Hypertension Diagnosis and Management in Africa Using Mobile Phones: A Scoping Review

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(Methodological Review)

***Abstract*—Target 3.4 of the third Sustainable Development Goal (SDG) of the United Nations (UN) General Assembly proposes to reduce premature mortality from non-communicable diseases (NCDs) by one-third. Epidemiological data presented by the World Health Organization (WHO) in 2016 show that out of a total of 57 million deaths worldwide, approximately 41 million deaths occurred due to NCDs, with 78% of such deaths occurring in low-and-middle-income countries (LMICs). The majority of investigations on NCDs agree that the leading risk factor for mortality worldwide is hypertension. Over 75% of the world's mobile phone subscriptions reside in LMICs, hence making the mobile phone particularly relevant to mHealth deployment in Africa. This study is aimed at determining the scope of the literature available on hypertension diagnosis and management in Africa, with particular emphasis on determining the feasibility, acceptability and effectiveness of interventions based on the use of mobile phones. The bulk of the evidence considered overwhelmingly shows that SMS technology is yet the most used medium for executing interventions in Africa. Consequently, the need to define novel and superior ways of providing effective and low-cost monitoring, diagnosis, and management of hypertension-related NCDs delivered through artificial intelligence and machine learning techniques is clear.**

***Index Terms*—Africa, blood pressure control, hypertension, mobile health (mHealth), mobile phones, non-communicable diseases (NCDs).**

I. Introduction

ALL over the world, premature death from non-communicable diseases (NCDs) has become a major source of concern within the past decade. A non-communicable disease is usually a chronic (long-lasting) disease which cannot be transmitted directly from one individual to another. Statistics presented by the World Health Organization (WHO) [1] show that in 2016, out of a total of 57 million deaths worldwide, approximately 41 million (71%) deaths occurred due to NCDs. Four major NCDs—specifically, cardiovascular diseases (CVDs), chronic respiratory diseases, cancer, and diabetes—cause the death of about 15 million men and women each year with age distribution between 30 and 70 years [1]–[3].

A. Significance to Low- and Middle-Income Countries

Even though many low- and middle-income countries (LMICs) do not have systems in place for collecting information on causes of death, estimates from incomplete data gathered by the WHO show that 78% of global NCD deaths occurred in LMICs in 2016 [2]–[4]. According to a World Bank classification conducted using the Atlas method [5], low- to upper-middle-income economies are defined as those with a gross national income (GNI) per capita ranging from $1,045 or less to just about $12,695 in a fiscal year [6]. Unfortunately, most countries in Africa fall within the low- and lower-middle-income groups and are faced with limited human, financial, and infrastructural resources. This situation provides a breeding ground for an impending NCD epidemic [7]–[10] that is mostly being driven by health service problems, population growth, acute poverty, rapid urbanization, as well as a proliferation of globalization strategies in marketing leading to consumption of products harmful to health [11]–[13]. Consequently, novel ways of providing effective and low-cost diagnosis and management of NCDs that can deliver superior results must be engaged.

B. NCD Risk Factors

NCD risk factors can be broadly categorized into modifiable behavioural and metabolic risk factors. Modifiable behaviours include, among other factors, physical inactivity and unhealthy diet, tobacco use, and the harmful use of alcohol [14], [15]–[17], while four key metabolic changes that can increase the risk of NCDs include raised blood pressure, obesity, hyperglycemia, and hyperlipidemia. According to [18], the leading risk factor worldwide leading to death is elevated blood pressure, which, if left uncontrolled, eventually leads to hypertension and finally, death through a number of complications. This finding is also confirmed by various studies done on major NCDs [19]–[21]. Outcomes of a randomized controlled trial (RCT) carried out

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TABLE I
HEALTH WORKFORCE STATISTICS 2021

Health Workforce from Select African Countries (2017-2020)							
	per 10,000 Population				*numbers*		
Country	**Physicians**	**Nursing & midwifery personnel**	**Dentists**	**Pharmacists**	**Medical and Pathology Laboratory Personnel**	**Physiotherapy personnel**	**Community health workers**
Algeria[N]	17.2	15.5	3.7	4.5	136	1,751	…
Egypt[N]	7.46	19.3	2.0	4.6	15,234	4,498	963
Libya[N]	20.9	65.3	8.8	6.0	…	…	…
Morocco[N]	7.3	13.9	1.4	2.6	595	377	…
Angola[S]	2.1	4.1	0.5	0.8	98	116	1,680
Botswana[S]	3.8	54.6	0.8	2.2	460	53	716
Lesotho[S]	4.7	32.6	0.2	1.9	205	17	14,508
Namibia[S]	5.9	19.5	0.7	2.4	…	155	2,292
Benin[W]	0.6	3.0	<0.05	0.3	668	58	…
Côte d'Ivoire[W]	1.6	6.6	0.2	0.4	2,380	60	14,556
Gambia[W]	0.8	9.5	<0.05	<0.05	41	1	2,080
Liberia[W]	0.5	19.5	<0.05	2.2	…	6	3,391
Comoros[E]	2.6	14.8	0.4	0.7	8	…	…
Ethiopia[E]	1.1	7.8	<0.05	0.5	8,005	240	42,630
Kenya[E]	1.6	11.7	0.3	0.2	6,000	1,000	58,079
Madagascar[E]	2.0	3.0	0.2	0.1	306	…	…

N = North Africa; S = South Africa; W = West Africa; E = East Africa. Source: Extracted from *World health statistics 2021* [29]

on stroke patients in both Ghana and Nigeria [22] show that the risk of hypertension for stroke occurrence is the highest in the world. Results obtained from these studies reasonably lead us to conclude that controlling the incidence of hypertension in Africa will significantly reduce the burden of disease. Hypertension is progressively assuming epidemic proportions in Africa [23], [24]. The most alarming aspect is that it now features in younger populations in many African countries [25], and many cases go undetected because of a poor health culture, thus making it difficult to initiate control strategies on time.

Historically, control and management of hypertension rely on antihypertensive drug use [26] and hospital visits, but more recently, hybrid therapy regimens are emerging, which include early detection and prevention strategies, lifestyle changes [27], and self-monitoring. This changing outlook in therapeutic approaches and public perceptions presents a wide vista of opportunities for Africa to achieve hypertension control. It is imperative to combat challenges such as poor attitudes towards basic personal health maintenance which are usually fueled by unfavorable cultural, religious and superstitious beliefs [28], low levels of awareness [27], inadequate medical facilities, poorly established health systems, poverty, and shortages of suitably qualified medical personnel [29] as shown in Table I.

C. ICT and Mhealth Strategies

An emerging trend in the management of NCDs is the use of information and communications technology (ICT), where management systems are deployed using mobile technologies and tools. These systems are also referred to as mobile health (mHealth) systems, and they present a promising area for providing reliable, efficient and cost-effective access to health services [7], [30]. One of the more popular devices employed for mHealth strategies is the mobile phone. Smartphones represent a subset of regular mobile phones because they possess more features and computing power. Their penetration within the past decade has significantly grown worldwide, although at different speeds and assimilation levels in advanced and emerging economies [31]. In this review, we shall be using both terms (i.e., smartphones and mobile phones) interchangeably to provide a broader context where relevant since both technologies can be used to make calls and send text messages. Documented evidence as far back as 2012 shows that over 75% of the world's mobile phone subscriptions reside in LMICs [32]. Current statistics obtained from the Nigerian Communications Commission (NCC) as of January 2019 show that the number of active lines for Global System for Mobile communications (GSM) services totals over 173 million, thus making Nigeria the African country with the highest smartphone penetration [33]. Similarly, about 83% of the total population in Kenya is in possession of a mobile phone [7]. The mobile phone is particularly relevant to mHealth deployment in Africa [34], [35] because of its prevalent use. Some of the characteristics that make its use so desirable include portability, ease of use, relatively low cost, personalized effects, and constant connectivity. Although several works have proposed some form of mHealth deployment, often, the peculiar dynamics of low resource settings (LRS) are never fully considered [36], hence the need to design, develop, and adapt smartphone interfaces and applications for expanded, frugal [37]–[40], and resilient functions in hypertension detection, diagnosis, and management. This study therefore attempts to show the practicability (or lack thereof) of hypertension diagnosis and management using mHealth technologies in the African region.

II. METHODS

Since this review is aimed at determining the scope of the bulk of literature available on hypertension diagnosis and management in Africa, with particular emphasis on interventions based on the use of the mobile/smart phone, key factors relating to hypertension diagnosis and management were highlighted with the intention of identifying and analyzing knowledge gaps in the body of research. For this review, Arksey's and O'Malley's method [41] for scoping reviews was employed, with reference to some other published works [42]. This method enabled easy determination of the inclusion criteria, identification of pertinent studies, study selection, and data charting.

A. Data Sources and Search Strategy

PubMed database served as the main information source, and it was queried for the following search terms: "(hypertension) AND (Africa) AND ((phone OR phones) OR (mobile phones OR smartphones) OR (smartphone OR mobile phone))". The search turned up only publications written in English and was filtered to reflect articles published within the past decade. Thirty publications were retrieved using this process.

B. Study Selection

Records retrieved from the procedure described above were scanned by their titles for a preliminary assessment of relevance. Thereafter, a detailed perusal of the abstracts of the remaining articles was carried out to identify articles related to the topic of interest. Studies were included in the selection if they: a) were carried out in African countries, or in a pool of LMICs that included at least one African country; b) focused on hypertension or elevated blood pressure, or comorbidities that included hypertension; and c) the technology used for such intervention was mobile phone based. In the first instance, precedence was given to review articles since they typically gather and summarize information from a large pool of articles related to the area of interest. Secondarily, RCTs as well as other germane studies were also included. After excluding select studies based on the inclusion criteria, 18 articles remained which formed the core of the scoping review. Furthermore, additional articles were retrieved from both the reference lists of the final selection for the scoping review and the discarded articles.

C. Data Extraction, Categorization, and Charting

A data extraction process was initiated based on examples obtained in [42]–[45]. Applicable data extracted were categorized and charted from the selected studies. The data extraction chart is presented in Table III in the Appendix. This table presents an overview of the characteristics of selected studies relating to paper cited, author, publication year, risk factor or disease, study population, duration of study, sample size, technology used, study/intervention, methodology, and finally, outcomes/results obtained for each article. Papers were subsequently chronicled by classification of intervention/study using a descriptive method.

III. Results

Overall, a total of 30 articles were retrieved from the search done on PubMed. Out of these, four were considered to be irrelevant to the topic of interest after reviewing only the titles. Additionally, eight more articles were classified as being ineligible for inclusion after reviewing the abstracts. Even though the interventions were directly or indirectly related to hypertension, either they were carried out in other LMICs outside of the African region, or the study deployment was not achieved by using any of a number of features offered by a mobile phone. Fig. 1 gives a graphical illustration of the entire procedure.

A. Study Characteristics and Distribution

A search period of ten years (spanning 2009 to 2019) was specified for records retrieval. The rationale behind this was to recover as much relevant information as possible while suppressing obsolete material. The earliest records available were dated

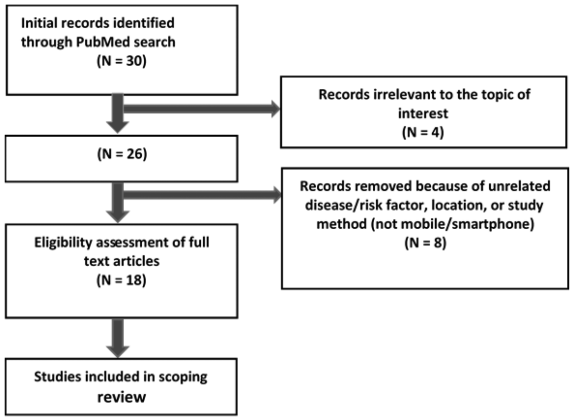

Fig. 1. Flow chart for search strategy and study selection.

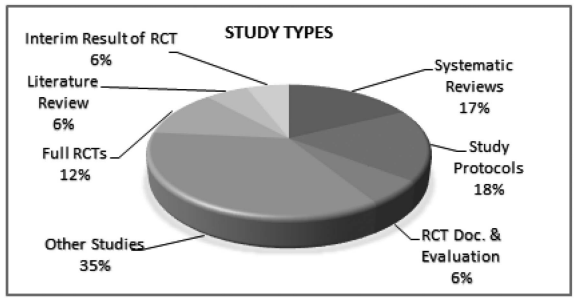

Fig. 2. Distribution of study types.

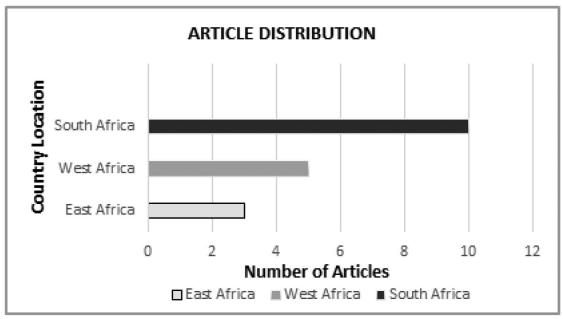

Fig. 3. Article distribution in relation to country location.

2014 [43], [46], [47], while the latest were published in 2018 [48]–[51], showing that adaptations of mHealth strategies for addressing NCD-related risk factors/conditions is a relatively new concept in the African region. The final selection of articles included four reviews, three study protocols for RCTs, one documentation of development and evaluation of a RCT, six studies of varying depth and breadth, and four RCTs. Fig. 2 shows the percentage distribution of articles.

Out of the four reviews, three were systematic reviews. All systematic reviews featured articles from a mix of LMICs, and each had only one documented intervention coming from Africa. In one of the systematic reviews, the documented intervention from Africa [52] had already been identified in the retrieval. All reviews reported hypertension as being a major risk factor for NCDs. One of the systematic reviews combined hyperlipidemia

TABLE II
FREQUENCY DISTRIBUTION OF TECHNOLOGY USED

Article Number (from Table 3)	*Text Messages*	*Mobile/Smartphone/ Tablet with App*	*Mobile/Smartphone/ Tablet without App*	*Wireless Measuring Devices*	*Web-based Data Storage and Tools*
4	+	+	-	+	+
7	+	-	+	-	+
9	+	-	+	-	+
10	+	-	+	-	-
11	+	-	+	-	+
12	+	+	-	+	+
13*	-	-	+	-	-
14*	-	-	+	-	-
16	+	-	+	-	-
18	+	-	+	-	-

Technology used = '+'
Technology not used = '-'
Phone survey/interview = '*'

as a risk factor, while others discussed NCDs such as diabetes and atherosclerotic cardiovascular disease. Of the three study protocols documented in the retrieval, two were targeted at West African countries [47], [53]. The third was directed in particular at South Africa [46], and the documentation of the development and evaluation of the RCT in [46] was presented in [51].

The largest segment of publications included studies covering different aspects of mHealth deployment and management. Two studies focused on deaf people in South Africa: the former dealt with improving their knowledge on hypertension [52], while the latter [54] evaluated the cost of health technologies deployed for hypertension in deaf patients. Other documented studies include a 10-year CVD risk identification tool deployed amongst Kenyans [50], an exploratory investigation of challenges surrounding hypertension management amongst stroke survivors [55], and the investigation of the level of awareness and management of elevated blood pressure amongst human immunodeficiency virus (HIV)-infected adults in Zambia [56]. The last study focused on the assessment of issues surrounding the use of private sector drug retail outlets for screening hypertension in Tanzania [57].

The RCTs featured in this review were implemented in South Africa and Ghana, respectively. Two separate interventions were implemented in South Africa, and both focused on supporting and improving treatment adherence for lowering blood pressure in adults [58], [59]. The intervention delivered in Ghana was implemented in multiple stages [48], [49], and it also had a similar objective of lowering blood pressure, specifically among stroke survivors, to reduce the risk of recurrent vascular events. Even though a study protocol for a RCT to be administered in Nigeria [47] was presented, no documentation concerning its actual implementation was uncovered in the search. Overall, the most represented country in terms of documentation in the African region was South Africa, followed by Ghana.

B. mHealth Technology Adaptations

The frequency chart depicted in Table II gives us an overall picture about the feasibility of employing ICT and the technological features of the mobile phone as diagnostic and management tools for detecting risk factors associated with NCDs. Studies carried out in [48], [53], and [60] are centered on the same intervention: Phone-based Intervention under Nurse Guidance after Stroke (PINGS). PINGS used interactive short message service (SMS) in combination with a Bluetooth blood pressure measuring device (UA-767Plus BT) to monitor and control blood pressure levels. Similarly, studies in [46], [51], [58], and [59] also reported different aspects of another intervention, SMS Text-message Adherence suppoRt (StAR), which combined interactive text messages with an open-source web-based electronic medical record system to test for the efficacy of the system in improving blood pressure control and treatment adherence.

Out of all the interventions documented in Table II (n = 10), a total of eight adapted the use of text messages (SMS) using mobile phones at the client end; two employed phone surveys/interviews (in the "Mobile/Smartphone/Tablet without App" column), while only two used a mobile app in synergy with a medical device. Only five studies reported using internet-based technologies and tools. All three systematic reviews included in the categorization chart reported a bevy of interventions on the use of mHealth technologies to address health-related issues [43]–[45]. However, only one intervention in each case was reported for Africa, and all studies used SMS to implement the intervention. Findings in [43] showed that most of the earlier interventions reported (i.e., before 2014) employed email and online websites, while more recent studies made use of smartphone technologies, applications and biosensors.

IV. DISCUSSION

Large-scale mobile health technology adaptation for mHealth deployment in Africa is increasingly becoming a viable and notable option to combat the rising menace of NCDs. The intent is to deploy these technologies maximally in the long run to solve challenges arising from sub-optimal medical facilities, lack of specialized medical knowledge, shortage of medical practitioners, economic constraints (e.g., out-of-pocket expenses), poor supply chain, location issues, and behavioural concerns, both on the side of users/patients and health providers/managers. This scoping review highlights and maps the body of work on the diagnosis and management of hypertension in Africa using mobile phones or smartphone devices.

In all, eleven studies carried out exclusively on the African continent were revealed which employed mHealth tools and technologies with varying degree of evidence. Studies done in [48], [53], and [60] in Table II represent different submissions on the same study (PINGS), while [46], [51], [58], and [59] focused on different stages of another study (StAR). Relative to the above, the three systematic reviews [43]–[45], also featured in the chart (Fig. 2), provide a broader coverage of interventions done across LMICs, albeit with different emphases. It is worthy of note, though, that only one intervention from Africa was reflected in each of the studies. Altogether, four major themes were extracted from the body of work consulted: namely, hypertension management and control (n = 7), cost evaluation of mHealth technologies (n = 1), screening for risk factor detection (n = 2), and health promotion using mobile phone technologies (n = 3).

Interestingly enough, only one intervention [49] reported use of some form of mobile application on a smartphone, which was combined with a Bluetooth-enabled blood pressure measuring device, to monitor blood pressure measurements and medication. Outcomes reported include a very positive attitude shown by a majority of participants to the mHealth technologies they had been exposed to. Many expressed their satisfaction with the intervention, while some even regretted not having been exposed to such earlier. Equally, a number of participants expressed the

desire to continue with the new knowledge and attitudes they had acquired through the interventions [48], [49].

The bulk of the evidence considered overwhelmingly shows that SMS technology is yet the most used medium for executing interventions in Africa. However, it would seem that text messages appear more suitable for programs dealing with medication adherence, health education, and interventions to promote physical activity and healthy diets than early detection, diagnosis and prognosis of disease. Despite the encouraging results recorded in the studies presented above which used text messages for deploying mHealth interventions, the general applicability of such interventions to every sector of the African populace is doubtful because of reported low levels of literacy that still exists in many parts of Africa. Given this limitation, it seems imperative that novel ways of providing effective and low-cost monitoring, diagnosis, and management of NCDs which can yet deliver superior results are to be engaged, either in combination with the use of text messaging, or with an entirely new focus. The use of Apps employing rich pictorials and graphical illustrations as well as frugal design principles may well compensate for the low levels of literacy and lack of specialized knowledge. Of particular note is the recommendation by the WHO and the UN of the use of infographics and iconography [61], [62] in conveying health messages to the public. These graphic visual representations of information, data, or knowledge can be color characterized to convey information quickly and clearly. Furthermore, the feasibility of horizontal models engaging quantitative approaches based on machine learning methods and decision support algorithms was underreported. Local manufacturing of phone accessories using 3D printing techniques was also little represented in the gathered evidence. In terms of detection and diagnosis of NCDs, integration of biosensors, either available on the mobile phone or attached as an external sensor, could potentially provide optimized capabilities for early detection and prevention, while exploiting communication capabilities (ICT) on the smartphone may improve linkage to and quality of care [7] with health care providers.

The negligible amount of evidence on interventions using mobile phone technologies beyond SMS in Africa to tackle the NCD burden suggests that further research is needed. Locally developed AI, ML, and 3D printing technologies can be successfully implemented through higher quality evidence-based research in the African health sector. This submission is supported by the fact that all eleven interventions included in this review report the feasibility and potential of carrying out mHealth interventions in Africa, particularly as regards NCDs and their risk factors, of which hypertension is the leading risk factor. Levels of evidence could vary from experimental RCTs and mixed methods research to systematic literature review of qualitative studies/quasi-experimental studies/RCTs (with or without meta-analysis), and also field studies. For example, Stokes *et al.* [63] report the design of an interpretable machine learning model from data obtained from a LMIC, for distinguishing pneumonia patients from bronchitis patients based on symptoms and signs alone. Pending further validation, this system could be suitable for incorporation into a diagnostic tool such as an application for use on a mobile phone. Similarly, Ellis *et al.* [64] presented the redesign of the inlet filter of an oxygen concentrator. The redesign is based on a reverse engineering approach, which makes use of activated charcoal coupled with 3D-printing methods, to accommodate environmental conditions that present in many African countries. In another work, Piaggio *et al.* [65] describe the design, prototyping and validation of a mobile app for testing the photopupillary reflex using an Android smartphone, specifically for low-resource settings. This is proposed for use in the screening of eye pathologies and brain trauma without requiring expensive settings or complex procedures. These are recent exemplars of evidence-based AI research focused on LRS, which can easily be adapted to the African context.

A worrying issue endemic to most African countries is the lack of infrastructural and organizational [66] healthcare capacity. The systematic reviews earlier mentioned highlighted some core concerns impacting negatively on the successful integration of mHealth technologies into the healthcare sector on the African continent. Though there were no lengthy discussions on these crucial aspects, common regional challenges identified include low systems and workforce capacity for managing data and digital technology and inadequate financing to support digital health; especially when considering levels of AI expertise, available infrastructure, existing AI financing arrangements, and logistics-related follow-up care. In [67] for example, Luxon argues that every aspect of healthcare infrastructure and organization should promote improved standards of care and wellbeing for patients and healthcare personnel. The need to include local populations in AI-based research that allows adaptions to local cultures, community needs, and languages cannot be overemphasized [68], [69]. Likewise, applying a systems-based approach to implementing national mHealth strategies [70], institution of strong regulatory and policy frameworks, and appropriate sourcing and monitoring of financing structures can ultimately ensure sustainability and reliability.

V. Conclusion

By carefully examining the scope of work presented in the results, it becomes evident that Africa is still at an infant stage in developing mHealth solutions and adaptations that can fast-track the process of providing reliable and effective solutions, applicable on a large scale, to counter and reduce the NCD threat and its resulting effects on the African populace. Culturally relevant solutions resilient to extant conditions in the African region are needed to provide lasting results. These solutions should mitigate the effects of poor responsiveness and availability of public and private sector health services and infrastructure, counter discordant beliefs about maintaining personal fitness [71], and reduce costs and challenges associated with accessing health facilities situated at great distances from patient locations. The outcomes from this scoping review suggest that implementing mHealth solutions to combat NCDs and related diseases exhibiting hypertension as their major risk factor would find large-scale acceptance among prospective users. This scoping review has served to highlight research gaps with respect to diagnosis and management of hypertension in Africa, and our findings show that with a greater adoption of mHealth technologies in Africa, there can be potential improvement of the NCD burden.

Appendix

Data Access Statement

This review is a re-analysis of data extracted from studies publicly available on PubMed. Data derived through the re-analysis undertaken in this study as well as all supporting data are available in the appendix of this paper and in the supplementary information accompanying the paper.

TABLE III
DATA CATEGORIZATION CHART

S/N	Paper Title/Publication, Author(s) and Year	Type of Study, Risk Factor/ Disease/Condition	Study Location, Setting	Duration of Study	Sample size	Technology proposed/used	Study/Intervention Objective	Methodology	Results/Outcomes
1	Phone-based Intervention under Nurse Guidance after Stroke (PINGS): Concept for Lowering Blood Pressure after Stroke in Sub-Saharan Africa, Ovbiagele – 2015	Literature Review, Hypertension/ Stroke	Proposed for SSA	Not stated	Proposed for ≤ 100 stroke patients	-Blue-toothed UA-767Plus BT BP device - Smartphone app. - SMS or voice mail reminder messages.	Development of a uniquely tailored multi-level smart phone medication adherence stops hypertension (SMASH) -based intervention to reduce the risk of recurrent vascular events among stroke survivors in SSA, by promoting sustained BP control, especially during the highest period of recurrence, i.e., the first 3 months after an index stroke.	In this proposed multi-level smart phone medication adherence stops hypertension (SMASH) - based intervention, patients would receive written & oral information on adherence criteria; take medications within 2 hours of designated times; measure BP values every 3 days - morning and evening, and respond to a brief beliefs, values and life goals questionnaire. Medication intake reports will be generated, and BP data scored using relevant algorithms.	Suggested outcomes include measuring recruitment/retention rates, patient /provider satisfaction, proportion of patients with systolic BP within control (<140/90 mmHg) at 3 months post-stroke, patient adherence, competence & autonomous self-regulation scores, etc.
2	Phone-based Intervention under Nurse Guidance after Stroke (PINGS): study protocol for a randomized controlled trial, Sarfo et al. - 2016	Study Protocol for RCT, Hypertension/ Stroke	Ghana; Teaching hospital (1)	9 months	60 recent-stroke survivors (≥18yrs; BP≥140/90 mmHg)	-Blue-toothed UA-767Plus BT BP device -Text messages (SMS) - Smartphone with app.	To test whether an m-Health technology-enabled, nurse-led, multilevel integrated approach is effective in improving BP control among Ghanaian stroke patients within 1 month of symptom onset compared with standard of care.	Patients would be randomly allocated into four clusters of 15 patients each per physician, with two clusters in the intervention arm, and two in the control arm. The intervention arm would receive a simple pillbox, a Blue-toothed UA-767Plus BT BP device and smartphone for monitoring and reporting BP measurements and	Primary outcome measure is comparison of BP control for intervention and control groups at 3, 6 and 9 months. Secondary outcome measures include competence and autonomous self-regulation scale scores and medication adherence.

								medication intake under nurse guidance for 3 months. Tailored motivational text messages would be delivered based upon levels of adherence to the medication intake.	
3	Phone-based Intervention under Nurse Guidance after Stroke: Interim Results of a Pilot Randomized Controlled Trial, Sarfo et al. - 2018	Interim Results of RCT	"	"	"	- Bluetooth BP device - Smartphone with App for monitoring BP measurements and medication intake.	To test the feasibility and preliminary efficacy of the intervention in improving BP control among Ghanaian stroke patients within one month of symptom onset.	Subjects in this 2-arm cluster pilot RCT were randomized to an intervention arm (n=30) and control arm (n=30). The intervention arm received a Blue-tooth BP device and smart phone for monitoring and reporting BP measurements and medication intake for 3 months, after which the intervention was withdrawn. The control arm received usual care.	Primary outcome measure was systolic BP <140 mmHg at 3 months; secondary outcomes included medication adherence, and autonomous self-regulation. Better medication adherence and a non-significant trend towards better systolic BP control was observed in the intervention arm compared to the control arm at 3 months, showing the intervention's feasibility and a preliminary signal of efficacy.
4	Phone-based intervention for blood pressure control among Ghanaian stroke survivors: A pilot randomized controlled trial, Sarfo et al. - 2019	RCT, Hypertension/ Stroke	"	"	"	"	To test whether an m-Health technology-enabled, nurse-led, multilevel integrated approach is effective in improving BP control among Ghanaian stroke patients within 1 month of symptom onset compared with standard of care.	"	Primary outcome measure was in proportion with clinic BP < 140/90 mmHg at 9 months, while secondary outcomes included medication adherence and autonomous self-regulation. The results obtained indicated that BP control was sustained for up to 9 months, even after the PINGS intervention was withdrawn by the 3rd month, thus indicating behavioural sustainability. Implementation feasibility on a large scale was also proved by participants' high level of satisfaction with the intervention.
5	Efficacy of a text messaging (SMS) based intervention for adults with	Study Protocol for RCT, Hypertensi	South Africa; Primary care clinic	12 months	At least 1215 participants	SMS, tablets, open-source web-based electronic	To test the efficacy of a SMS system integrated with clinical care in	In this 3-arm parallel group trial in adults treated for hypertension at a single primary care center in	Expected primary outcome is change in mean systolic blood pressure at 12-months follow-up from baseline. Expected

	hypertension: protocol for the StAR (SMS Text-message Adherence suppoRt trial) randomized controlled trial, Bobrow et al.-2014	on	(1).		proposed.	medical record system (OpenMRS version 1.6.1), Sana Mobile (an open-source Android platform).	improving blood pressure control and treatment adherence compared to usual care amongst patients being treated for high blood pressure.	Cape Town, participants are individually randomized to one of two trial intervention groups, or an enhanced usual care group (control) in a 1:1:1 allocation ratio. The intervention is delivered by an automated system of SMS text- messages providing clinic appointment and medication pick-up reminders, medication adherence support and hypertension-related education delivered remotely through informational or interactive SMS text-messages. Usual care is supplemented by infrequent non-hypertension related SMS text-messages.	secondary outcomes include proportion of patients with 80% or more of days covered with medication, participants achieving a systolic blood pressure less than 140 mmHg and a diastolic blood pressure less than 90 mmHg, hospital admissions, health status, retention in clinical care, satisfaction with treatment and care, and patient related quality of life.
6	Improving treatment adherence for blood pressure lowering via mobile phone SMS-messages in South Africa: a qualitative evaluation of the SMS-text Adherence SuppoRt (StAR) trial, Leon et al. – 2015	RCT, Hypertension	South Africa; Five community health centers (cross-sectional survey)	“	1372 Participants	SMS, tablets, mobile phones, open-source web-based electronic medical record system (OpenMRS version 1.6.1), Sana Mobile (an open-source Android platform), oscillometric device.	To test whether patients being treated for high blood pressure would witness relative changes in blood pressure by receiving either SMS with information only, interactive SMS or usual care.	This qualitative evaluation explored the trial participants’ experiences and responses to the SMS-text messages and identified barriers and facilitators to delivering adherence support via patients’ own mobile phones. Two focus groups and fifteen individual interviews were conducted. Comparative and thematic analysis were also used to identify themes.	Adherence support for treatment of raised blood pressure, delivered via SMS on patient’s own phone, was found to be acceptable, relevant and helpful, even for those who already had their own reminder systems in place.
7	Mobile phone text messages to support treatment adherence in	RCT, High blood pressure	“	“	“	“	“	In this Single-Blind RCT, patients treated for high BP were randomly allocated in a 1:1:1 ratio to information	Primary outcome was change in systolic blood pressure at 12 months from baseline, while secondary outcomes included

	adults with high blood pressure (sms-text adherence support [StAR]) a single-blind, randomized trial, Bobrow et al.- 2016							only, interactive SMS text messaging, or usual care. All trial staff were masked to treatment allocation, and analyses were based on the intention to treat principle.	proportion of participants with mean BP < 140/90 mmHg, health status, 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 during trial and numbers of clinic visits by participants. Only a small reduction in systolic blood pressure control compared with usual care was found. Adherence support for treatment of raised blood pressure, delivered via SMS on patient's own phone, was found to be acceptable, relevant and helpful.
8	Using the Medical Research Council framework for development and evaluation of complex interventions in a low resource setting to develop a theory-based treatment support intervention delivered via SMS text message to improve blood pressure control, Bobrow et al. – 2018	Documentation of development and evaluation of the StAR trial. Hypertension/CVDs	"	--	Stakeholders - 55; Patients - 127	SMS	To describe the design and evaluation of an adherence support intervention for high blood pressure using the Medical Research Council (MRC) Framework on complex interventions in line with reporting guidelines.	A non-sequential and flexible approach guided by the 2008 MRC Framework for the development and evaluation of complex interventions was used. Published literature and a multi-disciplinary expert group guided the development process. Health psychology theory and behavior change techniques key to adherence and persistence with chronic medications were selected. Semi-structured interviews and focus groups were also employed to identify key features of well-regarded messages and ways in	The MRC Framework can be successfully applied to develop and evaluate m-health interventions in a multilingual resource-constrained setting.

								which treatment adherence could be supported.	
9*	Comparison of two text message (mHealth) campaigns for the Deaf: Contracted out v. conducted in-house, Hacking et al. – 2016	Study (Cost Evaluation of health technologies), Hypertension/Pregnancy	South Africa; Public health facility (2) and non-clinical sites. (same as in 17* below)	--	Not stated.	- Cloud Computing (Google Forms, Google Cloud Storage), - General Packet Radio Service (GPRS)-enabled phones, - SMS	To evaluate the cost of two cell phone-based health information campaigns (hypertension and pregnancy), in which the costs of outsourcing SMS campaigns to a service provider were compared with conducting them in-house.	The study obtained data from hearing clinic attendees in resource-poor settings at two public health facilities in Cape Town as well as signing deaf people in similar economic situations, but at non-clinical sites. In both the hearing and deaf campaigns, the administration of questionnaires and collection of all data was performed by in-house fieldworkers. Bulk SMSs were set up each week, with any opt-outs being removed, and delivery failures tracked for follow-up.	Completing the SMS campaigns in-house had considerable savings and allowed for greater control over the campaigns, although it was administratively intensive.
10	Health promotion via SMS improves hypertension knowledge for deaf South Africans, Haricharan et al. - 2017	Descriptive Study, Hypertension	“	12 Months	82 participants (age ≥ 18)	SMS	This study aimed to assess whether a SMS-based health promotion campaign could improve Deaf people’s knowledge of hypertension and healthy living, as well as the acceptability of using SMSs for health promotion targeting Deaf people.	Before and after the campaign, questionnaires were administered to capture baseline and exit data of participants’ knowledge about hypertension. Results between baseline and exit data were compared and inputs from focus groups were analyzed using inductive thematic analysis.	SMSs were effective in improving Deaf people’s knowledge of hypertension and healthy living.
11	Community-based screening for cardiovascular risk using a novel mHealth tool in rural Kenya, Mannik et al.-	Study, Smoking-Diabetes-Hypertension/ Cardiovascular	Kenya, Rural health clinics.	22 Months	2865 subjects	-Automated blood pressure device. - SMS from any phone (cellular or smartphone).	To design and test a novel mHealth tool (mobile phone application) for use by community health workers (CHWs) in order to	CHWs were equipped and trained to use an automated blood pressure device and the mHealth tool, a two-way mobile phone application, AFYACHAT. AFYACHAT collects and	Qualitative feedback from the CHWs indicated that the AFYACHAT mHealth tool was simple to learn, easy to use in the field, provided timely responses (CVD risk stratification), and was well

	2018	Diseases (CVDs)				-RapidSMS (open-source toolkit)	identify individuals at a 10-year CVD risk who would benefit from education and/or pharmacologic interventions.	stores SMS data entered by a CHW on a subject's age, sex, smoking, diabetes and systolic blood pressure, and returns a text message with the category of 10-year CVD risk: 'GREEN' (< 10% 10-year risk of cardiovascular event); 'YELLOW' (from 10% to < 20%); 'ORANGE' (from 20% to < 30%); or 'RED' (≥ 30%).	accepted by the target population. It can also be used to efficiently screen large numbers of patients in rural African communities for their CVD risk.
12	Assessing Mobile Health Capacity and Task Shifting Strategies to Improve Hypertension Among Ghanaian Stroke Survivors, Nichols et al. - 2017	Descriptive Study, Hypertension/Stroke	Ghana; Teaching hospital (2), Tertiary medical center.	--	200 participants	BP Monitoring and Medication Reminder System (wireless Bluetooth-enabled BP monitor, smart phone with application & SMS), e-mail.	To explore the barriers, facilitators and perceptions toward mHealth related to HTN management among post stroke survivors.	Using a concurrent triangulation design, data was collected from stroke survivors, caregivers, community leaders, clinicians and hospital personnel. Exploration included perceptions of a nurse-led navigational model to facilitate care delivery, and willingness of stroke survivors and caregivers to use mobile health technology.	Findings strongly support mHealth strategies for post stroke care delivery and hypertension management, and task-shifting through a nurse-led navigational model. Barriers to care delivery and medication adherence across all levels of the social ecological model were also identified.
13	Awareness and management of elevated blood pressure among human immunodeficiency virus–infected adults receiving antiretroviral therapy in urban Zambia: a call to action, Bauer et al. - 2017	Cohort Study, Elevated blood pressure or Hypertension/ HIV, CVDs	Zambia; Urban public-sector antiretroviral therapy (ART) clinic (2).	11 Months	896 participants	Blood pressure monitoring device, Phone survey	To investigate the prevalence of high blood pressure (HBP) and hypertension (HTN), awareness of the diagnoses, and use of anti-hypertensive drugs were examined among HIV-infected individuals on antiretroviral therapy (ART).	Using two public sector ART clinics in Lusaka, BP was measured at ART initiation and every 6 months thereafter as a routine clinic procedure. Predictors of HBP (systolic BP ≥140 mmHg or diastolic BP ≥90 mmHg) during one year on ART were analyzed and the proportion with hypertension described. Also, a phone survey was used to understand patient awareness of HBP, use of anti-hypertensive drugs,	Data suggest that major improvements are needed in the management of HBP among HIV-infected individuals in settings such as Zambia.

								and history of cardiovascular events.	
14	The feasibility and acceptability of screening for hypertension in private drug retail outlets: a pilot study in Mwanza region, Tanzania, Michael et al. - 2016	Pilot Study, Hypertension	Tanzania; Drug retail outlets (8)	7 Months	971 customers (age ≥ 18)	- Digital, semi-automated blood pressure monitor with advanced oscillometric measurement. -Telephone interviews and follow-up calls.	To assess the feasibility and acceptability of using private sector drug retail outlets to screen for hypertension in Mwanza region, Tanzania	Customers ≥ 18 years were invited for screening in eight drug retail outlets. Socio-demographic characteristics, hypertension knowledge, hypertension screening and treatment history were collected. Subjects with systolic blood pressure over 140 mmHg were referred for follow up. Referral slips captured attendance. Mystery client visits and follow up phone calls were conducted to assess service quality.	Blood pressure screening was feasible and acceptable to customers of private drug retail outlets in two districts of Mwanza region, Tanzania, and therefore could be feasible to offer on a larger scale.
15	Randomized controlled trial of a multipronged intervention to improve blood pressure control among stroke survivors in Nigeria, Owolabi et al. 2014.	Study Protocol, Hypertension/Stroke	Nigeria	4 years	400 patients	Blood pressure monitor, SMS	To test whether a chronic care model-based initiative, tailored hospital-based risk reduction to impede vascular events after stroke (THRIVES), will significantly improve blood pressure control after stroke.	This prospective triple-blind RCT will include patients with a recent stroke discharged from four medical care facilities in Nigeria. The culturally sensitive, system-appropriate intervention comprises patient report cards, phone text messaging, an educational video, and coordination of post hospitalization care.	The primary outcome will be the improvement of blood pressure control, while secondary outcomes include control of other stroke risk factors, medication adherence, functional status, quality of life and cost analysis of intervention from the viewpoint of government policymakers.
16	Role of mobile phone technology in health education in Asian and African countries: a systematic review, Sahu et al. - 2014	Systematic Review, NCDs	Philippines, China, Kenya, South Korea, Taiwan and India	--	--	Mobile phone incorporating one or more of the following: MMS, SMS, video telephony, image transfer using mobile phone camera, voice or audio-visual,	To explore the role of mobile phone technologies in delivering health education programs in Asian and African countries.	PubMed was searched for RCTs, or controlled studies published between the years 2008 and 2011 that showed improved health outcomes through delivery of health educational interventions using cell phone or text messaging.	Mobile phone technology was shown to improve health outcomes for chronic disease conditions such as diabetes, heart disease, obesity, cardiopulmonary resuscitation guidance and hypertension. Overall results of the review indicated that mobile phone technologies can be a possible solution to improve healthcare outcomes.

						animation, email, internet access.			
17 *	Mobile Health (mHealth) Technology for the Management of Hypertension and Hyperlipidemia: Slow Start but Loads of Potential, Rehman et al. - 2017	Systematic Review, Hypertension & Hyperlipidemia/ Atherosclerotic Cardiovascular Disease (ASCVD)	USA, Canada, Italy, Mexico, Russia, South Africa (same as in 9* above), Netherlands	--	--	Internet access, email, phone calls, SMS, Bluetooth-enabled medication tray, Bluetooth-enabled or traditional BP measuring devices, BP monitoring devices, mobile apps, health sensors, mobile phones.	To describe and critically analyze recent studies evaluating the effectiveness of mHealth interventions in the management of hypertension and hyperlipidemia.	Not stated.	Data from these studies suggests that using mHealth interventions for blood pressure management may be effective. It also appears that the use of wireless devices in combination with mobile apps offered a greater opportunity to engage patients.
18	The effectiveness of e-& mHealth interventions to promote physical activity and healthy diets in developing countries: A systematic review, Müller et al. - 2016	Systematic Review, Hypertension & Diabetes	Mexico, Spain, South Africa, India, Iran, China, Philippines, Turkey, Brazil, Thailand, Pakistan, Malaysia, Peru, Argentina, Guatemala	--	--	Web-based health content, email, social networks, text messages, phone calls, audio-visuals, email, mobile apps, smartphones, wireless devices (e.g. wearable activity trackers, tablets).	To investigate the effectiveness of e- and mHealth interventions to promote physical activity and healthy diets in developing countries.	Major databases and grey literature sources were searched to retrieve studies that quantitatively examined the effectiveness of e-& mHealth interventions on physical activity and diet outcomes in developing countries. Additional studies were retrieved through citation alerts and scientific social media allowing study inclusion. The CONSORT checklist was employed to assess the risk of bias of the included studies.	Primary outcomes were measured physical activity and/or dietary behavior, while secondary outcomes included body mass index (BMI), waist-hip ratio, body fat, waist circumference, etc. Majority of studies demonstrated that e- and mHealth interventions were effective in promoting physical activity and healthy diets in developing countries.

* - Same study identified in two different papers (9*, 17*)

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