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Use of technology to prevent, detect, manage and control hypertension in sub-Saharan Africa: a systematic review

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ABSTRACT

Objective To identify and assess the use of technologies, including mobile health technology, internet of things (IoT) devices and artificial intelligence (AI) in hypertension healthcare in sub-Saharan Africa (SSA).

Design Systematic review.

Data sources Medline, Embase, Scopus and Web of Science.

Eligibility criteria Studies addressing outcomes related to the use of technologies for hypertension healthcare (all points in the healthcare cascade) in SSA.

Methods Databases were searched from inception to 2 August 2021. Screening, data extraction and risk of bias assessment were done in duplicate. Data were extracted on study design, setting, technology(s) employed and outcomes. Blood pressure (BP) reduction due to intervention was extracted from a subset of randomised controlled trials. Methodological quality was assessed using the Mixed Methods Appraisal Tool.

Results 1717 hits were retrieved, 1206 deduplicated studies were screened and 67 full texts were assessed for eligibility. 22 studies were included, all reported on clinical investigations. Two studies were observational, and 20 evaluated technology-based interventions. Outcomes included BP reduction/control, treatment adherence, retention in care, awareness/knowledge of hypertension and completeness of medical records. All studies used mobile technology, three linked with IoT devices. Short Message Service (SMS) was the most popular method of targeting patients (n=6). Moderate BP reduction was achieved in three randomised controlled trials. Patients and healthcare providers reported positive perceptions towards the technologies. No studies using AI were identified.

Conclusions There are a range of successful applications of key enabling technologies in SSA, including BP reduction, increased health knowledge and treatment adherence following targeted mobile technology interventions. There is evidence to support use of mobile technology for hypertension management in SSA. However, current application of technologies is highly heterogeneous and key barriers exist, limiting efficacy and uptake in SSA. More research is needed, addressing objective measures such as BP reduction in robust randomised studies.

PROSPERO registration number CRD42020223043.

Strengths and limitations of this study

- ► This is the first systematic review for use of technologies for hypertension healthcare in sub-Saharan Africa, providing a comprehensive review of the state of the art.
- ► Heterogeneity of included studies was too high for meta-analysis; therefore, results are reported narratively.
- ► Grey literature was not searched.
- ► The search was limited to studies published in English language.

INTRODUCTION

Cardiovascular disease (CVD) remains the most common cause of death due to non-communicable disease (NCD) worldwide, with 78% of deaths occurring in low and middle-income countries (LMICs).[1 2] Hypertension (high blood pressure (BP)) is considered by the WHO to be the leading risk factor for developing CVD[1] and by the Pan-African Society of Cardiology as the highest priority area for reducing heart disease and stroke in Africa.[3] In sub-Saharan Africa (SSA), the prevalence of hypertension is high, especially in younger subjects, estimated at 46% of the adult population, in contrast with 35% in high-income countries.[3] Reasons proposed for this include urbanisation, increase in life expectancy and lifestyle factors such as poor diet, physical inactivity and smoking.[4] A meta-analysis performed by Atakite *et al* reports that of those with hypertension in SSA, only 27% were aware of their condition, 18% were receiving treatment and 7% had controlled BP.[5]

Low numbers of trained healthcare providers combined with a lack of evidence-based guidance and a high cost in accessing healthcare services for patients in SSA are major challenges.[6] Cost-effective technologies will likely play a critical role to overcome such barriers, through decision support tools[7 8]; dissemination of health information including education and treatment reminders[9 10] and collection and storage of medical data.[11 12] Indeed, the value of information and communication technologies (ICT) to health services has been recognised

by the WHO for over 10 years.[13] eHealth is defined by the WHO as 'the cost-effective and secure use of ICT in support of health and health-related fields, including healthcare services, health surveillance, health literacy, and health education, knowledge and research'.[14] In this way, eHealth can be delivered through several key enabling technologies (KETs): mobile phone technology, artificial intelligence (AI) and the internet of things (IoT). Mobile phone use is high in SSA, 45% of the population subscribe to mobile services and this use is projected to increase.[15] Research interests into use of mobile phones for healthcare purposes in SSA primarily concern either infectious disease or maternal and child health,[16–18] but attention to NCD is growing.[19 20] AI has many possible definitions, in essence describing a motivation to replicate and automate human cognitive functions, having a myriad of healthcare applications,[21] which have been exploited in high-income countries. Although research in LMICs is relatively limited,[22] drivers such as high disease burden, few qualified healthcare workers and increasing phone and internet connection may drive a rapid advance in AI for healthcare in LMICs.[23] Wahl *et al* describe uses of AI in resource-poor settings, including expert systems assisting or compensating for a lack of personnel, health monitoring using natural language processing and signal processing for diagnostics.[22]

Successful application of the aforementioned technologies for tackling hypertension relies on a strong evidence base in design and implementation. In this way, this work seeks to systematically review the literature regarding the application of mobile phone technologies, AI and the IoT as KETs for healthcare provision for hypertension in SSA. The primary objective is to determine how and which KETs have been used, secondary concerns include study design, setting, quality and findings of outcomes relating to hypertension.

METHODS

Search strategy and selection criteria

The systematic review of KETs for healthcare provision for hypertension in SSA followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines.[24] We searched Embase, MEDLINE, Web of Science and Scopus electronic databases for studies published in English language only. The search was run from database inception to 23 November 2020 and updated on 2 August 2021.

Search terms covered hypertension (eg, "hypertension", "high blood pressure"), Artificial Intelligence (eg, "AI", "machine learning"), mobile phones (eg, "mobile phon*", "mobile"), internet of things (eg, "internet of things", "iot"), point of healthcare cascade (eg, "prevention", "screening") and countries of SSA (full strings in online supplemental S1).

Studies seeking to assess the application of KETs in SSA, for any point in the healthcare cascade for hypertension, were considered for inclusion. There were no restrictions set on study methodology in terms of participant recruitment, age or comorbidity. Studies were required to be conducted using populations from SSA countries, or from a pool of countries including at least one SSA country. For inclusion, studies must have provided an evaluation of the use of KETs for any aspect of healthcare for hypertension or used AI models for predicting or detecting significant events. Studies that focused only on prevalence or risk factors, that is, used statistical methods but did not develop AI-based predictive models, which were considered out of the scope of this review. The study protocol was registered with PROSPERO: International Prospective Register of Systematic Reviews and is found at: http://www.crd.york.ac.uk/prospero

Data analysis

Screening was completed independently by two authors (KS and BO). A reference search was conducted on any relevant review articles retrieved. For included studies, data were abstracted to a shared Microsoft Excel document, covering study design, study setting and population (age, demographics, comorbidity), details of KET used, study outcomes, controls/comparators (where applicable), target user (where applicable) and indications of acceptability to user (if provided). For randomised controlled trials, we sought to extract mean baseline and end point BP measurements (in mm Hg), with SD, for the intervention and control groups. If SD was not reported, it was calculated using the CI, as described in the Cochrane Handbook for Systematic Reviews of Interventions.[25] In the event that participants were lost to follow-up, the final number of participants who completed the study protocol was extracted. As heterogeneity among studies was high (no two studies evaluated the same intervention), we used a random-effects model to establish the effect of KET-based interventions on systolic BP reduction. We did the analysis in Open Meta-Analyst,[26] an open-source, cross-platform software for meta-analysis.

Methodological quality was assessed independently by two review authors (KS and BO) using the 2018 Mixed Methods Appraisal Tool[27] for assessing the quality of either quantitative, qualitative or mixed methods studies. Criteria were graded as 'unmet', 'met' or 'can't tell'. For mixed methods studies, provided most criteria were met (three or more out of five) for each component, the components were considered to have adhered to their respective quality criteria (criterion 5.5).

Role of funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation or writing of the report.

Patient and public involvement

Patients and the public were not involved in this research.

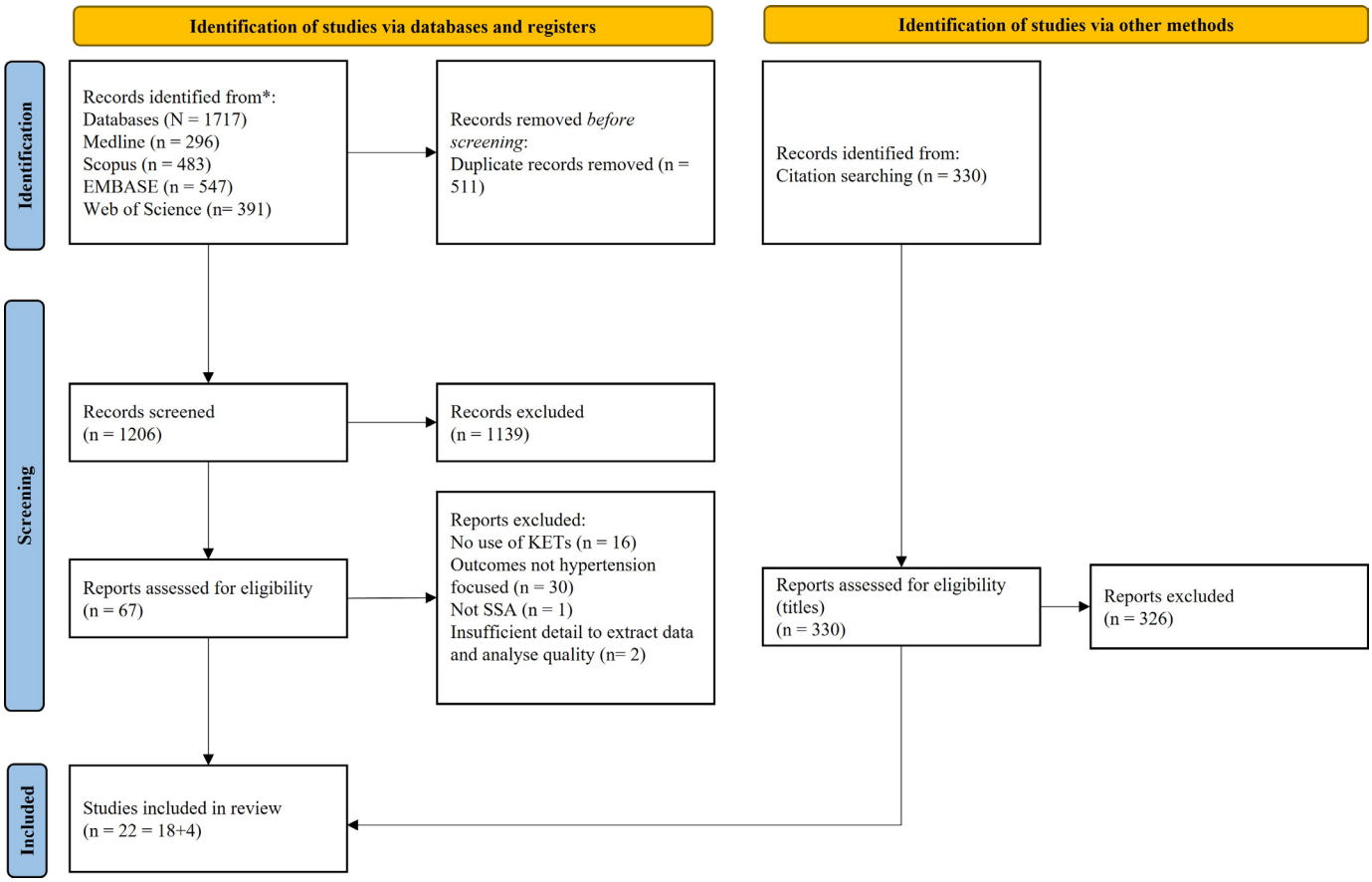

Figure 1 Study selection. KETs, key enabling technologies.

RESULTS

Searching MEDLINE, Scopus, Embase and Web of Science yielded 1717 titles. After duplicate removal, 1206 titles/abstracts were screened, with 1139 excluded. Of the remaining 67 full texts, 18 studies were found to meet the inclusion criteria (figure 1). A further four studies were identified through a linear search of the bibliographies of relevant reviews identified during the initial screening. Table 1 contains a summary of the characteristics of the included studies.

Study design, participants, location and aims were highly heterogenous (table 1). The distribution of studies by country is shown in figure 2. All included articles were reported on clinical investigations.[28–49] Two were observational studies[30 46] and 20 concerned evaluation of KET-based interventions.[28 29 31–45 47–49] Both observational studies used mixed methods to explore either current use of technology for hypertension management or hypertension prevalence, understanding and awareness. Several of the interventional studies fell within the same larger study, granting 14 unique experimental studies. Separate articles within these studies reported on different aspects such as impact of intervention, feasibility and perceptions. Eight studies were randomised controlled trials.[28 31 33 34 39–43 45 47] Quantitative primary outcomes were BP reduction and BP control. Other outcomes included treatment adherence, retention in care, awareness/knowledge of hypertension and completeness of medical records. Length of exposure was highly heterogeneous, ranging from 17 weeks to 2 years.

Quality was highest for qualitative and quantitative descriptive methods and relatively low for randomised or non-randomised studies (online supplemental table S2). Eleven of 13 studies comprising qualitative components satisfied all criteria,[29 31–35 38 43 46 47 49] whereas insufficient reporting of results in two studies meant it was not possible to determine if findings had been adequately derived or substantiated from the data.[37 45] In terms of randomised controlled trials, four met all quality criteria,[33 39 41 42] three did not use appropriate randomisation methods[28 34 40] and three did not report complete outcome data.[34 40 45] Notably, Barsky *et al* did not report sufficient information to judge four out of five criteria[45] and Vedanthan *et al* failed to meet any criteria.[40] Lack of complete outcome data was also an issue in four out of six non-randomised studies.[35 38 44 48] Three of four quantitative descriptive studies met all quality criteria[30 37 42] with one study subject to voluntary selection bias, which was discussed by the authors.[49]

All studies employed adult populations, with varying age requirements (table 1). Five studies used subjects or data collected in a predominantly urban setting,[31 34–36 38] six in rural locations,[28 32 37 40 45 46] two in both[30 41] and one study did not provide specific location or population demographic details.[29] The majority of the experimental research recruited subjects with elevated

Table 1 Characteristics of included studies

	Study location	Population (age (SD))	Duration	Sample size
Kingue *et al*[28]	Yaounde, capital city of Cameroon and rural health districts (within 50–250 km), Telemedicine centre based at Yaounde General Hospital	Age >15, with hypertension not at target level (SBP (or DBP) ≥140 (90) mm Hg or ≥130 (80) mm Hg (for those with diabetes or nephropathy). (Control: 57.6 (12.1), Intervention: 59.9 (10.4))	24 weeks	30 healthcare centres (10 intervention, 20 control). Total: 268 participants (A: Intervention n=165, B: Control n=103)
Ola-Olorun *et al*[29]	Nigeria, (Outpatient clinic Obafemi Awolowo University Teaching Hospital)	Long-term hypertension patients		Total: 187 participants (exposed to SMS, n=111)
Joubert *et al*[30]	Botswana (suburb)	Adults (>18) (39 (16))	NA	Total: 92 participants
Leon *et al*[31] (STAR)	South Africa, Cape Town, Primary care facility of a large public sector clinic,	A diverse sample of population of Bobrow *et al*2016[33]	NA	22 trial participants took part in two focus groups, 15 individual in-depth interviews
Vedanthan *et al*[32]	Kenya (rural)	Nurses, clinical officer	NA	Total: 13 participants (12 nurses, 1 clinical officer)
Bobrow *et al*[33] (STAR)	As above, Leon *et al* 2015[31]	Adults (≥21) with access and ability to use a mobile phone for SMS; diagnosed with hypertension; prescribed blood pressure lowering medication; and with SBP <220 mm Hg and <120 mm Hg at enrolment. (usual care: 54.7 (11.6), information only: 53.9 (11.2), interactive: 54.2 (11.6))	12 months	Total: 1372 participants (A: information-only SMS text-messages n=457, B: interactive SMS text-messages n=458, C: usual care n=457)
Hacking *et al*[34]	South Africa: Gugulethu township of Cape Town (densely populated, poor urban settlement)	Patients of hypertension clinic. (52.83 (11.62))	17 weeks	Total: 223 participants, (Intervention n=109, Control n=114)
Haricharan *et al*[35]	South Africa, Cape Town	Convenience sample	28 weeks	Total: 41 participants
Kleczka *et al*[36]	Kenya, Nairobi Health Centre	Patient charts classified with hypertension	6 months	Total: 70 patients' charts (291 clinical encounters for HTN across 49 patients (149 pre-intervention and 142 post-intervention))
Mannik *et al*[37] (AFYACHAT)	Kenya (rural), Two rural primary health clinics: Isiolo District, Marakwet District	Adults (>40 years) (50 (43–60))	22 months	Total: 2865 participants
Nelissen *et al*[38]	Nigeria (Lagos)	Hypertensive adults (54.9 (11.9))	6–8 months	Total: 336 participants
Sarfo *et al*[39] (PINGS)	Ghana, Outpatient Neurology clinic (Komfo Anokye Teaching Hospital KATH)	Adults >18, recently confirmed stroke (<1 month) by CT, with uncontrolled hypertension (SBP ≥140 mm Hg) (55 (13))	3 months/9 months	Total: 60 participants (Intervention n=30, Control n=30)
Vedanthan *et al*[40]	Western Kenya: rural healthcare facilities in Kosirai and Turbo divisions	Adults, with elevated BP (SBP ≥140 or DBP≥90). (60.8 (14.2))	15 months	Total: 1460 participants (A: usual care n=491, B: paper-based n=500, C: smartphone n=469)

Continued

Table 1 Continued

	Study location	Population (age (SD))	Duration	Sample size
Owolabi *et al*[41] (THRIVES)	Nigeria, A range of facilities chosen to represent the diverse South-western population and hospital types	Adults ≥18 with access to a mobile phone, recently discharged from hospital following a stroke. (57.2 (SD 11.7))	12 months	Total: 400 participants (Intervention n=200, Control n=200)
Sarfo *et al*[42] (PINGS)	As above, Sarfo *et al*[39]	Adults >18, recently confirmed stroke (<1 month) by CT, with uncontrolled hypertension (SBP ≥140 mm Hg)	9 months	Total: 60 participants (Intervention n=30, Control n=30)
Nichols *et al*[43] (PINGS)	As above, Sarfo *et al*[39]			24 patients, 8 caregivers, 7 research team
Cremers *et al*[44]	As above, Nelissen *et al*[38]	As above, Nelissen *et al*[38]	NA	In-depth interviews total: 30 patients (9 community pharmacists, 6 cardiologists) Structured interviews total: 328 patients
Barsky *et al*[45]	Tanzania (rural)	Adults (≥18) with uncontrolled hypertension. Either own mobile or be willing to take one	10 months	Total: 130 participants
Oduor *et al*[46]	Kenya (rural)	Adults with HIV and hypertension	NA	Total: 36 participants (27 medical practitioners, 9 patients)
Adler *et al*[47]	Ghana, Lower Manya-Krobo District (84% urban population)	Patients, nurses, clinicians, physician's assistant, pharmacist		Total: 55 participants (15 patients, 7 nurses, 1 clinician, 1 physician assistant, 1 pharmacist)
Vedanthan *et al*[48]	As above, Vedanthan *et al*[32]	Adults (>35) Confirmed diagnosis of hypertension (61 (13.2))	3 months	Total: 1051 participants (180 under care of nurse, 871 under care of clinical officer)
Aw *et al*[49] (AFYACHAT)	As above, Mannik *et al*[37]	Adults (>40 years) (50 (43–59))	5–8 months	Total: 1650 participants

DBP, diastolic blood pressure; SBP, sytolic blood pressure.

BP[40] or confirmed hypertension/prescribed antihypertensives,[28 29 31 32 34 36 38 39 47] with the aim of improving hypertension control, treatment adherence or health knowledge, otherwise, the aim of the study was to test a health tool for identifying hypertension or general CVD risk factors within a certain population.[37] In terms of comorbidity or other conditions, one study focused on patients having recently suffered stroke (with or without hypertension),[41] one focused on diabetic patients[28] one concerned HIV-positive hypertensive subjects[46] and one employed a convenience sample of a Deaf community.[35] In three cases, participants were required to have access to a mobile phone for inclusion in the study.[31 41 47]

Table 2 describes the different applications of technologies and their frequency of use. All studies used mobile phone technology, including Short Message Service (SMS), phone calls and mobile applications (apps), either alone or in combination. Odour *et al* evaluated the general use and perceptions of medical practitioners and patients towards technology, in particular, mobile technology, in dealing with hypertension and HIV. IoT devices employed were automatic BP monitors and their use was also facilitated by mobile phones.

SMS messages were mostly targeted to patients, for health knowledge improvement,[34 35] motivation/improved treatment adherence[29 39 41] or both.[31] Content included reminders for taking medication or attending clinics/appointments, educational information covering general healthy lifestyle suggestions (eg, eating habits, exercise) or hypertension information (eg, symptoms, further health consequences, medication information). SMS was also used in combination with other elements in broader interventions to facilitate decision support for healthcare providers (eg, through direct feedback of risk

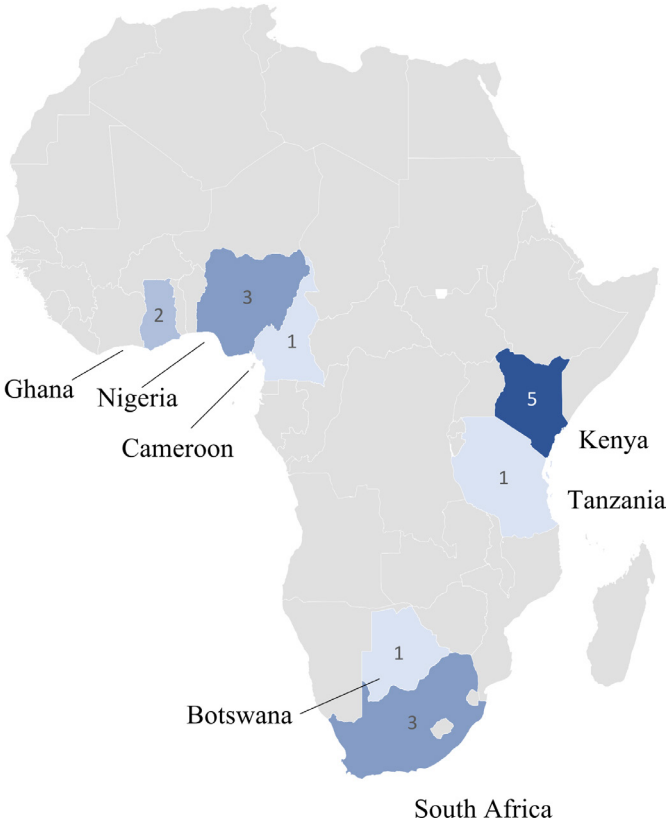

Figure 2 Distribution of studies across sub-Saharan Africa. Countries are coloured based on the number of studies conducted (darker indicates more studies) and annotated with frequency (where a large study had several associated publications, the location is reported once).

stratification)[28 37] or to provide an interactive connection between patients and pharmacists[29] or specialist telehealth connection (eg, direct feedback from cardiologist to pharmacists).[28 44]

Apps were targeted to healthcare providers, most frequently community health workers. Three studies used apps designed to mediate BP reading collection and dissemination of results for risk assessment and follow-up.[42 45 49] The DREAM-GLOBAL app received BP readings from an automatic monitor via Bluetooth (UA-767 Plus BT), relayed the readings to a remote central server, which then calculated the average reading and transmitted the patients' results to their primary healthcare provider by fax, and to the patient themselves by SMS.[45] For high BP readings, the patient was notified to seek advice with their healthcare provider. Similarly, in the Phone-based Intervention under Nurse Guidance after Stroke (PINGS) study, the same Bluetooth BP monitor was linked with an app for monitoring and reporting measurements as well as medication intake. Participants monitored their own BP, following training from a study nurse. Levels of medication intake were monitored, and tailored motivational SMS was delivered to participants based on these results.[39] The AFYACHAT mobile app functioned in a similar way, BP readings were entered by the CHW, along with other patient data, the app then provided an algorithmic risk stratification (based on WHO's prevention of CVD: Pocket Guidelines for Assessment and Management of Cardiovascular Risk, 2007) via SMS.[37 49] The Decision-Support and Integrated Record-Keeping (DESIRE) tool, an app designed for nurses to use on tablets, also provided clinical decision support, here through the AMPATH hypertension management algorithm, which is based on WHO clinical algorithms.[32] The DESIRE tool included functions for data entry and validation, decision support, alerts and reminders, and viewing historical data on. Other authors discussed the feasibility of mobile technology-facilitated screening for hypertension. Joubert *et al* collected survey data using a tablet computer to collect and relay patient information to a central database.[30] Another focus of research was digitisation and storage of patient data from previous paper-based systems. Kleczkaa *et al* described use of rubber stamp templates containing checklists of clinical practice guidelines; smartphone cameras were used to take images of these templates, which were then manually synched to a cloud-based database, with plans for further automation.[36] A cloud-based health record system was also used as part of the ComHIP hypertension improvement project, which facilitated delivery of SMS and aimed to allow all levels of health providers access to patients' records.

Concerning outcomes relating either to reduction of BP or improved BP control, the majority of experimental studies reported that their interventions resulted in improvements.[28 33 38 40 42] However, analysis by Nelissen *et al*[38] found that the mobile health (mHealth) app element of their intervention was not associated with the observed BP improvements, based on duration of patient activity measured by the app.[38] Four studies detected no difference[41] or statistically insignificant changes[33 39 40] between control and intervention groups. Vedanthan *et al* observed significant reduction in both systolic and diastolic BP regardless of whether their tablet-based decision support tool was used by nurses or clinical officers but did not have a control group. Heterogeneity in both outcomes investigated and reported prevented quantitative comparison. Results from three randomised controlled trials which reported baseline and endpoint values for systolic BP are presented in figure 3. It should be emphasised that these trials differed greatly in their intervention plan, study design and location (see table 1), and, therefore, it was not appropriate to report an overall effect. Bobrow *et al* and Owolabi *et al* met all quality criteria, however, Vedanthan *et al*[48] failed to meet any, with authors describing difficulties in data collection and high levels of missing data. Some authors stated it had not been feasible to power studies to detect significant BP reduction, for example, the 3-month interim results of the PINGS trial did not find significant BP reduction due to the intervention until after 9 months, when the proportion of participants with controlled BP became significantly higher in the intervention arm (46.7% vs 40%).[39 42] In some cases, authors noted that effects varied between subjects

Table 2 Summary of KETs used in study pool

	SMS (11)	Smartphone/ tablet with app (8)	Mobile/smartphone/ tablet without app (6)	IoT (3)	Web-based data storage and tools (7)	Description of technology	User
StAR: SMS-text Adherence Support[31 33] *†	+		+			SMS sent to patients to elicit behavioural changes, focusing on providing educational and motivational messages about hypertension and its treatment	Patient
LARK: Linkage And Retention to hypertension care in rural Kenya, Vedanthan *et al*[40] *†		+			+	Smartphone linked to electronic health record: Provides CHW with automatically updated list of patients requiring follow-up and real-time decision support using clinically approved care algorithms	CHW
Kingue *et al*[28] *†	+		+			Mobile phone communication: Links with telemedicine centre via SMS, voicemail and phone calls. Real-time feedback to aid decision making.	Healthcare provider
Owolabi *et al*[41] *†	+				+	SMS messages for appointment reminders and self-management support.	Patient and care provider
Hacking *et al*[34] *†	+					SMS messages containing information on hypertension and healthy lifestyle suggestions.	Patient
PINGS: Phone-based Intervention under Nurse Guidance after Stroke[39 42 43] *†	+	+		+	+	BP reading device, connects via blue tooth and smart phone given to patients, stores and reports BP measurements and medication intake. Also, motivational SMS based on adherence to medication.	Patient
ComHIP: Community-based Hypertension Management Project[47] *†	+		+	+	+	Telemedicine consultation by CVD nurse with physician in order to refer serious hypertension on, ICT messages for healthy lifestyles, treatment adherence support and treatment refill reminders, Cloud-based EMR system linked with SMS/voice messaging for treatment adherence, reminders and health messaging, digital sphygmomanometer	Patient and care provider
DESIRE: Decision-Support and Integrated Record-keeping[32 38 48] *		+				Tablet-based Decision Support and Integrated Record-keeping	Nurses/clinical officers
Pharmacy task shift[44] *		+				mHealth mobile application to facilitate communication between pharmacists and cardiologists	Pharmacists and remote cardiologists

Continued

Table 2 Continued

	SMS (11)	Smartphone/ tablet with app (8)	Mobile/smartphone/ tablet without app (6)	IoT (3)	Web-based data storage and tools (7)	Description of technology	User
AFYACHAT: health chat[37 49] *	+	+			+	mHealth mobile application for data collection including an algorithmic risk stratification based on WHO guidelines	CHWs
Ola-Olorun *et al*[29] *	+					SMS messaging to connect patient to pharmacist and also to deliver reminders for medication and clinic appointments to patients	Patient and pharmacist
Kleczka *et al*[36] *			+		+	Digital data extraction and management, including guidelines for specific diseases to be stamped, filled and digitised using mobile phones	Clinical staff
Haricharan *et al*[35] *	+					SMS containing information on hypertension (eg, symptoms, consequences) and tips for healthy living (eg, eating habits, exercise)	Patient (public, deaf)
Barsky *et al*[45] *†	+	+		+	+	Bluetooth-enabled blood pressure monitor, linked to a mobile phone with DREAM-GLOBAL app to collect readings. Central server assessed readings as normal or high. SMS directed to patient to prompt seeking healthcare	CHW, patient
Oduor *et al*[46]	+	+	+			Any reported by participants	Patients and care providers
Joubert *et al*[30]		+	+			Tablet computer used to collect survey data and transmit via tele-contact	Clinical staff

*Interventional studies.
†Randomised control trials.
BP, blood pressure; CHW, community health worker; CVD, cardiovascular disease; EMR, electronic medical records; ICT, information and communication technologies; KETs, key enabling technologies.

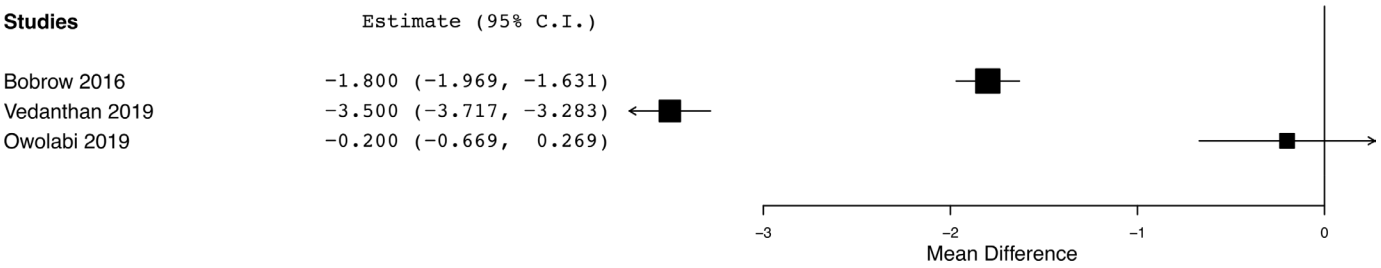

Figure 3 Change in mean systolic blood pressure (mm Hg) between control and intervention groups.

based on initial hypertension severity. An instance of this is Kingue *et al*, where greater overall improvements (BP improved or BP at target) in participants with stage 3 hypertension was observed.[28] Owolabi *et al* also observed a significant reduction in BP for a subset of subjects with baseline BP >140.90 mm Hg but not an overall significant reduction for all participants.[41]

In terms of health knowledge improvement, in one study, CVD nursers reported that their own hypertension awareness and knowledge increased as well as that of the community, due to the ComHIP project.[47] Hacking *et al* found no statistical change in overall health knowledge, however, medication adherence was significantly higher due to intervention and self-reported behaviour change improvements.[34] Haricharan *et al* reported significant improvements in overall knowledge of healthy living and hypertension following exposure to informative SMS messaging.[35] PINGS resulted in significant medication adherence improvements,[39] and a trial of telemedicine for hypertension in Camaroon (TELEMED-CAM) saw significantly higher medical visit adherence in their intervention group.[28] Ola-Olorun *et al* reported positive perceptions towards an SMS-based medicine information exchange between patients and pharmacists, patients requested information on adverse medication effects.[29] Clinical documentation improved for all NCDs investigated by Kleczka *et al*, with a 21% improvement in hypertension documentation scoring.[36]

When perceptions towards the proposed technology were gathered, interventions were well received by patients[29 31 34 47] and health professionals.[29 37 44 47] Reported concerns included access to/stability of internet connection,[47] power availability,[37 44 47] cost,[44 47] increased workload,[38] understanding of SMS wording,[32] unfamiliarity with mobile technology or technology not being 'user-friendly'[34 44] and duplication in digital patient records.[49] Focus groups and interviews conducted by Adler *et al* indicated that health providers and policymakers identified major challenges in the use of a cloud-based health records system, which would require heavy reliance on outside resources.[47]

DISCUSSION

Our systematic review of the literature found broad and diverse applications of KETs for tackling hypertension in SSA. The findings indicated that there is still relatively limited published research, particularly of controlled trials. All studies leveraged mobile phones for purposes of screening for hypertension, improving patient knowledge/treatment adherence or aiding non-physician healthcare workers in providing hypertension care. Other reviews targeted to SSA have focused on assessing either specific technological applications or different NCDs, and all noted a lack of published research.[18 20 50] Muiruri *et al*'s 2019 narrative literature review of telehealth interventions for hypertension in SSA[50] identified just eight studies, and in 2021, Osei *et al*[18] identified only 12 studies in a scoping review of mHealth for diagnosis or treatment of any disease in SSA. These authors also commented as we do on the paucity of studies of robust design, particularly those including control groups.[18 50]

Overall, our identified studies reported success in their outcomes, with overwhelmingly positive responses from participants towards the use of KETs. Consistent with our findings, other reviews comment on overall good acceptance of technologies by health workers[18 20] and SMS for health knowledge improvement and behaviour changes were identified as providing particularly promising positive results.[50] However, we found that very few studies were able to demonstrate statistically significant improvements over standard care, when evaluating objective measures such as BP reduction. This may indicate persistent difficulties in designing and implementing technology-based healthcare solutions in low-resource settings. Such difficulties were also evident from the quality analysis, for example, a frequent issue identified in the quality analysis for both randomised and non-randomised trials was a lack of complete outcome data, with authors describing difficulties with missing information and loss to follow-up as high as 50% in one study[35] and 58% in another,[48] an important consideration for future studies.

No publications using AI were identified in this study. Owoyemi *et al*[51] suggested that reasons for this may include limited available data, a lack of policy and legal framework, associated cost of uptake and inadequate infrastructure. Future research may explore predictive AI modelling either for screening and diagnostic tools and to identify and target the most promising areas for addressing patient lifestyle changes in SSA.

Many studies used KETs to facilitate task redistribution, which is a well-evidenced strategy to improving healthcare provision in areas with low numbers of qualified doctors/

specialists, for which the body of evidence relating to hypertension is growing.[52–57] Mobile technology provided decision support and record keeping tools aiming to empower non-physician workers in providing primary hypertension care. While perceptions and feedback from clinical staff and patients were overall positive, several key areas were consistently reported as major challenges for uptake of KETs. Fundamental issues in infrastructure are still a barrier to mobile technology for healthcare, evidenced by reported issues with internet, network and power coverage. In addition, several articles reported concerns around the ability of patients to use the technology and understand the information which was relayed, with calls for future research to investigate the feasibility and efficacy of audio visual rather than text communication.[34 42] Such findings have informed further development of the PINGS intervention, with upcoming phase III trials using a reductionist approach, removing a smartphone component and replacing with phone calls and audio and text messages.[58]

A notable finding was that few studies reported statistically significant benefits of KET-based interventions. Authors speculated that small sample sizes,[40] subject selection,[34 42] failed SMS delivery,[34] study design such that all patients received reminders,[33 45] free medication[33] or financial incentives[41] could have contributed to this, likely reflecting difficulty in retaining patients in care in SSA. It was also observed that interventions proved most effective among the highest risk groups, where it may be easiest to detect positive changes. Although not always found to be statistically significant, reductions in BP were observed, which, although modest, would, from a clinical perspective be anticipated to impact CVD development on a population level.[59] Our findings also indicated strategies using SMS to promote positive patient behaviour changes were highly successful.[34 39 47] It remains to be seen, however, whether self-reported behaviour changes translate into objective improvements in BP reduction.

Strengths and limitations of this study

A major limitation of this systematic review was the heterogeneity of the included studies, which did not allow for quantitative synthesis of outcomes/results. Since this study also failed to identify any reports of use of AI, it is possible that extending the search beyond the scientific literature may have found cases where AI was intrinsic as part of manufactured technology already being used for healthcare in SSA. A strength of this study is that it is the first systematic review concerning use of KETs for hypertension healthcare in SSA, and in this way provides a comprehensive overview of the current state of the art and indicates gaps to be addressed in future research.

CONCLUSION

Our study indicates that there is limited research on use of KETs for hypertension in SSA, particularly we did not identify any studies using AI. The study demonstrates that mHealth strategies provided positive impact on BP control, health knowledge and treatment adherence. Furthermore, stakeholder perceptions towards technology for hypertension prevention and management were positive. Therefore, further primary studies should be conducted, with an emphasis on objective measures such as BP reduction or BP control. It remains to be seen whether AI may also prove beneficial, such as through development of further diagnostic aids or boosting signals from cheap easily manufactured sensors.

Contributors KS, LP and FPPC designed the study. LP and FPPC coordinated and supervised the study. KS, BO, LP and FPPC designed the data collection and methodology. KS and BO screened records, extracted data and assessed quality. KS wrote the original draft. All authors critically revised and edited the manuscript. KS is the guarantor and accepts full responsibility for the work.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information.

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Test S1. Search terms

MEDLINE/Embase:
exp Cardiovascular Diseases/ or exp Hypertension/ or ("cardiovascular disease*" or CVD* or "hypertensi*" or "high blood pressure" or "blood pressure" or stroke or "heart disease").tw. and exp "Africa South of the Sahara"/ or (Sahara* or sub-Sahara* or "sub-Sahara* Africa" or SSA or Cameroon or "Central African Republic" or Chad or Congo or "democratic republic of the Congo" or "equatorial Guinea" or Gabon or "Sao Tome and Principe" or Burundi or Djibouti or Eritrea or Ethiopia or Kenya or Rwanda or Somalia or "south Sudan" or Sudan or Tanzania or Uganda or Angola or Botswana or Eswatini or Lesotho or Malawi or Mozambique or Namibia or Zambia or Zimbabwe or Benin or "Burkina Faso" or "Cabo Verde" or "Cote d'Ivoire" or Gambia or Ghana or Guinea or "Guinea-Bissau" or Liberia or Mali or Mauritania or Niger or Nigeria or Senegal or "Sierra Leone" or Togo).tw. and exp Artificial Intelligence/ or exp Artificial Intelligence/ or exp Cell Phone/ or exp "Internet of Things"/ or exp Telemedicine/ or ("artificial intelligence" or ai or "machine learning" or "deep learning" or "neural network*" or "reinforcement learning" or "naive bayes" or "decision tree" or "random forest" or "support vector machine" or "k-nearest neighbour" or "linear discriminant analysis" or classification or clustering or "supervised learning" or telehealth or telemedicine or mhealth or "mobile phone" or smartphone or "internet of things" or "cell phone").tw. OR (exp Artificial Intelligence/ or ("artificial intelligence" or ai or "machine learning").tw.) and ("logistic regression" or "logit regression" or "multiple regression").tw. and exp diagnosis/ or exp therapeutics exp treatment outcome/ or (prevent* or screen* or detection or diagnos* or management or treatment or control).tw.
Web of Science:
TS = (prevent* or screen* or diagnos* or treatment or therapeutics or management or control) and S =("artificial intelligence" or ai or "machine learning" or "deep learning" or "neural network*" or "reinforcement learning" or "naive bayes" or "decision tree" or "random forest" or "support vector machine" or "k-nearest neighbour" or "linear discriminant analysis" or classification or clustering or "supervised learning" or telehealth or telemedicine or mhealth or "mobile phone" or smartphone or "internet of things" or "cell phone") OR (TS=("artificial intelligence" or ai or "machine learning") AND TS=("logistic regression" or "logit regression" or "multiple regression")) and TS = ("Africa south of Sahara" or "Sahara" or "sub-Sahara*" or "sub-Sahara* Africa" or SSA or Cameroon or “Central African Republic” or Chad or Congo or “democratic republic of the Congo” or “equatorial guinea” or Gabon or “Sao Tome and Principe” or Burundi or Djibouti or Eritrea or Ethiopia or Kenya or Rwanda or Somalia or “South Sudan” or Sudan or Tanzania or Uganda or Angola or Botswana or Eswatini or Lesotho or Malawi or Mozambique or Namibia or Zambia or Zimbabwe or Benin or “Burkina Faso” or “Cabo Verde” or “Cote d’Ivoire” or Gambia or Ghana or Guinea or “Guinea-Bissau” or Liberia or Mali or Mauritania or Niger or Nigeria or Senegal or “Sierra Leone” or Togo) and TS=(cardiovascular disease CVD* or hypertensi* or high blood pressure or blood pressure or stroke or heart disease)
Scopus:
((TITLE-ABS-KEY ("cardiovascular disease*" OR cvd* OR "hypertensi*" OR "high blood pressure" OR "blood pressure" OR stroke OR "heart disease"))) AND (TITLE-ABS-KEY ("artificial intelligence" OR ai OR "machine learning" OR "deep learning" OR "neural network*" OR "reinforcement learning" OR "naive bayes" OR "decision tree" OR "random forest" OR "support vector machine" OR "k-nearest neighbour" OR "linear discriminant analysis" OR classification OR clustering OR "supervised learning" OR telehealth OR telemedicine OR mhealth OR "mobile phone" OR smartphone OR "internet of things" OR "cell phone") OR (TITLE-ABS-KEY ("artificial intelligence" OR ai OR "machine learning") AND TITLE-ABS-KEY ("logistic regression" OR "logit regression" OR "multiple regression"))) AND (TITLE-ABS-KEY ("Africa south of sahara" OR "sahara" OR "sub-sahara*" OR "sub-sahara* africa" OR ssa OR cameroon OR "Central African Republic" OR chad OR congo OR "democratic republic of the Congo" OR "equatorial guinea" OR gabon OR "Sao Tome and Principe" OR burundi OR djibouti OR eritrea OR ethiopia OR kenya OR rwanda OR somalia OR "South Sudan" OR sudan OR tanzania OR uganda OR angola OR botswana OR eswatini OR lesotho OR malawi OR mozambique OR namibia OR zambia OR zimbabwe OR benin OR "Burkina Faso" OR "Cabo Verde" OR "Cote d'Ivoire" OR gambia OR ghana OR guinea OR "Guinea-Bissau" OR liberia OR mali OR mauritania OR niger OR nigeria OR senegal OR "Sierra Leone" OR togo)) AND (TITLE-ABS-KEY (prevent* OR screen* OR diagnos* OR treatment OR therapeutics OR management OR control))

Table S1. Articles excluded on reading full text.

Authors	Source	Year	Title	Reason:
T.; Njuguna Mercer, B.; Bloomfield, G. S.; Dick, J.; Finkelstein, E.; Kamano, J.; Mwangi, A.; Naanyu, V.; Pastakia, S. D.; Valente, T. W.; Vedanthan, R.; Akwanalo, C.	Trials	2019	Strengthening Referral Networks for Management of Hypertension Across the Health System (STRENGTHS) in western Kenya: a study protocol of a cluster randomized trial	No KETs
I.; Joloba Ddumba, S.; Kakande, B.	Transactions of the Royal Society of Tropical Medicine and Hygiene	2019	Motivations for participating in the use of mobile smart phone app focusing on monitoring of hypertension among older persons in Uganda	Insufficient detail
F. S.; Adusei Sarfo, N.; Ampofo, M.; Kpeme, F. K.; Ovbiagele, B.	Journal of the Neurological Sciences	2018	Pilot trial of a tele-rehab intervention to improve outcomes after stroke in Ghana: A feasibility and user satisfaction study	Not hypertension
F. S.; Adamu Sarfo, S.; Awuah, D.; Sarfo-Kantanka, O.; Ovbiagele, B.	Journal of the Neurological Sciences	2017	Potential role of tele-rehabilitation to address barriers to implementation of physical therapy among West African stroke survivors: A cross-sectional survey	Not hypertension
F.; Pudney Lorgat, E.; van Deventer, H.; Chitsaz, S.	Cardiovascular Journal of Africa	2012	Robotically controlled ablation for atrial fibrillation: the first real-world experience in Africa with the Hansen robotic system	Not hypertension
R.; Kamano Vedanthan, J. H.; Naanyu, V.; Delong, A. K.; Were, M. C.; Finkelstein, E. A.; Menya, D.; Akwanalo, C. O.; Bloomfield, G. S.; Binanay, C. A.; Velazquez, E. J.; Hogan, J. W.; Horowitz, C. R.; Inui, T. S.; Kimaiyo, S.; Fuster, V.	Trials [Electronic Resource]	2014	Optimizing linkage and retention to hypertension care in rural Kenya (LARK hypertension study): study protocol for a randomized controlled trial	No KETs
E.; Nyota Oduor, T.; Wachira, C.; Osebe, S.; Remy, S. L.; Walcott, A.	Journal	Year	Medication Management Companion (MMC) for a rural kenyan community	No KETs
J. T.; Tham Kamwesiga, K.; Guidetti, S.	Disability and Rehabilitation	2017	Experiences of using mobile phones in everyday life among persons with stroke and their families in Uganda - a qualitative study	Not hypertension
J. T.; Eriksson Kamwesiga, G. M.; Tham, K.; Fors, U.; Ndiwalana, A.; von Koch, L.; Guidetti, S.	Global Health	2018	A feasibility study of a mobile phone supported family-centred ADL intervention, F@ce TM, after stroke in Uganda	Not hypertension
F. K.; Adoubi Diby, A.; Gnaba, A.; Ouattara, P.; Ayegnon, K. G.; Boidy, K.; Azagoh-Kouadio, R.; Meneas, G.; Manga, D.; Coulibaly, A.; Sall, F.; Nguessan, E.; Ehui, E.; Yangni-Angate, K. H.	European Research in Telemedicine	2015	Tele-expertise in the interpretation of the electrocardiogram of a black African population in the Ivory Coast (sub-Saharan Africa)	Not hypertension
G. S.; Wang Bloomfield, T. Y.; Boulware, L. E.; Califf, R. M.; Hernandez, A. F.; Velazquez, E. J.; Peterson, E. D.; Li, J. S.	Global heart	2015	Implementation of management strategies for diabetes and hypertension: from local to global health in cardiovascular diseases	No KETs
T.; Dewyer Aliku, A.; Namuyonga, J.; Ssinabulya, I.; Kamarembo, J.; Okello, E.; Bua, B.; Asiimwe, A.; Odong, F.; Akech, R.; Beaton, A.; DeStigter, K.; Lwabi, P.; Sable, C.	Global Heart	2018	Telemedicine Support of Cardiac Care In Northern Uganda: Leveraging Hand-held Echocardiography and Task Shifting	Not hypertension
M.; Sarfo Nichols, F. S.; Singh, A.; Qanungo, S.; Treiber, F.; Ovbiagele, B.; Saulson, R.; Patel, S.; Jenkins, C.	American Journal of the Medical Sciences	2017	Assessing Mobile Health Capacity and Task Shifting Strategies to Improve Hypertension Among Ghanaian Stroke Survivors	Not hypertension
H. L.; Duhig Nathan, K.; Vousden, N.; Lawley, E.; Seed, P. T.; Sandall, J.; Bellad, M. B.; Brown, A. C.; Chappell, L. C.; Goudar, S. S.; Gidiri, M. F.; Shennan, A. H.; Cradle- Trial Collaboration Grp	Trials	2018	Evaluation of a novel device for the management of high blood pressure and shock in pregnancy in low-resource settings: study protocol for a stepped-wedge cluster-randomised controlled trial (CRADLE-3 trial)	No KETs
J. S.; Inyiama Igwe, H. C.; Alo, U. R.; Ajah, I. A.	International Journal of Scientific and Technology Research	2020	Interpretation of eeg recordings for the purpose of diagnosing stroke disease	Not hypertension
J. S.; Inyiama Igwe, H. C.; Alo, U. R.; Ajah, I. A.	Journal		Classification of human brain signal for diagnosis of stroke disease using artificial neural network	Not hypertension
O.; Olabode Olabode, B. T.	Journal of Computer Science	2012	Cerebrovascular accident attack classification using multilayer feed forward artificial neural network with back propagation error	Not hypertension
N.; Imberti Maurizi, J. F.; Faragli, A.; Targetti, M.; Baldini, K.; Sall, A.; Cisse, A.; Gigli Berzolari, F.; Borrelli, P.; Avvantaggiato, F.; Perlini, S.; Marchionni, N.; Cecchi, F.; Parigi, G. B.; Olivotto, I.	European Heart Journal	2016	Comparative analysis of a 4-lead portable smartphone-based versus standard 12-lead electrocardiograph for cardiovascular screening in low-income settings	Not hypertension
N.; Faragli Maurizi, A.; Imberti, J.; Briante, N.; Targetti, M.; Baldini, K.; Sall, A.; Cisse, A.; Berzolari, F. G.; Borrelli, P.; Avvantaggiato, F.; Perlini, S.; Marchionni, N.; Cecchi, F.; Parigi, G.; Olivotto, I.	International Journal of Cardiology	2017	Cardiovascular screening in low-income settings using a novel 4-lead smartphone-based electrocardiograph (D-Heart®)	Not hypertension
J. J.; Salehian Manolakos, O.; Kraeker, C.; Manolakos, L.; Hunter, C. J.	Canadian Journal of Cardiology	2015	Rheumatic heart disease screening in Windhoek Namibia using portable echocardiography: A pilot project	Not hypertension
G. F.; Shirk Evans, A.; Muturi, P.; Soliman, E. Z.	Global Heart	2017	Feasibility of Using Mobile ECG Recording Technology to Detect Atrial Fibrillation in Low-Resource Settings	Not hypertension

Table S2. Quality analysis

	RefID	31	32	40	28	41	34	39	42	43	47	33	48	38	44	37	49	29	36	35	46	30	45
	First author	Leon	Bobrow	Vedanthan	Kingue	Owolabi	Hacking	Sarfo	Sarfo	Nichols	Adler	Vedanthan	Vedanthan	Nelissen	Cremers	Mannik	Aw	Ola-Olorun	Kleczka	Haricharan	Odour	Joubert	Barsky
	Year	2015	2016	2019	2013	2019	2016	2018	2019	2019	2020	2015	2020	2018	2019	2018	2020	2014	2018	2017	2019	2014	2019
SCREENING QUESTIONS	S1. Are there clear research questions?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	S2. Do the collected data allow to address the research questions?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1. QUALITATIVE STUDIES	1.1. Is the qualitative approach appropriate to answer the research question?	Yes					Yes			Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes		Yes	Yes		Yes
	1.2. Are the qualitative data collection methods adequate to address the research question?	Yes					Yes			Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes		Yes	Yes		Yes
	1.3. Are the findings adequately derived from the data?	Yes					Yes			Yes	Yes	Yes		Yes	Yes	Can't tell	Yes	Yes		Yes	Yes		Can't tell
	1.4. Is the interpretation of results sufficiently substantiated by data?	Yes					Yes			Yes	Yes	Yes		Yes	Yes	No	Yes	Yes		Yes	Yes		Can't tell
	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?	Yes					Yes			Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes		Yes	Yes		Can't tell
2. RANDOMIZED CONTROLLED TRIALS	2.1. Is randomization appropriately performed?		Yes	No	No	Yes	No	Yes	Yes														Yes
	2.2. Are the groups comparable at baseline?		Yes	No	No	Yes	Yes	Yes	Yes														Can't tell
	2.3. Are there complete outcome data?		Yes	No	Yes	Yes	No	Yes	Yes														Can't tell
	2.4. Are outcome assessors blinded to the intervention provided?		Yes	No	No	Yes	Can't tell	Yes	Yes														Can't tell
	2.5 Did the participants adhere to the assigned intervention?		Yes	Can't tell	Yes	Yes	Yes	Yes	Yes														Can't tell
3. NON-RANDOMIZED STUDIES	3.1. Are the participants representative of the target population?												Yes	Yes	Yes			Yes	Yes	No			
	3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?												Yes	No	Yes			Yes	Yes	Yes			
	3.3. Are there complete outcome data?												No	No	No			Yes	Yes	No			
	3.4. Are the confounders accounted for in the design and analysis?												Yes	Yes	Can't tell			Can't tell	Yes	Yes			
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?												No	No	Yes			Yes	Yes	Yes			
4. QUANTITATIVE DESCRIPTIVE STUDIES	4.1. Is the sampling strategy relevant to address the research question?															Yes	Yes					Yes	
	4.2. Is the sample representative of the target population?															Yes	No					Yes	
	4.3. Are the measurements appropriate?															Yes	Yes					Yes	
	4.4. Is the risk of nonresponse bias low?														Yes	Yes					Yes		
	4.5. Is the statistical analysis appropriate to answer the research question?														Yes	Yes					Yes		
5. MIXED METHODS STUDIES	5.1. Is there an adequate rationale for using a mixed methods design to address the research question?					Yes							Yes	Yes	Yes	Yes	Yes		Yes			Yes	
	5.2. Are the different components of the study effectively integrated to answer the research question?					Yes							Yes	Yes	Yes	Yes	Yes		Yes			Yes	
	5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?					Yes							Yes	Yes	Can't tell	Yes	Yes		Yes			Can't tell	
	5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?					Yes							Yes	Can't tell	Yes	Yes	Yes		Yes			Can't tell	
	5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?					No							No	Yes	Yes	Yes	Yes		No			No	
	% criteria met	100	100	0	40	90	70	100	100	100	100	100	70	73.33333333	82.35294118	86.66666667	92.30769231	90	90	80	100	62.5	30

Table S3. Extracted baseline and endpoint systolic blood pressure readings for randomised controlled trials

Author	Title	Year	Duration	Intervention type	Primary outcome	Secondary outcome	Monitoring tools	Groups	Number of participants (baseline)	Number of participants (endpoint)	Groups
Bobrow et al.	Mobile Phone Text Messages to Support Treatment Adherence in Adults With High Blood Pressure (StAR): A Single-Blind, Randomized Trial	2016	12 months	SMS-Text Adherence suppoRt. Patients with high BP received SMS. Information only: Messages for motivation for medicine collection/taking or attending clinic, messages for education of hypertension. Interactive: Received same messages and were able to respond for changing an appointment, and changing the timing and language of the text-messages	Change in Systolic Blood Pressure at 12-months from baseline	Proportion of participants achieving mean SBP <140mmHg and mean DBP <90mmHg. Health status (measured by self report questionnarire). Proportion of scheduled clinic appointments attended. Retention in clinical care. Satisfaction with clinic services and care. Hospital admissions. Self-reported adherence to medication. Basic hypertension knowledge. Number and type of medication changes made during trial. Number of clinic visits.	validated oscillometric device. Recorded six sequential readings at three-minute intervals. The mean blood pressure was calculated by discarding the initial reading and calculating the mean from the five remaining readings.	Usual Care (UC) Information Only (IO) Interactive (I)			
								UC	457	396	**UC**
								IO	457	406	**IO**
								I	458	394	**I**
Vedanthan et al.	Community Health Workers Improve Linkage to Hypertension Care in Western Kenya	2019	15 months	Patients with high BP. Tailored behavioral communication + mHealth. Paper based: Community health worker ugave tailored behavioural and motivational engagement. Smartphone: CHW did same as PB, but had real-time decision support and data entry linked to electronic health record. Cluster randomised	Co-primary outcomes: Linkage to care Change in SBP	N/A	automated Omron blood pressure machine, standard protocol (as described by World Health Organisation)	Usual Care (UC) Paper Based (PB) Smartphone (SP)			
								UC	422	355	**UC**
								PB	451	395	**PB**
								SP	465	356	**SP**
Owolabi et al.	Randomized Trial of an Intervention to Improve Blood Pressure Control in Stroke Survivors	2019	12 months	Patients with stroke-onset within one year. Intervention: chronic care model components of delivery system redesign (increased follow-up visits, pre-appointment phone texts), self-management support (patient report card, post-clinic follow-up phone texts, waiting room educational video), and clinical information systems (patient report card as part of medical chart, hospital registry).	Mean change in systolic blood pressure at 12 months	N/A	BP measurements were obtained and averaged from each subject with use of the Omron HEM-907XL26 according to a standardized protocol provided by the manufacturer about cuff size, cuff application, body position, and time intervals when taking a measurement.				
								UC (high BP)	**79**	**74**	**UC**
								Intervention (high BI	**89**	**84**	**Intervention**
								UC (all records)	**199**	**188**	**UC**
								Intervention (all reco	**199**	**186**	**Intervention**

Table S4. PRISMA checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	3
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	3
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	3
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	3
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	4
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	4
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	4
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	4
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	4
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	4
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	4
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	4
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	4

Section and Topic	Item #	Checklist item	Location where item is reported
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	N/A
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	N/A
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	N/A
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	N/A
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	4
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Supplementary
Study characteristics	17	Cite each included study and present its characteristics.	Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	7 and Supplementary
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	8
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	8
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	8
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	N/A
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	N/A
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	N/A
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	N/A
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	8
	23b	Discuss any limitations of the evidence included in the review.	8
	23c	Discuss any limitations of the review processes used.	9
	23d	Discuss implications of the results for practice, policy, and future research.	9
OTHER INFORMATION			

Section and Topic	Item #	Checklist item	Location where item is reported
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	3
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	3
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	3
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	1, 4, 9
Competing interests	26	Declare any competing interests of review authors.	9
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	N/A