Communicable diseases/vaccines							
Abiola et al. 2013 [39] Nigeria	P, N, O	84	8.5 ^b	4	62 (19)	Hepatitis B vaccine [effectiveness, dose, protection period]	HCPs had good knowledge of viral hepatitis B, but poor practice on vaccination. Provide further education to translate knowledge into good practice.
Abiola et al. 2016 [40] Nigeria	P, N	134	9 ^d	7	56 (20)	Hepatitis B vaccine [dose and use]	HCPs had fair knowledge of viral hepatitis B, but poor practice on post vaccination testing. The need for further training, compulsory occupational vaccination and post vaccination testing.
Abeje et al. 2015 [41] Ethiopia	P, PM, N/M, O	374	7 ^e	8	67 (18)	Hepatitis B vaccine [full course, usefulness, safety, effectiveness]	Low level on the infection and mode of transmission but moderate knowledge score about the vaccine. There is need for training on prevention and control and vaccines.
Adekanle et al. 2015 [42] Nigeria	P, PM, N, O	382	9.5 ^b	1	97 (-)	Hepatitis B vaccine [awareness of the vaccine]	Despite high awareness of the vaccine, perceived risk of the infection and vaccination coverage is low. Compulsory screening and vaccination may be needed.

(continues)

Table 2

(Continued)

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
Noubiap et al. 2014 [43] Cameroon	P	49	8.5 ^b	3	80 (16)	Hepatitis B vaccine [dose, immune response]	Fairly good knowledge on the vaccine but low uptake. The need to offer and urge residents to take the vaccine before beginning of residency training.
Audu et al. 2014 [44] Nigeria	P, PM, N, O	602	8.5 ^b	1	44 (-)	Human papilloma virus vaccine [awareness]	'Low knowledge of a vaccine that can prevent the commonest cancer in women in sub-Saharan Africa'. The authors recommend targeted interventions: via the 'man on the street' and traditional and religious leaders.
Hoque 2016 [45] South Africa	P	320	10 ^c	2	34 (12)	Human papillomavirus vaccine [effectiveness and type]	Doctors lacked knowledge of human papillomavirus infection and vaccine. There is a need for health education and on safety, efficacy and the best timing for human papillomavirus vaccination.
Wamai et al. 2013 [46] Cameroon	N	76	8 ^e	5	85 (8)	Human papillomavirus vaccine [use]	There is high awareness of the vaccine but more education is required to further increase nurses' willingness to recommend the vaccination.
Kamuhabwa et al. 2012 [47] Tanzania	P, PM, O	253	7 ^e	2	19 (22)	Influenza vaccine/prevention and treatment [antiviral medication and side effects]	Large knowledge gap on antiviral medications and adverse effects. Need for continued (postgraduate) education and professional development.
Fatiregun et al. 2012 [48] Nigeria	P, N	255	8 ^e	1	39 (-)	Influenza A (H1N1) vaccine	Poor knowledge of the vaccine but willingness to receive the vaccine was very high. One reason for refusal was fear over side effects. Intervention needed to increase uptake.
Masika et al. 2016 [49] Kenya	N	274	5.5 ^b	14	33 (14)	Adverse events following immunization (AEFI)	The majority of the respondents had poor knowledge and practice levels on AEFI surveillance; especially on how to investigate, report and manage post-immunization anaphylaxis. Training on AEFI surveillance for nurses.
Communicable diseases/Tuberculosis							
Adams et al. 2014 [50] Tanzania	P, N, O	117	4.5 ^b	3	90 (2)	Childhood tuberculosis [treatment and monitoring]	Overall knowledge was high and good implementation of national guidelines. Still there is need to address gaps in diagnosis, treatment and use of isoniazid preventive therapy.
Chukwu et al. 2016 [51] Nigeria	P	106	9 ^a	1	27 (-)	Childhood TB [regimen for category 1 TB]	Good overall disease knowledge but poor knowledge of category I TB medications. Despite good knowledge, practice was less appropriate. Need for focused training on childhood TB care.

(continues)

Table 2

(Continued)

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
Ukwaja et al. 2013 [52] Nigeria	P, N, O	30	5 ^b	5	77 (19)	Tuberculosis [regimen/duration and side effect]	Gaps in disease and medication knowledge, but especially a need to re-educate HCPs on infection control.
Rutta et al. 2014 [53] Tanzania	PM, O	295	6.5 ^b	5	37 (23)	Tuberculosis care [consequences of poor adherence]	Poor knowledge on consequences of inadequate medication adherence by retail drug outlet staff. Intervention implemented to improve identification of TB patients and referral to proper health facilities.
Communicable diseases/other							
Abera et al. 2014 [54] Ethiopia	P, N, O	385	9.5 ^b	13	47 (30)	Antimicrobial resistance [contributing factors for resistance and examples]	Poor knowledge on different aspects of antimicrobial resistance. Interventions should focus on [reducing] self-medication, raise awareness on resistance and improve access to antibiograms
Ajibade et al. 2014 [55] Nigeria	N	67	3 ^e	2	61 (25)	Perioperative antibiotic prophylaxis [administration and safety]	Nurse-anaesthetist had fair knowledge of rational surgical antibiotic prophylaxis. Further attention to peri-procedural prophylaxis needed, especially with regard to timing of antibiotic dosing.
Chukwu 2016 [56] Nigeria	P, PM, N	221	6 ^e	3	50 (31)	Probiotics [awareness, benefit, and microbe status]	HCPs are not aware of advantages of using probiotics for managing e. g. diarrhoea. Knowledge of HCPs may be improved through seminars, workshops and using pharmacists as messengers as they seemed more informed.
Fathi et al. 2016 [57] Egypt	P	319	7 ^d	9	69 (31)	Antimicrobial therapy and resistance [dose, specific agent]	Overall fairly good knowledge but limited awareness of specific issues: e.g. need for dose adjustments in patients with renal impairment or about local resistance patterns, or need to advise patients on proper use. Antimicrobial stewardship programmes are recommended for Egyptian hospitals.
Mbonye et al. 2016 [58] Uganda	P, O	170	7.5 ^b	1	18 (-)	Antibiotics [Amoxicillin/children pneumonia]	More than 80% of HCPs did not know amoxicillin as first line therapy for pneumonia. The need to regulate drug shops.
Mwanakasale et al. 2013 [59] Zimbabwe	P, N/ M, O	28	3 ^e	3	37 (7)	The challenges to control Human African Trypanosomiasis	In addition to poor medication knowledge of HCPs, especially shortages of trained health workers, inadequate diagnostic (laboratory) and treatment facilities, and shortage of trypanosomicides need to be addressed to improve care.

(continues)

Table 2

(Continued)

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
Ogbo et al. 2014 [60] Nigeria	P	186	7.5 ^b	8	22 (14)	Management of acute diarrhoea in children [product recommended]	Poor knowledge on products to manage diarrhoea, with only 15% of community pharmacists following WHO guidelines. Authors indicate a need for a campaign on the management of acute watery diarrhoea.
Omuemu et al. 2012 [61] Nigeria	P, N/M	59	9.5 ^b	12	38 (32)	Zinc supplementation in the management of childhood diarrhoea [types of diarrhoea treated with zinc supply and benefit]	HCPs lack adequate knowledge on how to supplement zinc. Social marketing campaigns are proposed to promote zinc supplementation in children with diarrhoea.
Peltola et al. 2015 [62] Malawi	O	115	7 ^e	3	63 (52)	Sepsis management	Knowledge on practical management was relatively good, but 'Surviving Sepsis Campaign' therapeutic strategies were poorly known. Sepsis guidelines need to be adapted to healthcare structures in underdeveloped countries.
Thriemer et al. 2013 [63] DR Congo	P	184	8 ^d	10	56 (32)	Antibiotic prescribing [simulated cases based on safety of medication for pregnancy, resistance issue and administration route]	Low to mediocre knowledge of HCPs, especially of local resistance patterns and lack of independent drug information. The authors indicated a need for local antibiotic guidelines and courses on rational use.
Non-communicable diseases							
Adeyeye et al. 2015 [15] Nigeria	N	78	3 ^e	8	68 (16)	Knowledge, skills and competency of nurses in the treatment of asthma	The knowledge of nurses about drug delivery devices and peak flow meters was poor. Need for structured courses on asthma management, including hands-on training with various devices and peak flow meters.
James et al. 2012 [65] Nigeria	P	128	7 ^c	3	26 (21)	Long-acting antipsychotic injections (LAIs) [medication safety, efficacy/indication and prescribing]	HCPs had (too) positive attitudes to injectable antipsychotics but their knowledge on adverse effects was low and needs to be improved as did patient counselling.
Obumneme-Anyim et al. 2014 [67] Nigeria	P	283	6.5 ^b	4	62 (8)	Asthma [medication used in treatment of acute exacerbation]	Good knowledge on epidemiology and clinical features of asthma, but fair knowledge on treatment only. A need for continued medical education to improve knowledge on stepwise combination therapy and putting knowledge into practice.
Ozoh et al. 2014 [69] Nigeria	P	182	6 ^e	1	58	COPD/medication	Level of knowledge on COPD management is sub-optimal. There is a need to develop a systematic COPD education programme to improve knowledge.
Ogboli-Nwasor et al. 2013 [68] 2013 Nigeria	P	82	8 ^a	8	33 (25)	Cancer pain management [guideline/protocol focused]	Elemental lack of knowledge of pain management in cancer patients. This requires formal training as part of continuous medical education in low-resource settings.

(continues)

Table 2

(Continued)

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
Fadare et al. 2014 [64] Nigeria	P, PM, N, O	170	10 ^c	3	60 (32)	Palliative care [morphine and pain relief]	Fair knowledge on morphine use and precaution but poor overall palliative care knowledge. Introduce palliative care management in the curriculum of HCPs.
Murila et al. 2012 [66] Kenya	P, N	192	3 ^e	2	1 (0)	Neonatal resuscitation [medications and fluids]	Inadequate knowledge of resuscitation, with no knowledge on relevant medicines. There is a need to increase quality and duration of undergraduate training.
Sakafu et al. 2016 [70] Tanzania	P	50	9 ^e	4	46 (44)	Management of differentiated thyroid cancer and the use of radioactive iodine	There is insufficient knowledge on proper management and use of radiopharmaceuticals. Attention should be given to nuclear medicine in postgraduate continuous medical education.
Family planning and gynaecology							
Reiss et al. 2016 [19] Kenya		235	6.5 ^e	9	39 (28)	Abortifacient [regiment and side effects, other uses]	Limited medical abortion knowledge. Training may improve the quality of information and access to safe abortion.
Amin 2016 [71] Egypt	PM	167	9 ^a	10	30 (26)	Oral contraceptives [options for breast feeding mother, side effects, backup options]	Low knowledge of contraceptives. Continuous medical education should focus on misconceptions around contraception and health risks and on managing missed pills.
Bains et al. 2014 [72] Uganda	PM	26	9 ^c	1	57 (-)	Maternal-fetal medicine Not medication specific	Pharmacists had fair overall knowledge of medicines used during pregnancy and lactation. There is, however, a need to revise current undergraduate curricula and increase access to high-quality drug information resources, especially for low-income countries.
Morhason-Bello et al. 2014 [73] Nigeria	P	255	8.5 ^b	11	58 (29)	Emergency contraception [type, indication, regimen]	HCPs had a fair overall knowledge on emergency contraceptives. However, they lacked knowledge of emergency contraception policy and proper counselling. Undergraduate and on-the-job training recommended.
Mohammed et al. 2016 [74] Nigeria	P, N/ M	292	6 ^a	7	43 (25)	Obstetric knowledge [specific medication use for (pre-) eclampsia, PPH and others]	Nurses/midwives had poor knowledge on medicines used in obstetrics. Undergraduate curricula should be fully implemented and continuing education introduced.
General topics (without specific disease)							
Savage 2015 [16] Tanzania	N	242	6.5 ^b	1	33 (-)	Drug dose calculation	Nurses had poor pre-test dose calculation skills, these improved after a training programme. However, arithmetic skills could be supported in less developed settings by providing calculators.

(continues)

Table 2

(Continued)

Author/Publication year [ref]/Country	HCPs	Sample size	Quality score	Number of questions	Knowledge score %, mean (SD)	Main topic	Conclusion/recommendations
							But other course materials may be tested.
Kamuhabwa et al. 2015 [18] Tanzania	PM	183	6 ^e	2	95 (8)	Dispensing practice of prescribed medicines/mystery shopper approach [OTC, drug–drug/food interaction]	Knowledge on drug–drug (food) interactions and prescription-only drugs was high. However, authors' conclusions were that dispensing practices were inadequate, and prescription-only drugs should be handled by trained professionals only.
Auta et al. 2012 [75] Nigeria	O	236	7.5 ^b	1	34 (–)	Self-medication [OTC, indication, C/I, side effect, brand/generic names]. Not medication specific	Poor knowledge on OTC, indication, contraindication, side effects, brand and generic names. The need for education on self-medication.
Onigbinde et al. 2012 [76] Nigeria	O	135	8 ^d	9	28 (11)	Topical pharmacotherapy [active ingredients, topical antibiotics, NSAIDs, side effects and C/Is]	Poor knowledge of topical pharmacotherapy. The need for continuing professional development program/seminars.
Ajemigbitse et al. 2014 [77] Nigeria	P	30	7 ^d	3	90 (4)	Medication prescribing errors [medication use, indication, formulation]	Good knowledge on medication indication, different formulation and dose, but low awareness for making prescribing errors. Principles of rational prescribing and of making prescribing errors should be taught in practice.
Ogunleye et al. 2016 [78] Nigeria	P, PM N, O	2386	8.5 ^b	3	90 (6)	Medication errors (general)	High prevalence of medication errors, and knowledge of errors differed across professional groups. Multifaceted interventions are suggested.

Tool (questionnaires) validation:^aSelf-made with expanded/formal validation process,^bSelf-made with pretest only,^cCited previous developed tool and used as such, or^dCited previously developed tool with modification, and^eSelf-made without clear explanation for validation

On the overall score, papers without standard deviation are these with only one knowledge question

HCPs: healthcare professionals; P: physician, PM: pharmacist, N/M: Nurse midwife, O: Other HCP; ACT; Artemisinin-based Combination Therapy, IPTp; Intermittent Preventive Therapy in pregnancy (malaria chemoprevention in pregnancy), ADR; adverse drug reaction, OTC; Over-the-counter, DM; diabetes mellitus, PMTCT: Prevention of mother-to-child transmission

Finally, papers that had the lowest quality scores reported higher medication knowledge by HCPs than the studies with medium or high quality.

Disease focus

Communicable diseases (215 questions, 45 papers). The majority of papers and medication-related knowledge questions were for medicines used for malaria, HIV/AIDS, tuberculosis and for vaccines.

Forty-eight questions in 11 papers queried HCPs about their medication knowledge to treat or prevent malaria [17,

20–29]. These questions identified knowledge gaps across all aspects of antimalarial medication use; i.e. dosing, drug–drug (food) interactions, contraindications, appropriate use in specific patient groups (paediatrics, pregnancy and adults). The main finding, as reported by authors, was the lack of knowledge on rational and effective use of artemisinin-based combination therapy and implementation of recommended intermittent preventive treatment in pregnancy or medications for specific age groups.

Forty-seven questions in nine papers were on antiretroviral medications for HIV/AIDS [30–38]. In these papers, it is reported that HCPs lacked knowledge on use of microbicides

Table 3Quality score per item ($n = 64$)

Quality score items	Weight (point)	No. of papers with score of			
		2 pt	1 pt	0.5 pt	0 pt
Q1. Sampling method	1		34		30
Q2. Sample size calculation	1		28		36
Q3. Response rate	1		50		14
Q4. Participants' characteristics	1		52		12
Q5. Clarity how knowledge score was measured	2	57	3		4
Q6. What is the appropriate answer	1		51	3	10
Q7. Tool validation	1		15	28	21
Q8. Descriptive data	1		57		7
Q9. Explain missing data	1		57		7

to prevent HIV and other sexually transmitted diseases, that they were unable to identify medications used for post-exposure prophylaxis (PEP), and did not know the time point to initiate PEP, duration of treatment and effectiveness of PEP. The main finding in these papers was that PEP was underused, and it was speculated that this was partly due to the low level of PEP-related knowledge.

Forty-eight questions were about different types of vaccines; 23 on hepatitis B [39–43], eight on human papilloma virus [44–46], three on influenza [47, 48] viruses, and 14 questions on adverse events following immunization [49]. Questions were about overall awareness of different types of vaccines, and the effectiveness, what comprised a dose/full course, how long the vaccines offered protection, and about the safety of vaccination, adverse reactions after immunization, and medication used to prevent/relieve vaccination-related immune reaction. The papers on hepatitis B reported overall good knowledge of the vaccine (56–97%), but despite this good knowledge, HCPs' perceived benefit and actual use of the vaccine was low. All but one paper reported poor knowledge of vaccines for human papilloma and influenza viruses, and also about adverse reactions following immunization.

Fourteen questions from four papers were on knowledge of medication used to treat tuberculosis [50–53], focusing on child tuberculosis treatment, knowledge of the complex treatment regimens (number of medications, duration of therapy and safety concerns), and about the consequences of poor treatment adherence. Two of these papers reported poor knowledge on tuberculosis treatment regimens and consequences of medication non-compliance.

The remaining 58 questions in papers focusing on medications for communicable diseases were about medications for human African trypanosomiasis, anti-diarrheal agents, sepsis management, general antimicrobial indications, safety or resistance [54–63]. Topics in these papers were timing of administration and safety issues of perioperative antibiotic prophylaxis, prevention of antimicrobial resistance and contributing factors, inappropriate antibiotic prescribing, and diarrhoea management in children. The main findings from these papers were that HCPs had a fair knowledge of

what constitutes rational antimicrobial use, but poor knowledge of antimicrobial resistance and especially on products for diarrhoea.

Non-communicable diseases (38 questions; 8 papers).

Medication questions on non-communicable diseases concerned cancer treatment and cancer-related pain management and palliative care in two papers ($n = 12$), medications for asthma/COPD ($n = 12$) in three papers, four on management of thyroid cancer and use of radioactive iodine in one paper, and finally three papers on antipsychotics [15, 64–70]. The main knowledge questions were more general, as the papers focused mostly on general disease management and type of medication to be used. The main findings were knowledge gaps on palliative care, use of radioactive iodine for thyroid cancer, long active long-acting antipsychotic injections, asthma/COPD and cancer pain management.

Family planning and gynaecology (31 questions; 5 papers).

Thirty-one questions in five papers were about contraceptives or medication used in gynaecological procedures [19, 71–74]. The knowledge questions were about appropriate use of medication for (pre-)eclampsia, neonatal resuscitation, emergency contraceptives (type, dose, indication, side effects and time window for use), and abortifacient medication use and complications. The studies reported limited knowledge on medical abortion, pharmacotherapeutics of oral and emergency contraceptives. Many papers indicated also important attitudinal issues affecting the proper use of especially emergency contraceptives and abortifacients.

Without specific disease focus (27 questions; 6 papers). Six papers (14%) with 27 medication-related knowledge questions did not have a specific disease focus (grouped under 'other' in Table 2) [16, 18, 75–78]. Questions were more general including self-medication, topical medications (anti-pain and antibiotics), dose calculation and prescribing errors. Authors reported this type of general knowledge to be poor as

with other disease groups. In particular, there was low level of knowledge on self-medication practices, prescribing errors and pharmacotherapy of dermatological products.

Discussion

We provide a comprehensive overview of medication knowledge based on a review of 64 papers including 13 911 HCPs from 12 African countries. Overall, 52% (SD 28) of HCPs answered a total of 306 knowledge questions correctly. Physicians, nurses and midwives were most often included, but pharmacists were also well represented. Most (70%) studies were about communicable disease medications including antimalarial, antiretroviral medications for HIV, and different types of vaccines. The large majority of included studies were of medium to high quality but especially validation of the questionnaire was either poorly performed or described. Most papers reported as a main finding that HCP lacked sufficient medication knowledge and needed training to improve this knowledge.

Medication knowledge

Our paper shows that, using a systematic approach, it is possible to synthesize a comprehensive overview of medication knowledge from papers that may have a wider scope, e.g. focusing on overall disease management. The overall knowledge score of 52% shows that medication knowledge continues to be a problem. The issue seems generic for all medicines across different disease areas, as medication knowledge questions were answered relatively similarly between different disease areas. Although there is no universally accepted threshold to define adequate knowledge, we think that the score found in our study is suboptimal considering the pass mark (60%) often used in medical colleges or in educational practice in general. Most papers concluded that knowledge was suboptimal despite the fact that no paper had a predefined acceptable knowledge score. Knowledge is also lower in comparison with a study conducted in 15 countries in Europe (70%), two studies in Norway (score > 60%), and one study performed in The Netherlands (score > 70%) [1, 3, 4, 6]. Observed medication knowledge deficits among HCPs in our study may be explained by a lack of adequate drug information resources and up-to-date reference books, limited access to internet (mainly outside the main cities), and due to lack of integration of (clinical) pharmacology courses with major professional courses in under- and post-graduate courses. Pharmacology courses are often delivered early in the study curriculum, before professional courses (internships) specifically for physicians and nurses take place. This makes it difficult to integrate medication knowledge and clinical skills. An attractive scenario would be to test whether building 'personal formularies' during formal training of HCPs would increase medication knowledge, and whether sufficient attention is paid also to prescribing skills, which would result in more rational prescribing [79]. The comparison with the above studies should be made cautiously as the papers in our study covered a much broader range of topics, a wider variety of medication knowledge questions, had different study designs, different types of

HCPs included and an emphasis on medication-related knowledge questions in the area of communicable diseases.

Our results suggest that (clinical) pharmacology and therapeutics education may have to be strengthened in Africa.

According to Brinkman *et al.* [4], the way (clinical) pharmacology and therapeutics are taught greatly influences prescribing competence. They showed that knowledge was significantly higher among students who attended schools using problem-based or mixed-learning methods than those attending traditional learning curricula. Moreover, they also showed that factual knowledge alone had a weak correlation with prescribing skills [80]. The 'six steps' approach advocated in the 'Guide to good prescribing' adopted by the WHO, which is widely used in medical training programmes around the globe [81], could be a good start for this. The European Association of Clinical Pharmacology and Therapeutics presented in a recent study a blueprint for a core curriculum to assure prescribing competency in Europe. This programme may not be translated in full to the African situation, but some teaching methods such as role-playing sessions, case-based discussion groups and student run clinics may work well [82]. Additionally, electronic tools like mobile apps may help HCPs maintaining and updating medication knowledge [17]. Strengthening drug information services may be another way to improve medication knowledge.

Disease focus

It is not surprising that most of the articles in our review were about medications to treat or prevent communicable diseases. These diseases present the major health challenge in Africa [83]. The reported lack of knowledge on various aspects of rational medication use and drug resistance challenges effective prevention and eradication programmes. The most discussed issues included malaria, in particular the use of artemisinin-based combinations and Prevention of Mother to Child Transmission (PMCT), HIV, especially PEP, and vaccinations.

Another area that was well studied was vaccines, where we observed knowledge gaps for different types of vaccines for hepatitis B (HBV), influenza and human papilloma viruses (HPV). Awareness of available HBV vaccines in our study (56–97%) was in line with a previous report [84]. Cervical cancer caused by human papillomavirus (HPV) is the leading cause of cancer mortality among women in Africa [85]. Although the general population in the region has some knowledge of HPV and may be quite willing to get vaccinated [86], the knowledge deficit on the efficacy and safety of the vaccines reported in our study for HCPs needs to be addressed before they are likely to support and engage in effective vaccination campaigns. Other studies on communicable diseases were on rational antimicrobial medication use and resistance, highlighting the known antibiotic use challenges that need training and continuous education of HCPs.

Even though the burden of NCDs, such as hypertension, diabetes mellitus, asthma/COPD, stroke and cancer are increasing in Africa, relatively little attention is still paid to these diseases by health policy makers [87, 88]. It is therefore not surprising to see also few medication knowledge studies for these diseases. Of the NCDs, cancer and asthma/COPD were most widely studied, which are diseases with complex

medical treatments that require high levels of HCP knowledge and skills.

In developing nations, including the majority of African countries, contraceptive use remains low with obvious consequences for population growth and thus with a high unmet need for improved family planning activities [88]. One of the major barriers reported for low use of family planning is inadequate knowledge about contraceptive methods and how to use these in the general population [89, 90]. Three papers included in our study substantiate these findings [71, 73, 91]. Due to cultural, religious and social influences, the role of HCPs is crucial for improving the uptake of contraceptives. Interventions to improve HCPs' knowledge may help to achieve the sustainable development goal 3 (reduce child mortality and improve maternal health) set by the United Nations [92]. The papers included in our study also suggest that attitudinal issues need to be overcome among HCPs.

Medication benefit versus harm aspect

In our study, most of the knowledge questions were on medication benefit. Our study suggests that the harmful aspects of medication use receive little attention, even in research. In line with this, adverse drug reaction reporting from sub-Saharan Africa is the lowest in the world [93, 94].

Strengths and limitations

To the best of our knowledge, this is the first study of this type in Africa that provides a comprehensive overview of HCPs' medication knowledge. We used a semi-quantitative approach to facilitate a global interpretation of the large amount of published data. Our review revealed a wide range of medication and disease topics across studies. The pooled estimates should thus be interpreted with caution as the studies were highly heterogeneous, reporting a wide range of diseases that used various measuring tools. The emphasis in this paper is on descriptive rather than quantitative differences in medication knowledge.

Another limitation of this study was that our quality score assessment tool was not validated. The tool was self-developed, and although it is based on the STROBE checklist, pre-tested and highly intuitive, different cut-offs or weights attached to assessment criteria could have resulted in small differences in the classification of study quality. The emphasis in this paper is therefore on a textual description of medication knowledge and general areas for improvement that should not be driven by a specific knowledge score value. In almost all papers in our review, knowledge was measured using paper-based surveys, i.e. studies did not look at prescribing practices or outcomes. The difference between paper-based knowledge scores and practical skills need to be further explored in African settings.

We did not check systematically the references of included papers for potential additional relevant studies. We think, however, this would have only minimally changed our findings, as we already included an eclectic sample of studies into HCPs' medication knowledge. Our search was limited to a five-year period (2012–2016), it allowed us to focus on studies that reflect the current situation with respect to HCPs' medication knowledge. It also allowed us to maintain a broad focus of HCP medication knowledge across disease

areas, while curbing the already large number of retrieved studies.

Conclusion

Overall, our study indicates there continues to be a considerable lack of knowledge about medication in the African region. Our study suggests that there is a general need to improve education and continuous training of HCPs about medication. In particular, revised teaching methods for under- and postgraduate students may be used to improve prescribing competency. Electronic tools such as health apps may be used to provide knowledge at time of prescribing. This indicates a continued need to improve the situation, for example by paying more attention in the education system and on-the-job training. In addition, more information is needed on the effects of better knowledge on the quality of prescribing and medication use, and in the ultimate effects on health outcomes. It is also important to set up a system for monitoring HCP training programmes.

Competing Interests

There are no competing interests to declare.

The authors wish to thank Anne-Marie Jipping for her support in the early phase of the study. The study was part of a PhD project funded by NUFFIC (Netherlands Organization for International Cooperation in Higher Education); NF-PhD 12/402.

References

- 1 Keijsers CJ, Brouwers JR, Wildt DJ, Custers EJ, Ten Cate OT, Hazen AC, *et al.* A comparison of medical and pharmacy students' knowledge and skills of pharmacology and pharmacotherapy. *Br J Clin Pharmacol* 2014; 78: 781–8.
- 2 Nierenberg DW. A core curriculum for medical students in clinical pharmacology and therapeutics. *Clin Pharmacol Ther* 1990; 48: 606–10.
- 3 Simonsen BO, Johansson I, Daehlin GK, Osvik LM, Farup PG. Medication knowledge, certainty, and risk of errors in health care: a cross-sectional study. *BMC Health Serv Res* 2011; 11: 175.
- 4 Brinkman DJ, Tichelaar J, Schutte T, Benemei S, Böttiger Y, Chamontin B, *et al.* Essential competencies in prescribing: a first European cross-sectional study among 895 final-year medical students. *Clin Pharmacol Ther* 2017; 101: 281–9.
- 5 Roelens K, Verstraelen H, Van Egmond K, Temmerman M. A knowledge, attitudes, and practice survey among obstetrician-gynaecologists on intimate partner violence in Flanders, Belgium. *BMC Public Health* 2006; 6: 238.
- 6 Simonsen BO, Daehlin GK, Johansson I, Farup PG. Differences in medication knowledge and risk of errors between graduating nursing students and working registered nurses: comparative study. *BMC Health Serv Res* 2014; 14: 580.
- 7 Huebler F, Lu W. Adult and youth literacy: national, regional and global trends, 1985–2015. Montreal: UNESCO Institute for Statistics, 2013.

- 8 Kane J, Landes M, Carroll C, Nolen A, Sodhi S. A systematic review of primary care models for non-communicable disease interventions in sub-Saharan Africa. *BMC Fam Pract* 2017; 18: 46.
- 9 Ajuwon GA, Rhine L. The level of Internet access and ICT training for health information professionals in sub-Saharan Africa. *Health Info Libr J* 2008; 25: 175–85.
- 10 Pastakia SD, Pekny CR, Manyara SM, Fischer L. Diabetes in sub-Saharan Africa – from policy to practice to progress: targeting the existing gaps for future care for diabetes. *Diabetes Metab Syndr Obes* 2017; 10: 247–63.
- 11 Kayima J, Wanyenze RK, Katamba A, Leontsini E, Nuwaha F. Hypertension awareness, treatment and control in Africa: a systematic review. *BMC Cardiovasc Disord* 2013; 13: 54.
- 12 Maslove DM, Mnyusiwalla A, Mills EJ, McGowan J, Attaran A, Wilson K. Barriers to the effective treatment and prevention of malaria in Africa: a systematic review of qualitative studies. *BMC Int Health Hum Rights* 2009; 9: 26.
- 13 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med* 2009; 151: 264–9.
- 14 Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening of Reporting of Observational Studies in Epidemiology [STROBE] statement: guidelines for reporting observational studies. *Gac Sanit* 2008; 22: 144–50.
- 15 Adeyeye O, Kuyinu Y, Bamisile R, Oghama C. A preliminary assessment of nurses' asthma education needs and the effect of a training programme in an urban tertiary healthcare facility. *Afr J Respir Med* 2015; 10.
- 16 Savage AR. Educational audit on drug dose calculation learning in a Tanzanian school of nursing. *Afr Health Sci* 2015; 15: 647–55.
- 17 Bruxvoort K, Festo C, Kalolella A, Cairns M, Lyaruu P, Kenani M, *et al.* Cluster randomized trial of text message reminders to retail staff in Tanzanian drug shops dispensing artemether-lumefantrine: effect on dispenser knowledge and patient adherence. *Am J Trop Med Hyg* 2014; 91: 844–53.
- 18 Kamuhabwa AR, Ignace AM. Dispensing practice of prescribed medicines in the private pharmacies in urban areas of Tanzania. *Indian J Pharm Sci* 2015; 77: 542–9.
- 19 Reiss K, Footman K, Akora V, Liambila W, Ngo TD. Pharmacy workers' knowledge and provision of medication for termination of pregnancy in Kenya. *J Fam Plann Reprod Health Care* 2016; 42: 208–12.
- 20 Kamuhabwa AA, Silumbe R. Knowledge among drug dispensers and antimalarial drug prescribing practices in public health facilities in Dar es Salaam. *Drug Healthc Patient Saf* 2013; 5: 181–9.
- 21 Mangham LJ, Cundill B, Achonduh OA, Ambebila JN, Lele AK, Metoh TN, *et al.* Malaria prevalence and treatment of febrile patients at health facilities and medicine retailers in Cameroon. *Trop Med Int Health* 2012; 17: 330–42.
- 22 Mbachu CO, Uzochukwu BS, Onwujekwe OE, Ilika AL, Oranuba J. How do health workers perceive and practice monitoring and evaluation of malaria control interventions in south-east Nigeria? *BMC Health Serv Res* 2013; 13: 81.
- 23 Mbonye AK, Lal S, Cundill B, Hansen KS, Clarke S, Magnussen P. Treatment of fevers prior to introducing rapid diagnostic tests for malaria in registered drug shops in Uganda. *Malar J* 2013; 12: 131.
- 24 Watsierah CA, Onyango RO, Ombaka JH, Abong'o BO, Ouma C. Provider knowledge of treatment policy and dosing regimen with artemether-lumefantrine and quinine in malaria-endemic areas of western Kenya. *Malar J* 2012; 11: 436.
- 25 Rabiou KA, Davies NO, Nzeribe-Abangwu UO, Adewunmi AA, Akinlusi FM, Akinola OI, *et al.* Malaria prevention and treatment in pregnancy: survey of current practice among private medical practitioners in Lagos, Nigeria. *Trop Doct* 2015; 45: 6–11.
- 26 Mannan AA, Elmardi KA, Idris YA, Spector JM, Ali NA, Malik EM. Do frontline health care providers know enough about artemisinin-based combination therapy to rationally treat malaria? A cross-sectional survey in Gezira State, Sudan. *Malar J* 2015; 14: 131.
- 27 Onwujekwe OC, Soremekun RO, Uzochukwu B, Shu E, Onwujekwe O. Patterns of case management and chemoprevention for malaria-in-pregnancy by public and private sector health providers in Enugu state, Nigeria. *BMC Res Notes* 2012; 5: 211.
- 28 Rusk A, Smith N, Menya D, Obala A, Simiyu C, Khwa-Otsyula B, *et al.* Does anti-malarial drug knowledge predict anti-malarial dispensing practice in drug outlets? A survey of medicine retailers in western Kenya. *Malar J* 2012; 11: 263.
- 29 Minyaliwa C, Bandawe C, Mwale RJ. How much do Blantyre dispensers in hospital and community pharmacies know about the new malaria treatment guidelines? *Malawi Med J* 2012; 24: 1–4.
- 30 Etokidem AJ, Ogaji DS, Okokon IB. Knowledge and perception of microbicides among healthcare providers in Calabar, Nigeria. *Afr Health Sci* 2014; 14: 281–7.
- 31 Mathewos B, Birhan W, Kinfe S, Boru M, Tiruneh G, Addis Z, *et al.* Assessment of knowledge, attitude and practice towards post exposure prophylaxis for HIV among health care workers in Gondar, North West Ethiopia. *BMC Public Health* 2013; 13: 508.
- 32 Mponela MJ, Oleribe OO, Abade A, Kwesigabo G. Post exposure prophylaxis following occupational exposure to HIV: a survey of health care workers in Mbeya, Tanzania, 2009–2010. *Pan Afr Med J* 2015; 21: 32.
- 33 Owolabi RS, Alabi P, Ajayi S, Daniel O, Ogundiran A, Akande TM, *et al.* Knowledge and practice of post-exposure prophylaxis (PEP) against HIV infection among health care providers in a tertiary hospital in Nigeria. *J Int Assoc Physicians AIDS Care (Chic)* 2012; 11: 179–83.
- 34 Ruud KW, Srinivas SC, Toverud E. Knowledge of HIV and its treatment among health care providers in South Africa. *Int J Clin Pharmacol* 2014; 36: 352–9.
- 35 Ajibola S, Akinbami A, Elikwu C, Odesanya M, Uche E. Knowledge, attitude and practices of HIV post exposure prophylaxis amongst health workers in Lagos University Teaching Hospital. *Pan Afr Med J* 2014; 19: 172.
- 36 Ogbonna K, Govender I, Tumbo J. Knowledge and practice of the prevention of mother-to-child transmission of HIV guidelines amongst doctors and nurses at Odi Hospital, Tshwane District. *S Afr Fam Pract* 2016; 58: 167–71.
- 37 Musa J, Adamu IS, Muhammad Z, Egbodo C, Mohammed C. Knowledge of HIV prevention and willingness to collaborate in vaginal microbicides trials – survey of Nigerian gynecologists. *Niger J Med* 2012; 21: 185–9.
- 38 Aminde LN, Takah NF, Dzudie A, Bonko NM, Awungafac G, Teno D, *et al.* Occupational post-exposure prophylaxis (PEP) against human immunodeficiency virus (HIV) infection in a health

- district in Cameroon: assessment of the knowledge and practices of nurses. *PLoS One* 2015; 10: e0124416.
- 39 Abiola AO, Omoyeni OE, Akodu BA. Knowledge, attitude and practice of hepatitis B vaccination among health workers at the Lagos State accident and emergency centre, Toll-Gate, Alausa, Lagos State. *West Afr J Med* 2013; 32: 257–62.
 - 40 Abiola AO, Agunbiade AB, Badmos KB, Lesi AO, Lawal AO, Alli QO. Prevalence of HBsAg, knowledge, and vaccination practice against viral hepatitis B infection among doctors and nurses in a secondary health care facility in Lagos state, South-western Nigeria. *Pan Afr Med J* 2016; 23: 160.
 - 41 Abeje G, Azage M. Hepatitis B vaccine knowledge and vaccination status among health care workers of Bahir Dar City Administration, Northwest Ethiopia: a cross sectional study. *BMC Infect Dis* 2015; 15: 30.
 - 42 Adekanle O, Ndububa DA, Olowookere SA, Ijarotimi O, Ijadunola KT. Knowledge of hepatitis B virus infection, immunization with hepatitis B vaccine, risk perception, and challenges to control hepatitis among hospital workers in a Nigerian tertiary hospital. *Hepat Res Treat* 2015; 2015: 439867.
 - 43 Noubiap JJ, Nansseu JR, Kengne KK, Wonkam A, Wiysonge CS. Low hepatitis B vaccine uptake among surgical residents in Cameroon. *Int Arch Med* 2014; 7: 11.
 - 44 Audu BM, Bukar M, Ibrahim AI, Swende TZ. Awareness and perception of human papilloma virus vaccine among healthcare professionals in Nigeria. *J Obstet Gynaecol* 2014; 34: 714–7.
 - 45 Hoque ME. Factors influencing the recommendation of the Human Papillomavirus vaccine by South African doctors working in a tertiary hospital. *Afr Health Sci* 2016; 16: 567–75.
 - 46 Wamai RG, Ayissi CA, Oduwo GO, Perlman S, Welty E, Welty T, *et al.* Awareness, knowledge and beliefs about HPV, cervical cancer and HPV vaccines among nurses in Cameroon: an exploratory study. *Int J Nurs Stud* 2013; 50: 1399–406.
 - 47 Kamuhabwa A, Chavda R. Health-care providers' preparedness for H1N1/09 influenza prevention and treatment in Dar es Salaam, Tanzania. *J Infect Dev Ctries* 2012; 6: 262–70.
 - 48 Fatiregun AA, Adeyemo AA, Olowookere SA. Willingness to receive pandemic influenza A (H1N1) vaccine among doctors and nurses in public health facilities in Ibadan, Nigeria. *Vaccine* 2012; 30: 2315–9.
 - 49 Masika CW, Atieli H, Were T. Knowledge, perceptions, and practice of nurses on surveillance of adverse events following childhood immunization in Nairobi, Kenya. *Biomed Res Int* 2016; 2016: 3745298.
 - 50 Adams LV, Olotu R, Talbot EA, Cronin BJ, Christopher R, Mkomwa Z. Ending neglect: providing effective childhood tuberculosis training for health care workers in Tanzania. *Public Health Action* 2014; 4: 233–7.
 - 51 Chukwu JN, Ukwaja KN, Ekeke N, Nwafor CC, Meka AO, Madichie NO, *et al.* Assessment of current practices in management of childhood TB among frontline clinicians in Southern Nigeria. *Int Health* 2016; 8: 269–76.
 - 52 Ukwaja K, Alobu I, Onu E. Frontline healthcare workers' knowledge of tuberculosis in rural south-east Nigeria. *Afr J Respir Med* 2013; 9: 7–10.
 - 53 Rutta E, Tarimo A, Delmotte E, James I, Mwakisu S, Kasembe D, *et al.* Understanding private retail drug outlet dispenser knowledge and practices in tuberculosis care in Tanzania. *Int J Tuberc Lung Dis* 2014; 18: 1108–13.
 - 54 Abera B, Kibret M, Mulu W. Knowledge and beliefs on antimicrobial resistance among physicians and nurses in hospitals in Amhara Region, Ethiopia. *BMC Pharmacol Toxicol* 2014; 15: 26.
 - 55 Ajibade A, Olaitan PB. Knowledge, attitude and practice of perioperative antibiotic prophylaxis among nurse-anaesthetists in Nigeria. *Niger J Med* 2014; 23: 142–8.
 - 56 Chukwu OA. Assessing the awareness and knowledge on the use of probiotics by healthcare professionals in Nigeria. *J Young Pharm* 2016; 8: 53.
 - 57 Fathi I, Sameh O, Abu-Ollo M, Naguib A, Alaa-Eldin R, Ghoneim D, *et al.* Knowledge, attitudes, and beliefs regarding antimicrobial therapy and resistance among physicians in Alexandria University Teaching Hospitals and the associated prescription habits. *Microb Drug Resist* 2017; 23: 71–8.
 - 58 Mbonye AK, Buregyeya E, Rutebemberwa E, Clarke SE, Lal S, Hansen KS, *et al.* Prescription for antibiotics at drug shops and strategies to improve quality of care and patient safety: a cross-sectional survey in the private sector in Uganda. *BMJ Open* 2016; 6: e010632.
 - 59 Mwanakasale V, Songolo P, Daka V. Challenges in the control of Human African Trypanosomiasis in the Mpika district of Zambia. *BMC Res Notes* 2013; 6: 180.
 - 60 Ogbo PU, Aina BA, Aderemi-Williams RI. Management of acute diarrhea in children by community pharmacists in Lagos, Nigeria. *Pharm Pract (Granada)* 2014; 12: 376.
 - 61 Omuemu VO, Ofuani IJ, Kubeyinje IC. Knowledge and use of zinc supplementation in the management of childhood diarrhoea among health care workers in public primary health facilities in Benin-City, Nigeria. *Glob J Health Sci* 2012; 4: 68–76.
 - 62 Peltola L, Goddia C, Namboya F, Brunkhorst FM, Pollach G. Sepsis – knowledge of non-physician personnel in Africa: a cross-sectional study in Malawian district hospitals. *Med Klin Intensivmed Notfmed* 2015; 110: 49–54.
 - 63 Thriemer K, Katuala Y, Batoko B, Alworonga JP, Devlieger H, Van Geet C, *et al.* Antibiotic prescribing in DR Congo: a knowledge, attitude and practice survey among medical doctors and students. *PLoS One* 2013; 8: e55495.
 - 64 Fadare JO, Obimakinde AM, Afolayan JM, Popoola SO, Aduloju T, Adegun PT. Healthcare workers knowledge and attitude toward palliative care in an emerging tertiary centre in South-west Nigeria. *Indian J Palliat Care* 2014; 20: 1–5.
 - 65 James BO, Omoaregba JO, Okonoda KM, Otefe EU, Patel MX. The knowledge and attitudes of psychiatrists towards antipsychotic long-acting injections in Nigeria. *Ther Adv Psychopharmacol* 2012; 2: 169–77.
 - 66 Murila F, Obimbo MM, Musoke R. Assessment of knowledge on neonatal resuscitation amongst health care providers in Kenya. *Pan Afr Med J* 2012; 11: 78.
 - 67 Obumneme-Anyim I, Oguonu T, Ayuk A, Iloh K, Ndu I. Knowledge of asthma among doctors practicing in three south eastern states of Nigeria. *Ann Med Health Sci Res* 2014; S253–8.
 - 68 Ogboli-Nwasor E, Makama J, Yusufu L. Evaluation of knowledge of cancer pain management among medical practitioners in a low-resource setting. *J Pain Res* 2013; 6: 71–7.
 - 69 Ozoh OB, Awokola BI, Buist SA. A survey of the knowledge of general practitioners, family physicians and pulmonologists in Nigeria regarding the diagnosis and treatment of chronic obstructive pulmonary disease. *West Afr J Med* 2014; 33: 100–6.

- 70** Sakafu LL, Mselle T, Mwaiselage J, Msengwa A, Maunda K, Eddin BS. Clinician's awareness and knowledge on the management of differentiated thyroid cancer and the use of radioactive iodine in Tanzania. *Tanzan J Health Res* 2016; 18: 1–8.
- 71** Amin ME. Pharmacists' knowledge and interest in developing counseling skills relating to oral contraceptives. *Int J Clin Pharmacol* 2016; 38: 395–403.
- 72** Bains S, Kitutu FE, Rahhal A, Abu Samaha R, Wilby KJ, Rowe H. Comparison of pharmacist knowledge, perceptions and training opportunities regarding maternal-fetal medicine in Canada, Qatar and Uganda. *Can Pharm J (Ott)* 2014; 147: 345–51.
- 73** Morhason-Bello IO, Adedokun BO, Mumuni TO, Bello FA, Abdus-Salam RA, Lawal OO, *et al.* Knowledge and use of emergency contraception by medical doctors on internship in a tertiary healthcare facility in Nigeria. *Niger J Clin Pract* 2014; 17: 431–5.
- 74** Mohammed SI, Ahonsi B, Oginni AB, Tukur J, Adoyi G. Obstetric knowledge of nurse-educators in Nigeria: levels, regional differentials and their implications for maternal health delivery. *Health Educ J* 2015; 75: 198–207.
- 75** Auta A, Omale S, Folorunsho TJ, David S, Banwat SB. Medicine vendors: self-medication practices and medicine knowledge. *N Am J Med Sci* 2012; 4: 24–8.
- 76** Onigbinde AT, Olaogun MO, Irohgue K. An evaluation of the knowledge level of Nigerian physiotherapists on topical pharmacotherapy. *Hong Kong Physiother J* 2012; 30: 36–42.
- 77** Ajemigbitse AA, Omole MK, Ezike NC, Erhun WO. Assessment of the knowledge and attitudes of intern doctors to medication prescribing errors in a Nigeria tertiary hospital. *J Basic Clin Pharm* 2013; 5: 7–14.
- 78** Ogunleye OO, Oreagba IA, Falade C, Isah A, Enwere O, Olayemi S, *et al.* Medication errors among health professionals in Nigeria: a national survey. *Int J Risk Saf Med* 2016; 28: 77–91.
- 79** Vries TP, Daniels JM, Mulder CW, Groot OA, Wewerinke L, Barnes KI, *et al.* Should medical students learn to develop a personal formulary? *Eur J Clin Pharmacol* 2008; 64: 641–6.
- 80** Brinkman DJ, van Rossem AP, Tichelaar J, Richir MC, van Agtmael MA. Does medical students knowing more about drugs lead to better treatment choices? *J Clin Pharmacol* 2017; 57: 1071–2.
- 81** Brinkman DJ, Tichelaar J, Mookink LB, Christiaens T, Likic R, Maciulaitis R, *et al.* Key learning outcomes for clinical pharmacology and therapeutics education in Europe: a modified Delphi study. *Clin Pharmacol Ther* 2017; 104: 317–25.
- 82** De Vries T, Henning R, Hogerzeil H, Fresle D. Guide to good prescribing: WHO action programme on essential drugs. Geneva: World Health Organization, 1994.
- 83** World Health Organization. Global health observatory (GHO) data. Available at <http://www.who.int/gho/tb/en> 2015 (last accessed 5 October 2018).
- 84** Malewezi B, Omer SB, Mwagomba B, Araru T. Protecting health workers from nosocomial hepatitis B infections: a review of strategies and challenges for implementation of hepatitis B vaccination among health workers in sub-Saharan Africa. *J Epidemiol Glob Health* 2016; 3: 229–41.
- 85** De Vuyst H, Alemany L, Lacey C, Chibwasha CJ, Sahasrabudde V, Banura C, *et al.* The burden of human papillomavirus infections and related diseases in sub-Saharan Africa. *Vaccine* 2013; 31: F32–46.
- 86** Perlman S, Wamai RG, Bain PA, Welty T, Welty E, Ogembo JG. Knowledge and awareness of HPV vaccine and acceptability to vaccinate in sub-Saharan Africa: a systematic review. *PLoS One* 2014; 9: e90912.
- 87** Mocumbi AO. Lack of focus on cardiovascular disease in sub-Saharan Africa. *Cardiovasc Diagn Ther* 2012; 2: 74–7.
- 88** Cappuccio FP, Miller MA. Cardiovascular disease and hypertension in sub-Saharan Africa: burden, risk and interventions. *Intern Emerg Med* 2016; 11: 299–305.
- 89** Cleland J, Bernstein S, Ezech A, Faundes A, Glasier A, Innis J. Family planning: the unfinished agenda. *Lancet* 2006; 368: 1810–27.
- 90** Sabo L, Schrage S. Emergency contraception in Wisconsin: a review. *WMJ* 2006; 105: 40.
- 91** Ibrahim ZM, Ahmed MR, Shaaban MM. Knowledge, attitude and practice of emergency contraception among health care providers in Ismailia, Egypt. *Middle East Fertility Soc J* 2013; 18: 246–52.
- 92** Barredo L, Agyepong I, Liu G, Reddy S. Goal 3 Ensure healthy lives and promote well-being for all at all ages. *UN Chronicle* 2014; 4: 9–10.
- 93** Berhe DF, Juhlin K, Star K, Beyene KG, Dheda M, Haaijer-Ruskamp FM, *et al.* Adverse drug reaction reports for cardiometabolic drugs from sub-Saharan Africa: a study in VigiBase. *Trop Med Int Health* 2015; 20: 797–806.
- 94** Ampadu HH, Hoekman J, de Bruin ML, Pal SN, Olsson S, Sartori D, *et al.* Adverse drug reaction reporting in Africa and a comparison of individual case safety report characteristics between Africa and the rest of the world: analyses of spontaneous reports in VigiBase®. *Drug Saf* 2016; 39: 335–45.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

<http://onlinelibrary.wiley.com/doi/10.1111/bcp.13746/supinfo>

Table S1 Search strategy and terms

Table S2 Classifying knowledge questions into benefit, harm, or both/general oriented

Table S3 Quality score tool