Combating chronic diseases in Africa

The efficacy, the need and the implementation of mobile phone-based health interventions against non-communicable diseases in Sub-Saharan Africa

vorgelegt von
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'The continent is too large to describe. It is a veritable ocean, a separate planet, a varied, immensely rich cosmos. Only with the greatest simplification, for the sake of convenience, can we say 'Africa'. In reality, except as a geographical appellation, Africa does not exist.'´

Ryszard Kapuściński (2001) in the book 'The Shadow of the Sun'

Contents

Chapter 1: Introduction

Victor Stephani

1.1 Globalisation, Urbanisation and Ageing

The phenomena of globalisation, urbanisation and ageing occur almost everywhere in the world. In addition to the blessings they bring, they also have direct and indirect negative effects on people's health.

This happens through developments such as the global marketing of unhealthy products and its impact on consumer behavior (globalization), the more inactive life and the unhealthier environment in the city (urbanization), and the physical and psychological decline that comes with a longer expectancy of life (ageing) [1-3].

As a result of these developments, certain risk factors are promoted that increase the likelihood for people of getting so-called *diseases of wealth*, better known as non-communicable diseases (NCDs).

NCDs are the contrary to communicable diseases (CDs). They are non-infectious diseases, which means that they are usually not transmitted directly from one person to another and they are caused by lifestyle and environmental factors, ageing or inheritance. Examples of NCDs are cardiovascular diseases, cancer, asthma or diabetes.

In recent years, the phenomena described above have also happened in one of the poorest regions of the world: The area south of the Sahara Desert, known as Sub-Saharan Africa (SSA). There, globalization has influenced the lives of many people, e.g. through the aggressive marketing of alcohol by multinational companies [4]. The promise of a better life in the city has nine-folded the urban population in the last 50 years [5]. And due to various improvements (e.g. in health care for CDs), the average age in SSA has increased by about 16 years between 1970 and 2016, from 44.05 to 60.39 years (in the same period, world life expectancy increased by about 14 years, from 58.65 to 72.03 years) [6].

As a result of these developments, the number of people suffering from NCDs has increased. Between 2000 and 2017 the number of deaths caused by NCDs has risen from 23.5% to 34.4% - and it is expected that this trend will continue and NCDs will be the leading cause of death by 2030 [7]. NCDs are therefore considered as a second burden of disease, alongside the still prevalent burden of infectious diseases (such as HIV/AIDS, Malaria or tuberculosis).

One of the main characteristics of NCDs is their chronicity. They persist over time and do usually not cure. Therefore, they require, unlike acute diseases, lifelong care and an active

patient who is the daily manager of the disease. Early detection and treatment is important since it can reduce the severity of the disease and its negative consequences for individuals and the society. However, in the past most health care systems in SSA have focused on infectious diseases and have been built to combat acute events and single episodes of care (e.g. malaria or diarrhea) [8].

The treatment of people with one (or more) chronic disease(s) therefore overwhelms most health systems, which already face many problems such as lack of resources, inadequate infrastructure or poor management [9].

1.2 The mobile revolution

Since the second half of the 20th century Information and Communication Technology (ICT) has found its way into many areas of life. The age of digitalization has begun.

In the past decade, one of the biggest drivers of the digitalization was and still is the rapid spread of mobile phones (and other mobile units) in combination with the ongoing expansion of the mobile infrastructure.

The number of global SIM (Subscriber Identity Module) connections (e.g. through mobile phones or tablets), has increased from less than one billion in 2000 to 7.9 billion in 2018 [10, 11]. And the number of 'unique mobile subscribers' (UMS, individuals responsible for one or more SIM connections) reached 5.1 billion in 2018, meaning that more than two-thirds (67%) of all human beings have access to the mobile infrastructure (and it is expected that it will rise to over 70% by 2025) [11]. This makes the mobile technology to the most widespread of all technologies.

The mobile revolution has also arrived in Africa. Over the last years there has been an explosive growth of the mobile infrastructure in SSA. The region is regarded as the fastest growing mobile market in the world: the UMS rate has risen from 28% in 2013 to 45% in 2018, and it is estimated to hit 50% by 2020 [11].

Moreover, the network coverage which complements the spread of mobile phones has also developed remarkably in recent years. In some African countries there is almost the same coverage of the 2G network (second generation cellular technology) as in some European countries [12].

As a result, in some regions of SSA the access to the mobile infrastructure is better than access to paved roads or sanitary facilities [13].

1.3 mHealth in Africa

It has been recognized that the mobile infrastructure could be used to address health issues and improve patient care and management [14].

The use of mobile phones (or mobile units) for health services and information is usually referred to as 'mHealth' (mobile Health) [15].

Some SSA countries have experienced a real boom of 'mHealth interventions' in recent years. Many pilot projects have been and are being implemented - it is estimated that there are already more than 500 interventions on the continent [16]. Examples (NCD and non-NCD specific) of such mHealth interventions are:

- Automated text message reminders sent to patients with HIV/AIDS reminding them to take their medication (e.g. [17])
- Mobile phone-based communication between providers and pregnant women in order to register, monitor and guide the women through the pregnancy (e.g. [18])
- Text message-based reporting of shortages of pharmaceuticals by Community Health Workers (CHW) (e.g. [19])
- Mobile applications that allow users and patients to ask medical questions and then communicate with a doctor or CHW without any physical contact (e.g [20])

With the occurrence of such mHealth interventions, the question of its effects also arose. Numerous published studies and several systematic reviews have started to report on that. They have indicated that patients can potentially benefit from these interventions and that mHealth has a positive effect on health outcomes. However, in the area of research on mHealth in developing countries, the focus has so far been on HIV/AIDS, malaria, and maternal and child health [21-24]. Research in the area of mHealth against NCDs remains scarce.

1.4 Objective and structure of the dissertation

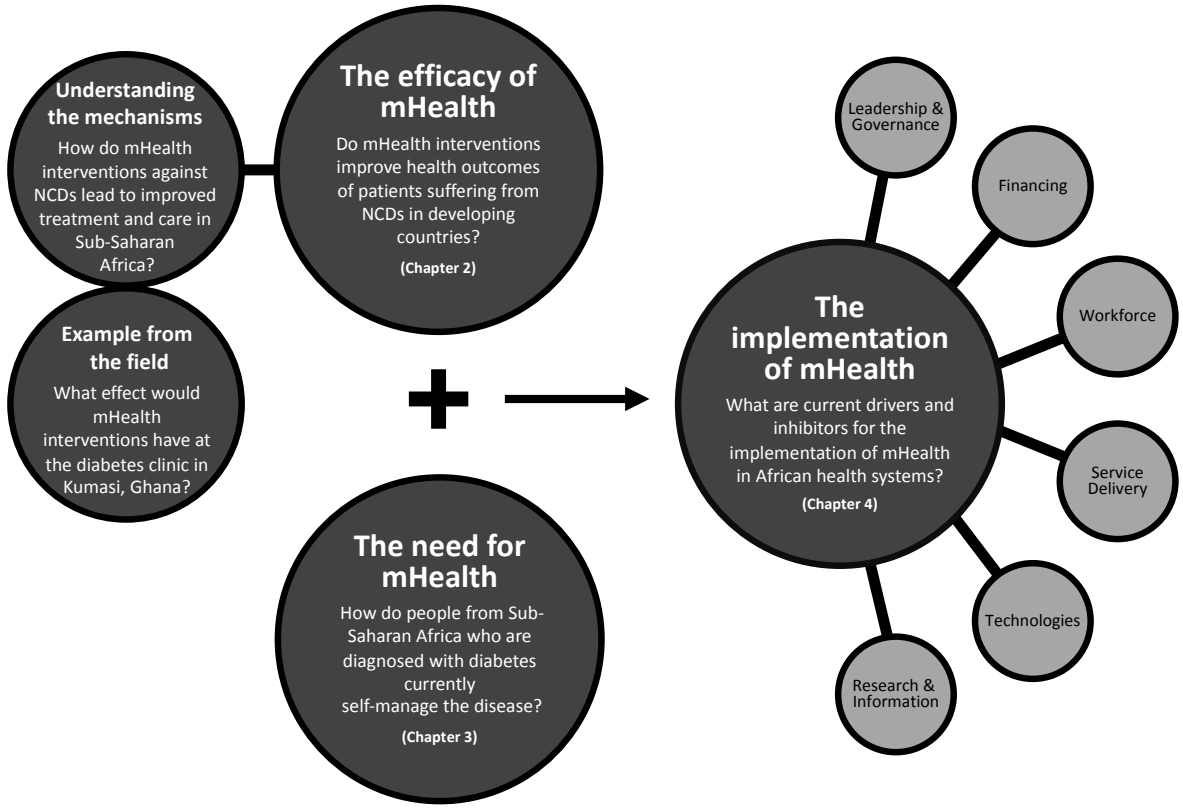
Due to this scarcity, the aim of this thesis is to analyze the area of mHealth against NCDs in SSA.

The main results can be found in 5 publications, their topics are displayed in the figure below.

The first part (chapter 2) is represented by 3 publications and deals primarily with the efficacy and the effects of mHealth against NCDs. It evaluates the effects of mHealth on health-related outcomes in low- and middle-income countries (publication 1) and the mechanisms that lead to improved treatment and care for patients with NCDs (publication 2). A field experiment using these findings further analyzes the potential of mHealth in a certain context, in this case a diabetes clinic at a hospital in Ghana (publication 3). While the first part (chapter 2) primarily studies the efficacy of mobile phone-based health interventions, the second part (chapter 3) takes a look at the current situation of people suffering from NCDs in SSA. This is done by analyzing the self-management behavior of people suffering from diabetes in SSA countries. Finally, the third part (chapter 4) looks at how such interventions could be implemented into African health systems. This analysis is structured around the WHO (World Health Organization) framework of health systems, that describes health systems in terms of six 'building blocks' (light grey bubbles in the figure).

The rational and the methodology of the individual Chapters will be briefly outlined below.

Figure 1: Overview of dissertation structure. The individual publications are represented by the dark grey bubbles



1.5 Chapter outline

Chapter 2: The efficacy of mHealth and the mechanisms behind it

Do mHealth interventions improve health outcomes of patients suffering from non-communicable diseases in developing countries?

In the area of research on mHealth in developing countries, the focus has so far been on HIV/AIDS, malaria and/or mother/child health interventions. Several systematic reviews have indicated that mHealth can be used effectively in these areas [22-24].

However, research on the efficacy of mHealth against NCDs is scarce. No systematic review on this was identified. Therefore, in the first part of the chapter, the efficacy of mHealth against NCDs in developing countries is analyzed by doing a systematic literature review.

In order to include a sufficient number of Randomized Controlled Trials (RCTs), the inclusion criteria are not limited to the African setting. Instead, RCTs from other low-resource settings (meaning low- and middle-income countries (LMICs)) are considered as well.

The review includes a systematic literature search of three major scientific databases. The aim is to analyze whether the clinical outcomes of patients receiving mobile phones as part of their therapy are better than those of patients receiving conventional treatment (i.e. without mobile phone intervention).

How, why, for whom and in what circumstances do mHealth interventions against non-communicable diseases lead to improved treatment and care in Sub-Saharan Africa?

Since mHealth interventions are interventions that largely differ from each other (e.g. in their range of functions, in their used setting or targeted health conditions), it is important to understand the mechanisms that link context, intervention and outcomes. Therefore, in this part, a realist review is conducted, which is aiming at a better understanding of the causal pathways linking mHealth to improved care for patients with NCDs.

A systematic search for literature is carried out in four main databases and studies reporting on the impact of mHealth interventions on patients with NCDs in SSA are retrieved. Only studies that describe the relationship between the intervention and the effect on NCD care are included.

These identified relationships are finally summarized in a new framework, which is mainly based on Andersen Behavioral Model of Health Services Utilization [25]. It determines

people's decision to use mHealth by so called PNE factors: **P**redisposing characteristics, **N**eeds and **E**nabling resources.

What effect would mHealth interventions have at the diabetes clinic in Kumasi, Ghana?

Since the context of an mHealth intervention is crucial for its success, it has to be considered prior to its introduction. Therefore, the third part of chapter 2 reports from a field study which was conducted at the diabetes clinic at the Komfo Anokye Teaching Hospital (KATH) in Ghana. The KATH is one of the main teaching hospitals in Ghana and is located in Kumasi. 150 Patients, who attended the diabetes clinic and have so far not used their mobile phone for health-related services, were surveyed. All questions were derived from the PNE factors which have been identified as part of the previously conducted realist review. On the basis of this survey it is possible to assess whether a mHealth intervention would have an effect at the diabetes clinic in Kumasi.

This chapter is based on 3 papers. Two have been published in peer-reviewed journals and one (the third part) is in peer review at the time of submission of this dissertation (03/2019).

Chapter 3: The need for mHealth.

How do patients with type 2 diabetes from Sub-Saharan Africa currently self-manage the disease?

While Chapter 2 adopts a more *supply-side* perspective of mHealth (i.e. what does the technology offer?), Chapter 3 deals with the *demand-side* and the extent to which mHealth against NCDs is actually needed (i.e. why should the technology be used?).

This requires a better understanding of the current care and management of people with NCDs in SSA. This will be done taking an exemplary NCD: diabetes. Diabetes is selected as an example because the prevalence in SSA has increased rapidly over the past years (estimates assumed about 7.1% in SSA in 2014) and it is currently one of the leading causes of NCD-related deaths [26].

One integral part for treating chronic diseases, such as diabetes, is the day by day care conducted by the patient, also known as self-management. It is assumed that mobile phone-based interventions do have a high potential for improving adherence to the recommended self-management behavior [27].

In order to estimate the need for such interventions, this part therefore analyzes the current self-management behavior of patients with diabetes in SSA.

This is done by systematic review, based on the Cochrane recommendations. Observational and experimental studies reporting self-management behavior of people with type 2 diabetes mellitus and living in Sub-Saharan Africa are retrieved from three databases. Qualitative and quantitative results are combined and summarized according to recommended self-management behavior as defined by the American Diabetes Association (ADA).

This chapter is based on a published study in a peer-reviewed journal.

Chapter 4: The implementation of mHealth.

What are current drivers and inhibitors for the implementation of mHealth in African health systems?

Assuming that mHealth interventions are able to improve the health outcomes of patients with NCDs in SSA, and assuming that the need for such interventions is very high, it is necessary to ask about the current barriers to a large-scale implementation of mHealth. Therefore, the last part (chapter 4) looks at the implementation of mHealth and assesses current barriers and enablers.

For the analysis, 10 representative countries from SSA are selected. Each country is assessed against a set of indicators that help to measure the degree of implementation of mHealth against NCDs. The catalogue of indicators is derived from the 'health system building blocks framework', which was published by the WHO and subdivides health systems into six building blocks (service delivery, leadership & governance, workforce, financing, technologies, research & information) [28]. Data for the indicators are gathered from various sources: databases, literature reviews and expert interviews.

This chapter consists of a working paper, published at the Technical University Berlin University Press.

Abbreviations Chapter 1

ADA	American Diabetes Association
CDs	Communicable Diseases
CHW	Community Health Worker
ICT	Information and Communication Technology
KATH	Komfo Anokye Teaching Hospital
LMICs	Low- and Middle-Income Countries
mHealth	Mobile Health
NCDs	Non-Communicable Diseases
PNE factors	Predisposing Characteristics, Needs and Enabling Resources Factors
RCTs	Randomized Controlled Trials
SIM	Subscriber Identity Module
SSA	Sub-Saharan Africa
UMS	Unique Mobile Subscribers
WHO	World Health Organization

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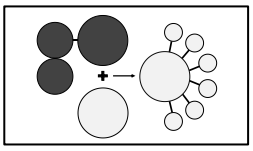
Chapter 2:
The efficacy of mHealth and the mechanisms behind it



2.1 The efficacy of mHealth

Do mHealth interventions improve health outcomes of patients suffering from non-communicable diseases in developing countries?

Article:

Stephani, V., Opoku, D., & Quentin, W. (2016). A systematic review of randomized controlled trials of mHealth interventions against non-communicable diseases in developing countries. *BMC Public Health*, *16*(1), 572.

Stephani et al. BMC Public Health (2016) 16:572
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BMC Public Health

RESEARCH ARTICLE Open Access

A systematic review of randomized controlled trials of mHealth interventions against non-communicable diseases in developing countries

Victor Stephani*, Daniel Opoku and Wilm Quentin

Abstract

Background: The reasons of deaths in developing countries are shifting from communicable diseases towards non-communicable diseases (NCDs). At the same time the number of health care interventions using mobile phones (mHealth interventions) is growing rapidly. We review studies assessing the health-related impacts of mHealth on NCDs in low- and middle-income countries (LAMICs).

Methods: A systematic literature search of three major databases was performed in order to identify randomized controlled trials (RCTs) of mHealth interventions. Identified studies were reviewed concerning key characteristics of the trial and the intervention; and the relationship between intervention characteristics and outcomes was qualitatively assessed.

Results: The search algorithms retrieved 994 titles. 8 RCTs were included in the review, including a total of 4375 participants. Trials took place mostly in urban areas, tested different interventions (ranging from health promotion over appointment reminders and medication adjustments to clinical decision support systems), and included patients with different diseases (diabetes, asthma, hypertension). Except for one study all showed rather positive effects of mHealth interventions on reported outcome measures.
Furthermore, our results suggest that particular types of mHealth interventions that were found to have positive effects on patients with communicable diseases and for improving maternal care are likely to be effective also for NCDs.

Conclusions: Despite rather positive results of included RCTs, a firm conclusion about the effectiveness of mHealth interventions against NCDs is not yet possible because of the limited number of studies, the heterogeneity of evaluated mHealth interventions and the wide variety of reported outcome measures. More research is needed to better understand the specific effects of different types of mHealth interventions on different types of patients with NCDs in LaMICs.

Background

As a result of increasing life-expectancy and growing welfare in low and middle income countries (LaMICs), there is a steady shift away from communicable to non-communicable diseases (NCDs) [1–3]. NCDs pose a major threat to public health in LaMICs. In 2010, NCDs already accounted for half of Disability Adjusted Life Years (DALYs) lost and for 58 % of all deaths in these countries [4]. It is predicted that this number will increase to 70 % of all deaths in 2020 [5]. The economic cost of the NCDs burden for LaMICs are estimated to reach US$21 trillion by 2030 [3].

The ability of LaMICs to provide treatment and care for the increasing number of patients with NCDs is limited by insufficient health care infrastructure, especially in rural areas [6]. At the same time there is a rapidly growing, hidden infrastructure: 90 % of the world's population now lives within reach of a mobile phone signal [7] and the developing world has the fastest-growing cellphone subscriber market in the world [8, 9]

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with a mobile-cellular subscription rate of almost 90 % in 2013 [10].

The number of health care interventions using mobile phones (short mHealth interventions) is growing rapidly [11]. In particular in LaMICs, mHealth is perceived to have great potential for improving health care provision for both communicable and non-communicable diseases [12]. Most of the available literature on mHealth interventions is focused on communicable diseases (such as HIV and Malaria) or on maternal care [13]. However, the number of studies focusing on mHealth for patients with NCDs has considerably increased over the last few years. In fact, two thirds of all articles on the topic have been published between 2012 and 2015 (based on a Web of Science search with the keywords TS = (mHealth OR "mobile Health" or tele*) AND TS = ("developing") AND TS = (NCD OR "non-communicable diseases"). Yet, evaluations of mheatlh interventions often do not follow rigorous scientific standards of randomized controlled trials (RCTs), and consequently, they carry a relatively high risk of bias [14].

Two reviews are available that have included studies analyzing certain aspects of mHealth interventions for NCDs in LaMICs: Beratarrechea et al. [15] evaluated text and automated voice interventions for chronic diseases in the developing world and Bloomfield et al. [16] performed a review of mHealth interventions against NCDs focusing only on Sub-Saharan African countries. However, as Beratarrechea et al. [15] did not focus specifically on NCDs and because Bloomfield et al. [16] focused exclusively on Sub-Saharan Africa, a comprehensive overview of the effectiveness of mHealth interventions for improved treatment and care of patients with NCDs living in LaMICs remains unavailable.

The aim of this study was 1) to systematically review the available evidence generated by randomized controlled trials (RCTs) of mHealth interventions for people with NCDs living in LaMICs, and 2) to assess the relationship between intervention characteristics and reported health-related outcomes. We focused on RCTs since they remain the gold standard for evidence of effectiveness of health interventions [17].

Method

Inclusion criteria

Studies were included for this review if they met the following inclusion criteria:

- The study reported results of an RCT, as defined by JN Matthews [18]
- The trial took place in at least one country that was classified as an LaMIC as defined by the World Bank classification of country income groups [19]
- The intervention involved the use of mHealth as defined by the Global Observatory for eHealth [11]
- Trial participants were patients suffering from NCDs as defined by the WHO [20]
- The study was published in English or German
- The study was published before August 2015 (no limit concerning the start date)

Literature search method

An initial systematic literature search was performed between December 2013 and February 2014 in MEDLINE (PubMed), CENTRAL and Business Source Complete. An update of the search was performed in August 2015.

After piloting appropriate search words, the terms were constructed around (1) "mHealth", (2) "Low and Middle Income Countries" and (3) "Non Communicable Disease". Search terms for the operationalization of NCDs were derived from WHO's Global Burden of Disease Report. In addition to the medical terms specified in the Global Burden of Disease Report (e.g., myocardial infarction or dermatological cancer), we added more common terms such as heart or skin (for including interventions against skin cancer) to the search algorithm.

The search conducted in CENTRAL is shown in the Additional file 1: Table S1. It was carried out using the free text search with Boolean operators and MeSH descriptors using the terms Telemedicine [MeSH] AND Developing Countries [MeSH] (with no filter for diseases and the enabled option of exploding all trees). The same search-approach was applied using MEDLINE. Due to a low number of results in the database Business Source Complete it was feasible to exclude the field of terms for NCDs and to include solely the location and intervention of interest.

In addition, reference lists of included studies and identified existing reviews were screened for relevant titles.

After removal of duplicates, the resulting list of titles (Medline 730, CENTRAL 116, Business Source Complete 125) was screened and studies whose titles/abstracts clearly indicated that they were not concerned with mHealth intervention trials for NCDs in LaMICs (e.g., if titles indicated that they focused on developed countries or HIV) were excluded from further consideration.

Full-text articles of 114 studies were retrieved and assessed, resulting in 8 articles included for this review. The screening process was conducted independently by two reviewers (VS and DO). Disagreements were discussed between authors and resolved by consensus.

Data collection and analysis

For each included study, information was collected on key characteristics of the RCTs concerning:

1) the study location (country, urban/rural);
2) the population (disease, inclusion and exclusion criteria for trial participants);
3) the intervention characteristics, including information on the type of mHealth intervention (e.g., text message, phone call), the data transmitted (e.g., appointment reminders, advice and medication reminders), interactivity of the intervention (i.e., whether it was possible for patients or providers to respond to information received), and personalization (i.e., whether timing or content of information were specific for the patient);
4) the comparator (control) group intervention (e.g., booklet with information on asthma instead of text message with information); and
5) outcomes reported by the studies, including clinical outcomes, compliance, quality of life, costs and other outcomes.

In order to assess the relationship between intervention characteristics and outcomes, studies were categorized into one of four types of mHealth interventions as suggested by Howitt et al. [21] (with slight modifications). We distinguished between interventions for 1) health promotion & awareness, 2) remote monitoring & care support, 3) disease surveillance & outbreak detection, and 4) decision support system.

Meta-analytic techniques were not employed because differences between studies concerning the type of intervention, the included study participants (different diseases), and the reported outcome measures (clinical outcomes, compliance, etc.) made a meaningful analysis of pooled data impossible.

Risk of bias

Risk of bias was assessed qualitatively concerning selection bias (sequence generation and allocation sequence concealment), performance bias (blinding of participants and personnel), detection bias (blinding of outcome assessment), extent of loss to follow-up, reporting bias (selective outcome reporting), and other bias (e.g., imbalance in baseline characteristics). We used the Cochrane Collaboration's tool for assessing risk of bias and information on assessment were derived from the text [22]. The full risk assessment of the included studies is available in the Additional file 2.

Results

Literature search results

Figure 1 illustrates the literature search and selection process, and presents reasons for exclusion of studies. We identified a total of 969 studies in the three databases and 23 studies were retrieved from references of other studies. Full texts of 114 studies were screened of which 106 were excluded, mostly because they did not deal with mHealth ($n = 43$), did not report results of an RCT ($n = 25$), did not take part in LaMICs ($n = 13$) or because of other reasons ($n = 25$). The final analysis included 8 studies, which met all inclusion criteria.

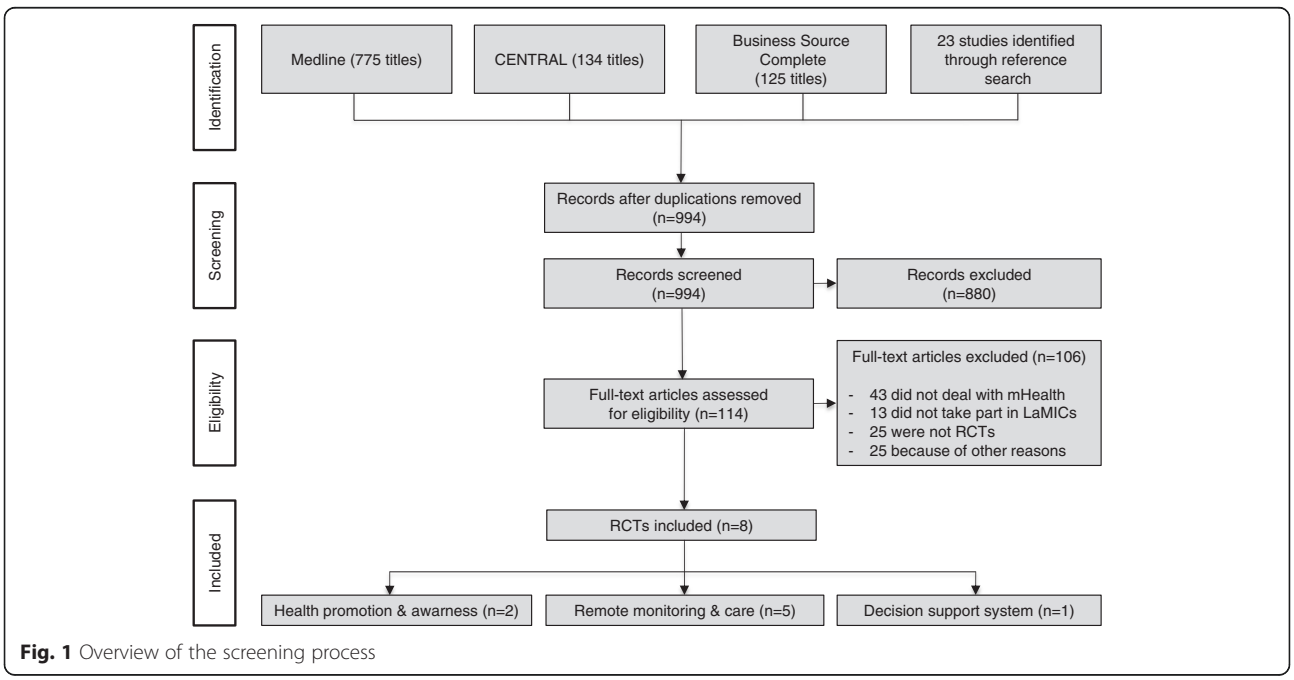

Fig. 1 Overview of the screening process

Characteristics of included studies

Trial characteristics

Table 1 summarizes the main characteristics of the eight included trials. Five studies were conducted in lower middle income countries (LMICs), three in upper middle income countries (UMICs). Two studies [23, 24] reported results of trials, which included patients in both a LMIC and a UMIC (Mexico and Honduras, and India and China, respectively). The participating patients came mostly from urban areas and were recruited mainly from primary care centers or urban hospitals. Three studies dealt with diabetes [25–27], two with asthma patients [28, 29], two with patients suffering from cardiovascular diseases, [23, 24] and one with patients having different NCDs [30], including hypertension, asthma and diabetes.

A total of 4375 participants were included in all eight studies, of whom 2095 received a mHealth intervention, 314 received an alternative landline-telephone based intervention, and 1966 were included in the control group. Trial size varied from 16 participants [29] to 2086 participants [24]. The mean age in the intervention group was 57.2 years and in the control group 57.8 years. Studies reported a wide range of outcomes, which were classified for the purposes of our review into disease specific clinical outcomes, compliance and others.

Intervention characteristics

Table 2 provides an overview about the main characteristics of the mHealth interventions that were evaluated in the eight RCTs. Two interventions informed patients with diabetes about the management of the disease and gave general advice on a healthy lifestyle (category health promotion & awareness): One informed the participants through an internet webpage and frequently sent text messages [25], while the other sent a text message once in three days to the study participants [26]. Both interventions were not personalized to the participants and not interactive.

The most basic intervention in the category of remote monitoring & care support was an appointment-reminder system, where text messages were sent 24–48 h before the patients' scheduled appointments [30].

Four interventions required the patients to record key parameters of their disease, e.g., the Peak Expiratory Flow Rate (PEFR) for patients with Asthma [28, 29], the blood glucose level for patients with Diabetes [27] or the blood pressure for patients with hypertension [23]. They did so by using additional devices (home blood pressure monitor, glucometer, peak expiratory flow meter) and the patients were then asked to send this data either via a text message to a physician [29], to type their records into an interactive phone software [28] or they were called by a specialist and transmitted the information via a phone-call [23, 27]. In all the four studies, patients received personalized disease-management advice.

Only one intervention fell into the category of clinical decision support systems [24]. Community health workers (CHWs) treating patients with cardiovascular diseases in rural areas received a smartphone with an application consisting of prompts regarding the patients' clinical values, adherence to treatment and other parameters. The application was tailored to the local customs.

Results of the RCTs

Table 3 provides an overview of all relevant outcomes reported by the eight included studies, illustrating significance of differences in outcomes between the intervention and control groups. The eight studies reported results for a total of 15 different measures of clinical outcome 9 measures of compliance, 2 measures of quality of life (QoL) and 13 other outcome measures.

The two *health promotion & awareness* interventions targeted diabetic patients but none of the reported outcome measures was available from both studies. In the study by Balsa and Gandelman [25], where diabetic patients received a text message that intended to motivate their use of a website, neither clinical outcomes nor other outcomes were improved. In the study by Shetty et al. [26], where patients received a text message with advice on nutrition, physical activity and drug intake, several clinical outcome measures showed significant improvements, although compliance measures did not improve significantly.

Out of the five studies evaluating tools for *remote monitoring and care support*, one study evaluated an interactive telephone-intervention for patients with diabetes [27]. Patients were advised to self-monitor their Blood Glucose level and received therapeutic advice over the phone twice a month. The study found that clinical and compliance outcomes improved significantly more strongly in the intervention group than in the control group.

Two studies evaluated interactive mHealth interventions for patients with asthma [28, 29], where patients transmitted information about their pulmonary function (as assessed by the peak expiratory flow rate, PEFR) to a physician and received personalized therapeutic advice (e.g., medication adjustments). Both studies found that individuals showed improved pulmonary function tests (FEV1% predicted and PEFR), although this finding was not significant in the study by Ostojic et al. [29], which included only a total of 16 participants. Liu et al. [28] also found significant improvements of quality of life, while Ostojic et al. [29] found significant improvements of PEFR variability and of some self-reported clinical outcome measures (e.g., coughing and night symptoms) although not of others, and no effect on compliance.

Table 1 Characteristics of the interventions

	Intervention					
Study name	Used channel	Received information	Control group	Timing	Interactivity	Personalization
Balsa and Gandelman [25]	Internet platform & text messages	New topics about type 2 Diabetes and healthy lifestyle	Brief educational brochure	Not reported	No	No
Shetty et al. [26]	Text messages	Medical nutrition therapy, physical activity and drug intake reminders	Oral advises on diet modification and physical activity	Once in three days	No	No
Liew et al. [30]	Text messages	Appointment reminder	No reminder	Once; 24–48 h before the scheduled appointment	No	Yes
Liu et al. [28]	Interactive software on cellphone	Adjustments of therapy	Booklet for written asthma diary and action plan	Immediately after the data has been uploaded	Yes	Yes
Ostojic et al. [29]	Text messages	Adjustments of therapy	No weekly therapeutic advise	Weekly	Yes	Yes
Piette et al. [23]	Mobile blood pressure monitor & phone calls	Advises and medication reminder	No weekly therapeutic advise	Weekly	Yes	Yes
Shahid et al. [27]	Glucometer & Phone calls	Adjustments of therapy	Self monitoring with Glucometer and regular follow up after 4 months	Every 15 days	Yes	Yes
Tian et al. [24]	Smartphone application	Advises on medication prescription and lifestyle changes	Usual cardiovascular management programs	Monthly	No	Yes

Table 2 Study design characteristics of included RCTs

Study	Location	Income group	Conditions	Place of recruitment	Inclusion criteria	Sample size	Mean Age (Intervention; control)	Planned Follow-up	Measured outcomes
Balsa and Gandel-man [25]	Uruguay (urban)	UMIC	Type 2 Diabetes	Waiting rooms of internists treating diabetic patients at three HMOs in Montevideo	Adult patients with Diabetes 2; Access to Internet (at least once a week)	195 (intervention) 193 (control)	n/d	6 months	Clinical, Others
Shetty et al. [26]	India (urban)	LMIC	Diabetes	Patients at a diabetes centre in Chennai	Type 2 Diabetes with a minimum duration of 5 years; Minimum of high school Education; HbA1c value ranging between 7 % to 10 %	110 (intervention) 105 (control)	50.1; 50.5	1 year	Clinical, Compliance
Liew et al. [30]	Malaysia (urban)	UMIC	Different chronic diseases (mainly NCDs)	Two primary care clinics in Kuala Lumpur	Registered with the clinics for at least 6 months; return appointment between 1 and 6 months; ownership of a mobile phone	314 (telephone) 398 (text mesages) 309 (control)	57.7; 58.1; 60.7	At least 6 months	Compliance
Liu et al. [28]	Taiwan (urban)	UMIC	Asthma	Outpatient clinics of Chang Gung Memorial Hospital, Linkou, northern Taiwan	Moderate to severe Asthma	43 (intervention) 46 (control)	54; 50	6 months	Clinical, Compliance, QoL
Ostojic et al. [29]	Croatia (urban)	UMIC	Asthma	General Hospital "SvetiDuh", Zagreb	Moderate Asthma for at least 6 months; consistent access to a cellphone, able to use text messages	8 (intervention) 8 (control)	24.5; 24.8	16 weeks	Clinical, Compliance, Costs
Piette et al. [23]	Honduras (rural), Mexico (urban)	UMIC, LMIC	Hypertension	Four private and two public clinics in Cortes, Honduras and one primary care center in Real de Monte	SBP > = 130 mm Hg if diabetic and SBP > = 140 mm Hg if non-diabetic; between 18 and 80 years; access to a cellphone and able to use it	89 (intervention) 92 (control)	58.0; 57.1	6 weeks	Clinical, Others
Shahid et al. [27]	Pakistan (rural)	LMIC	Diabetes	Department of Endocrinology, Liaquat National Hospital	Patients between 18–70 years, residing in rural areas of Pakistan, HbA1c ≥ 8.0 % and having personal functional mobile phone	220 (intervention) 220 (control)	48.95; 49.21	6 months	Clinical, Compliance
Tian et al. [24]	China (rural), India (rural)	UMIC, LMIC	Cardiovascular Diseases	CHWs at 27 villages from 15 townships in China and 20 villages in Haryana State, India	High cardiovascular risk individuals: above 40 years and a self-reported history of coronary disease	1095 (intervention); 991 (control)	59.7; 60.4	One year	Clinical, Compliance

Table 3 Overview of intervention-group outcomes compared to control-group outcomes

Study	Balsa and Gandelman [25]	Shetty et al. [26]	Shahid et al. [27]	Ostojic et al. [29]	Liu et al. [28]	Piette et al. [23]	Liew et al. [30]	Tian et al. [24]
Intervention	Health promotion & awareness		Remote monitoring & care support					Decision support system
Personalization	No		Yes					
Interactivity	No		Yes				No	
Disease	Diabetes			Asthma		Hyper-tension	Various NCDs	CVDs
Clinical outcomes								
SBP[a] (mm Hg), Mean	+/–		++			+ / ++[b]		++
Fasting blood glucose level	+/–							
BMI[c], kg/m^2		+/–[d]	+/–[e]					
PPG[f] < 180 mg		++						
HbA1c[g]		++[h]	++[i]					
TC[j] < 150 mg/dl		++						
HDL-C[k] > 40 mg/dl		+/–						
LDL-C[l] < 100 mg		++	++					
FEV1%[m], predicted				+	++			
PEFR[n], L/min				+	++			
PEFRvariability				++				
Coughing				++				
Night symptoms				++				
Wheezing				+/–				
Limitation of activities				+/–				
Compliance outcomes								
Attendance		+					++	
ICS[o] dosage				+/–	+			
Systemic steroids				+/–	+			
Antileukotrienes				+/–	+/–			
Long-acting beta2-agonist								
Anti-hypertensive medication use								++
Aspirin								++
Adherence to diet prescription		+/–	++					
Adherence to physical activity		+	++					
Quality of life related outcomes								
Physical component					++			
Mental component					++			
Cost								
Monetary				-				
Timely				-				
Other outcomes								
Knowledge	+/–							
Perception of health quality	+/–							
Health-related behaviors	+/–							
Physician-Patient relationship	+/–							

Table 3 Overview of intervention-group outcomes compared to control-group outcomes *(Continued)*

Number of visits to emergency department	++		
Depression scores		++	
Perceived overall health		++	
Overall satisfaction with care		++	
Medication problems		++	
Current smoker, %			+/−
Awareness of harms of high salt diet, %			+/−
Receiving monthly follow-up, %			++
Hospitalization during the past year, %			+

(+/−): no difference; (+): superior to control group without significance; (++): superior to control group with significance ($p < 0.05$); (−): inferior to control group. A more detailed summary of reported outcomes, specifying values for intervention and control groups is available in Stephani et al. [44]
[a]Systolic Blood Pressure
[b]Subgroup of low-literacy people/people with higher education needs
[c]Body Mass Index
[d]BMI < 26
[e]BMI < 25
[f]Postprandial Plasma Glucose Test
[g]Glycated hemoglobin
[h]HbA1c < 8 %
[i]mean HbA1c level
[j]Total Cholestorol
[k]High-Density Lipoprotein Cholesterol
[l]Low Density Lipoprotein
[m]Peak Expiratory Flow Rate
[n]Forced Expiratory Volume in 1 second
[o]Inhaled Corticosteroid

Piette et al. [23] found that their intervention providing personalized advice to hypertensive patients on the basis of their self-recorded blood pressure lowered systolic blood pressure in the intervention group, although this finding was significant only in a subgroup of 117 out of 181 participants with low literacy or high hypertension information needs.

Liew et al. [30] found that text messages and telephone appointment reminders lowered non-attendance of patients significantly when compared to controls.

The only study of a decision support system by Tian et al. [24] found that medication compliance of patients treated by CHWs, who were supported by smartphones, increased significantly, and they had significantly lower blood pressure when compared with controls.

The impact of mHealth on **costs** in terms of time and money for physicians and patients was observed by only one trial [29]. It was estimated that the intervention would lead to additional monetary costs per patient of €0.67 per week for text messages sent to physicians, and that physicians spent 2 min per patient per week at a cost of 1 Euro per patient.

Discussion

This is the first review focusing specifically on RCTs of mHealth interventions against NCDs in LaMICs. Despite much enthusiasm about the 'great potential' of mHealth for addressing NCD needs in LaMICs and despite a growing body of literature on the topic, we found only eight studies that reported results of RCTs performed in LaMICs. Except for one study [25], these showed generally positive effects of mHealth interventions on reported outcome measures. However, because trials tested different interventions (ranging from health promotion over appointment reminders and medication adjustments to clinical decision support systems), and included patients with different diseases (diabetes, asthma, hypertension), and – partially as a result of this – reported very different outcome measures, it is impossible to generalize these findings.

Nevertheless, our review provides a first glimpse of the slowly emerging evidence base on the effectiveness of mHealth interventions for NCDs and has important implications for policy-makers and researchers. First, it is remarkable that the evaluated mHealth interventions generally showed positive effects on reported outcome measures, including clinical outcomes, compliance, and quality of life. This finding is in line with findings from a much broader literature on communicable disease and maternal care, where many different kinds of mHealth interventions have been found to improve clinical outcomes and compliance of patients – although results have been shown to vary depending on the specific type of intervention [31–33].

Second, our results suggest that particular types of mHealth interventions that were found to have positive effects on patients with communicable diseases and for improving maternal care are likely to be effective also for NCDs. For example, text message appointment reminders have been found to lead to higher pre-natal visit rates of pregnant women [34–36], and two studies included in our review show that they are also effective at increasing attendance rates of patients with NCDs [26, 30]. Similarly, drug intake reminders have been found to improve treatment adherence of people with AIDS and Malaria [37–39], and one study in our review showed that drug intake reminders (combined with other information on medical nutrition and physical activity) improve clinical outcomes of patients with Diabetes [26].

Third, our results show that there is very limited evidence on the effects of mhealth in low income countries as all included studies reported results of trials conducted in middle income countries. Furthermore, when considering the 4 broad categories of mHealth interventions that we defined at the beginning, i.e., interventions of 1) health promotion & awareness, 2) remote monitoring & care support, 3) disease surveillance & outbreak detection, and 4) decision support system, it is evident that available RCTs have focused mostly on mHealth interventions falling into category 2. Also Bloomfield et al. [16] concluded that there is very limited evidence concerning a wide range of health systems challenges, which could potentially be addressed by the implementation of mHealth interventions. In our review, several studies evaluating *clinical decision support* systems were identified during full-text screening [40–43] but they had to be excluded because they were no RCTs. Information on cost-effectiveness of mHealth interventions is largely unavailable and only one study included in our review considered the effect of mHealth on costs of care [29].

An important limitation of our review is that we excluded all studies that did not report results of RCTs. Observational studies and non-randomized trials may provide important bits of information that are useful for understanding the effectiveness of mHealth. Nevertheless, we opted for excluding these studies as non-randomized trial designs carry a greater risk of being flawed as a result of multiple biases [22]. Another limitation of the review process could have been the restriction to the two languages German and English. Furthermore, given the limited number of studies, it was not possible to compare results of different studies. Effects of mHealth are likely to differ depending on the specific type of intervention, the specific disease, and the specific context. Consequently, it is impossible to draw firm conclusions on the effectiveness of mHealth interventions in general, e.g., by carrying out pooled analyses of outcome data. Finally, the specific effects of different kinds of mHealth interventions on different kinds of patients with NCDs living in LaMIC could not be investigated. For example, it is likely that the effectiveness of interventions depends on whether patients can interact with health professionals and whether information is personalized to the patients. Although our review includes studies with both interactive and non-interactive interventions as well as studies with both personalized and non-personalized information, the specific effects of these different interventions could not be compared because they were provided to different patients (in difference settings) and reported different outcome measures.

Conclusion

Our review shows that there are only eight studies reporting results of RCTs of mHealth interventions for patients with NCDs in LaMICs. These have generally found positive results. However, a more detailed analysis of the specific effects of different types of mHealth interventions on different types of patients and a firm conclusion about the effectiveness of mHealth against NCDs is impossible because of the small number of studies and the heterogeneity of reported outcome measures.

Nevertheless, our results indicate that some findings of the positive effects of mHealth interventions for patients with communicable diseases and for maternal care can be replicated by mhealth interventions for patients with NCDs. However, we can only repeat the conclusions of previous reviews [15, 16] that more research is needed to fill the many gaps in knowledge about mHealth interventions for NCDs in LaMICs.

Additional files

Additional file 1: Table S1. Search method conducted with the CENTRAL-database (DOC 30 kb)

Additional file 2: Table S2. Bias of the included studies (DOC 34 kb)

Abbreviations

CHWs, community health workers; DALYs, Disability Adjusted Life Years; FEV1%, Forced Expiratory Volume in 1 second; LaMICs, low and middle income countries; LMICs, lower middle income countries; mHealth, mobile health; NCDs, non-communicable diseases; PEFR, peak expiratory flow rate; RCTs, randomized controlled trials; UMICs, upper middle income countries

Authors' contributions

VS conceived the idea, collected data, participated in analysis and drafting of manuscript. WQ participated in analysis and drafting of manuscript. DO collected data, participated in analysis and drafting of manuscript. All authors read and approved the final manuscript.

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article and its Additional files 1 and 2.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable

Ethics approval and consent to participate
Not applicable

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2.2 Understanding the mechanisms

How, why, for whom and in what circumstances do mHealth interventions against non-communicable diseases lead to improved treatment and care in Sub-Saharan Africa?

Article:

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A realist review of mobile phone-based health interventions for non-communicable disease management in sub-Saharan Africa

Daniel Opoku*, Victor Stephani and Wilm Quentin

Abstract

Background: The prevalence of non-communicable diseases (NCDs) is increasing in sub-Saharan Africa. At the same time, the use of mobile phones is rising, expanding the opportunities for the implementation of mobile phone-based health (mHealth) interventions. This review aims to understand how, why, for whom, and in what circumstances mHealth interventions against NCDs improve treatment and care in sub-Saharan Africa.

Methods: Four main databases (PubMed, Cochrane Library, Web of Science, and Google Scholar) and references of included articles were searched for studies reporting effects of mHealth interventions on patients with NCDs in sub-Saharan Africa. All studies published up until May 2015 were included in the review. Following a realist review approach, middle-range theories were identified and integrated into a Framework for Understanding the Contribution of mHealth Interventions to Improved Access to Care for patients with NCDs in sub-Saharan Africa. The main indicators of the framework consist of predisposing characteristics, needs, enabling resources, perceived usefulness, and perceived ease of use. Studies were analyzed in depth to populate the framework.

Results: The search identified 6137 titles for screening, of which 20 were retained for the realist synthesis. The contribution of mHealth interventions to improved treatment and care is that they facilitate (remote) access to previously unavailable (specialized) services. Three contextual factors (predisposing characteristics, needs, and enabling resources) influence if patients and providers believe that mHealth interventions are useful and easy to use. Only if they believe mHealth to be useful and easy to use, will mHealth ultimately contribute to improved access to care. The analysis of included studies showed that the most important predisposing characteristics are a positive attitude and a common language of communication. The most relevant needs are a high burden of disease and a lack of capacity of first-contact providers. Essential enabling resources are the availability of a stable communications network, accessible maintenance services, and regulatory policies.

Conclusions: Policy makers and program managers should consider predisposing characteristics and needs of patients and providers as well as the necessary enabling resources prior to the introduction of an mHealth intervention. Researchers would benefit from placing greater attention on the context in which mHealth interventions are being implemented instead of focusing (too strongly) on the technical aspects of these interventions.

Keywords: mHealth, Mobile phone, Non-communicable diseases, Chronic diseases, Sub-Saharan Africa, Realist review, Health policy

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Background

In sub-Saharan Africa (SSA), the prevalence of non-communicable diseases (NCDs) is increasing rapidly [1], placing a growing burden on already weak health systems in the region [2, 3]. At the same time, the use of mobile phones is continuously rising, expanding the opportunities for the implementation of mobile phone-based health interventions (mHealth interventions) [4–6]. The World Health Organization (WHO) has proposed the further development and more widespread use of mHealth interventions for the prevention, management, and treatment of NCDs and their risk factors as part of its Global Action Plan for the prevention and control of NCDs [7].

In fact, mHealth interventions are increasingly used in low- and middle-income countries, including those in SSA [8]. Three recent systematic reviews, two specifically focusing on the use of mHealth interventions for the care and management of NCDs in SSA [6] and in developing countries [9], and the other looking more broadly at the use of mHealth interventions against chronic diseases in developing countries [10], found that the included studies generally reported positive outcomes. However, the authors also noted that there was insufficient evidence to support the scale-up of mHealth interventions because there were only five studies from SSA countries [6] and only nine studies from developing countries [9, 10]. In addition, the authors highlighted that further research was needed to better understand the causal pathways linking mHealth to improved care for patients with NCDs [6].

Traditional systematic reviews, which are often focused on randomized controlled trials, usually do not allow one to uncover causal pathways or to identify contextual mechanisms that may explain whether, why, and how interventions might work [11]. Realist reviews have emerged as an alternative method for systematic reviews, aiming to provide answers for policy makers about the causal mechanisms that link context, intervention, and outcomes [12].

Understanding these mechanisms is particularly relevant for complex interventions, such as mHealth interventions, which are implemented in vastly different healthcare settings (varying from rural communities [13, 14] to major university hospitals [15]), use various functions of mobile phones (from text messaging [16–18] to picture transmission [19]), target widely different health conditions (from skin lesions [20] to maternal health [21, 22]), and are put to use by persons with very different backgrounds, behaviors, skills, and beliefs [23–25].

This review aimed to understand how, why, for whom, and in what circumstances mHealth interventions contribute to improved treatment and care for patients with NCDs. More precisely, the first question ("how?") that the review aimed to answer was: What is the specific contribution that mHealth makes to patient treatment and care? As the review proceeded, it became clear that the main contribution of mHealth interventions is that they facilitate (remote) access to previously unavailable — and often specialized — services. Therefore, the objective of this review was to answer the following specific questions: (1) What are the causal mechanisms ("why?") that explain if an mHealth intervention facilitates access to care? (2) How do patient and provider characteristics ("for whom?") influence these mechanisms? (3) What is the influence of contextual factors ("what circumstances?") on these mechanisms?

Methods

This review followed guidelines for realist reviews [11, 12, 26, 27] because the research questions could not be answered using more traditional forms of systematic reviews. Realist reviews focus on identifying (middle-range) theories, which can provide guidance to the available literature. These theories then help us to understand the mechanisms that explain why an intervention has worked in one context but not in another. However, such Context-Mechanism-Outcome (C-M-O) relationships identified in realist reviews do not imply that a specific context will *always* lead to a specified outcome. Instead, realist reviews assume that outcomes are the result of choices made by individuals whose interactions are influenced by the intervention and by the context of implementation [12, 26, 27]. (See Table 1 for the operational definition of the C-M-O model of hypotheses adapted in this review.)

Scoping the literature and searching for relevant studies

An initial scoping review was conducted to identify candidate theories (see below) and to obtain a broad overview of the available literature on mHealth interventions aiming to improve treatment and care for patients with NCDs in SSA. Following this initial search, the review question was progressively refined to focus more specifically on the contribution of mHealth to facilitating access to previously unavailable care.

A search strategy was developed, using various combinations of the following search terms: "mHealth", "non-communicable diseases", and "sub-Saharan Africa". PubMed, Cochrane Library, Web of Science, and Google Scholars, were searched and re-searched from March to May 2015. (Additional file 1 provides details of the search strategies developed for the four databases.) In addition, a hand search was performed of the *Journal of Telemedicine and Telecare*, the *Journal of Telemedicine and e-Health*, and of reference lists of screened studies and existing reviews.

Inclusion and exclusion criteria

The review included various study designs (randomized controlled trials, mixed methods, and qualitative interview

Table 1 Operational definition of the C-M-O model of hypotheses adapted in this review

C-M-O	Operational definition
Context	This is defined as the prevailing conditions and circumstances within which patients and/or healthcare providers behave or decide to use mobile phone-based health interventions for the treatment and care of non-communicable diseases in sub-Saharan Africa. For example: - Patient/provider predisposing characteristics (age, gender, etc.) - Patient/provider needs - Patient/provider enabling resources
Mechanism	The factors or active "ingredients" of a mobile phone-based health intervention which directly/indirectly influence both intended and unintended health outcomes and/or outputs of the treatment and care of non-communicable diseases in a well-defined context in sub-Saharan Africa. For example: - How easy to use the patients and healthcare providers find the mobile technology involved in the intervention - How useful patients and healthcare providers perceive the mHealth intervention to be over alternative programs and forms of accessing healthcare
Outcome	This constitutes the sustained use of mHealth interventions and — in turn — better patient access to care

studies) and publication types (peer-reviewed articles, gray literature, and other forms of research reports). Titles, keywords, and abstracts were screened by the corresponding author (DO) to identify relevant studies based on a set of inclusion criteria developed during the initial scoping review. A second reviewer (VS) also independently screened retrieved studies. If there was disagreement between reviewers, studies were retained for full-text screening. The following inclusion criteria were applied: (1) studies took place in sub-Saharan Africa (i.e., in at least one of the 47 countries in the WHO African region), (2) interventions relied on the use of (mobile) phones, (3) studies focused on NCD-related treatment and care, and (4) studies provided an evaluation of the relationship between the intervention and NCD care. No language restrictions or time limits were applied.

Full-texts of 126 studies were retrieved and independently screened by DO and VS. At this stage, studies were excluded if interventions were based on phones and not primarily on mobile phones. In case of doubts, corresponding authors of studies were consulted for clarification. Studies were also excluded if they did not report results of (clinical) outcomes and/or an assessment of the intervention by patients, professionals, or proxies (e.g., relatives or guardians). In case of disagreements between DO and VS on the eligibility of studies, these were resolved by WQ.

Identifying candidate theories

During the initial scoping review, a number of candidate theories with potential explanatory value for mHealth interventions were explored. The identified theories and models included the Middle-Range Theory of Self-Care of Chronic Illness [28], the Theory of Reasoned Action/Theory of Planned Behavior [29], Rosenstock's Health Belief Model [30], Andersen's Behavioral Model of Health Services Utilization [31, 32], Young's Choice-Making Model [33], and Davis's Technology Acceptance Model [34, 35]. (See Additional file 2 for the reasons of inclusion/exclusion.)

Following discussions within the review team, Andersen's Behavioral Model of Health Services Utilization was retained because it could potentially provide insights into the mechanisms linking contextual and individual level factors with improved access to care. According to Andersen's model, peoples' decisions to use (or access) healthcare services are determined by three main factors: (1) predisposing characteristics (e.g., age, health beliefs), (2) enabling resources (e.g., availability of providers), and (3) need (e.g., burden of disease) [32].

As the review proceeded, Davis's Technology Acceptance Model was found to provide additional insights into mechanisms that are important for explaining improved access to care through mHealth interventions. Davis's Technology Acceptance Model posits that the use and acceptance of technology is determined by two factors: *perceived usefulness* and *perceived ease of use*. According to Davis's theory, health professionals will perceive a technology to be useful if they believe that it will help them to do a better job, and they will perceive a technology to be easy to use if they believe that it can be used without effort [35].

Data extraction, analysis, and synthesis

Two data extraction templates were developed using Excel to collate information on the included studies for analysis and synthesis. One template was used to summarize the characteristics of included studies (author(s), year of publication, title, study design, and country where the study took place). The other template for results and synthesis mainly contained information on the (type of) intervention, modality of interaction, outcome/outputs, and the five categories of the theoretical model: *predisposing characteristics, enabling resources, need, perceived usefulness, and perceived ease of use*.

The data synthesis involved team discussions in relation to whether the information extracted was rightly placed in the various domains and adjusted accordingly. Common themes were highlighted, examined, and refined in the light of their theoretical contributions. This involved classifying

findings from different studies into the categories of the theoretical model in order to understand the Context-Mechanism-Outcome (C-M-O) relationship. For example, if a study reported that older age groups were more likely to make use of an intervention because they found it more useful than younger age groups, this finding was classified into the category of a *predisposing characteristic* that leads to *perceived usefulness*.

Results

Search results and study characteristics

A total number of 6201 citations were retrieved, out of which 6181 were excluded after the appraisal process displayed in Fig. 1. The raw inter-rater agreement between DO and VS was 97% (123/126) after full-text screening. Additional file 3 provides information on key characteristics of the 20 included studies. The studies were published between 2005 and 2015, and presented information on 18 interventions in various areas of care (dermatology, mental healthcare, cancer, diabetes, and hypertension).

The contribution of mHealth to improved treatment and care for patients with NCDs

The main contribution of mHealth interventions to improved treatment and care for patients with NCDs in SSA countries is that they facilitate (remote) access to previously unavailable — and often specialized — services. In fact, almost all included studies highlighted this characteristic feature of mHealth interventions [20, 36–51].

However, the configuration of mHealth interventions differed considerably across settings, concerning involved actors and the mechanisms through which they facilitated access to care. In 12 studies, mHealth interventions essentially consisted of mobile phone-based consultations between two healthcare providers, where a specialized provider could be reached by another provider, thus indirectly improving patient access to specialized care [36, 38–43, 45, 47–49, 52]. In 8 studies, mHealth interventions connected a patient to a provider, thus directly facilitating patient access to (professional) care [20, 37, 46, 50, 51, 53–55].

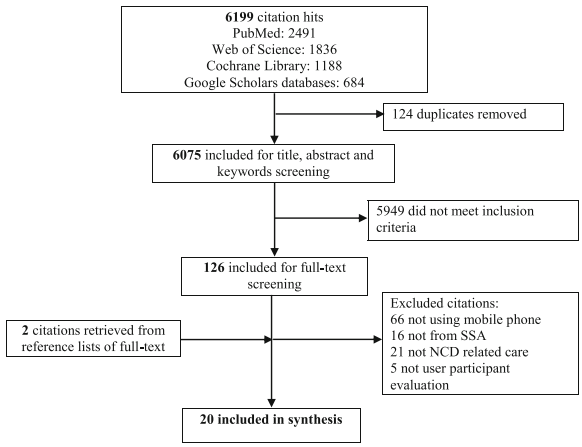

Fig. 1 Flowchart displaying the search results and the screening process for the primary studies

Participating patients or providers usually required only a few days of training on how to use the mobile technology (such as the mobile phone and its application software) and the consultation procedures [41, 43, 46–48, 50, 55]. An important feature of most mHealth interventions was that interactions between participants usually took place on the basis of standardized information exchange protocols [36, 39, 40, 42, 43, 45–47, 49, 52, 54]. These protocols helped to establish the purpose of the consultations and contributed to systematically ascertaining symptoms, diagnoses, and treatment. (See Additional file 3 for further details.)

From candidate theories toward a framework for understanding mHealth interventions

During the early stages of the review, Andersen's model and his conceptualization of predisposing characteristics, enabling resources, and need helped to focus the analysis on the role of the context in explaining why mHealth interventions contribute to improved access for some patients and in some areas but not in others. However, as the review proceeded, it became increasingly clear that the context has only an indirect influence on access to health services facilitated by mHealth interventions. At this stage, Davis's Technology Acceptance Model and his conceptualization of perceived usefulness and perceived ease of use contributed to understanding the mechanisms that link the context to improved mHealth based access to healthcare.

The two models of Andersen and Davis were then integrated into a framework for understanding the contribution of mHealth interventions to improved access to care for patients with NCDs in SSA. The framework is illustrated in Fig. 2 and shows that mHealth consultations take place either between a patient and a provider or between two providers with one provider facilitating patient access to another provider with certain specialized skills. The most important patient context factors (predisposing characteristics, enabling factors, and need) are shown on the left-hand side of the figure, while the most important context factors for (specialized) providers are shown on the right-hand side. For providers facilitating access between patients and (specialized) providers, context factors are sometimes more similar to those of patients and sometimes more similar to those of (specialized) providers.

In the center of the figure, arrows indicate the C-M-O relationship: The context factors influence the perceptions of patients and providers concerning how useful

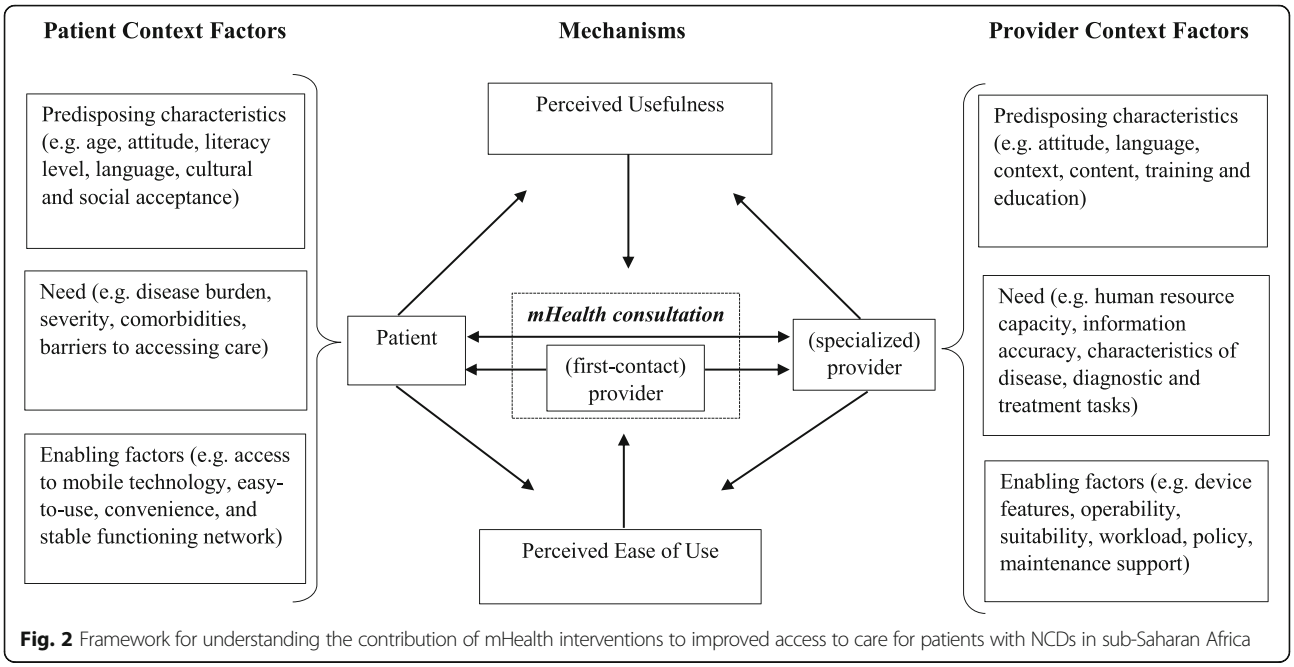

Fig. 2 Framework for understanding the contribution of mHealth interventions to improved access to care for patients with NCDs in sub-Saharan Africa

they find the mHealth intervention in comparison with other forms of service delivery, such as traditional face-to-face contacts or alternative computer-based telemedicine. Similarly, these factors also influence the perceived ease of use of mHealth in comparison with other options for service delivery. If interventions are perceived to be useful and easy to use, this will lead to the sustained use of mHealth interventions and — in turn — to better patient access to care (see Table 1).

Main findings from the literature

Table 2 summarizes the main findings from the literature, using the framework described above. It specifies separately for patients, (first-contact) providers, and (specialized) providers, what predisposing characteristics, enabling resources, and needs influence the perceived usefulness and the perceived ease of use.

Predisposing characteristics

For patients, the most important predisposing characteristic associated with the perception that a mHealth intervention was more useful than an alternative was the patients' cultural and social acceptance of the mobile technology, which involved familiarity with the technology in the community and absence of negative myths [38, 40, 41, 46, 53, 55]. Other important predisposing characteristics of patients included positive attitudes toward the intervention and the ability to communicate in a comfortable language (see Table 2). Similar predisposing characteristics were also reported for providers, i.e., positive attitudes [38, 40, 52], fluency in the language of the locality [46, 54], and sufficient training to use the technology [47, 52].

For both patients and (specialized) healthcare providers another important predisposing characteristic associated with the perception that mHealth was useful was source confidentiality [20, 39, 40, 49, 51]: Healthcare providers have to be confident that the information received via the mobile phone is accurate, and patients have to trust the (specialized) provider on the line in order to perceive the intervention as useful.

The perceived ease of use of an mHealth intervention depended most importantly on the predisposing characteristic that patients and providers were able to understand the language (see Table 2). In addition, studies reported that mHealth interventions have to be specifically designed to be easy to use for particular groups of patients, such as older age groups [55], or people with low educational levels [50, 55] or poor socio-economic backgrounds [50]. First-contact providers found mobile phone technologies easy to use if they were simple, relevant, and essentially combined local content and language [42]. Specialized providers' perception of ease of use was influenced by the accessibility of technical support, especially when there was the need to identify and solve technical problems such as software bugs [52].

Need

Patient needs were found to be particularly important factors influencing the perceived usefulness of mHealth interventions. If patients faced access barriers such as long travel times, waiting times, and high travel costs, mHealth interventions were perceived to be useful [20, 42, 45, 46, 48–50, 52, 53, 55]. Furthermore, three studies found that sicker patients were more likely to

Table 2 Detailed classification of evidence supporting the framework for understanding why, for whom, and in what circumstances mHealth interventions work in sub-Saharan Africa

	Patient		(First-contact) provider[a]		Specialized provider[b]	
Mechanism	Perceived usefulness	Perceived ease of use	Perceived usefulness	Perceived ease of use	Perceived usefulness	Perceived ease of use
Context						
Predisposing characteristics	• Cultural and social acceptance (familiarity/ usage of mobile technologies) [38, 40, 41, 46, 53, 55] • Positive attitude (motivated, self-empowered, activeness) [38, 55] • Age group (middle/older) [51] • Language of communication (language of locality) [46, 54, 55]	Suitability and simplicity for: • (Older) age group [55] • (Low) literacy, educational levels [50, 55] • (Poor) socio-economic backgrounds [50] • Not physically active [50]	• Positive attitude (enthusiastic, motivated, empathetic, interest, dedication, volunteer) [38, 40, 52] • Prerequisite knowledge (to provide adequate information) [47]	• Simple, relevant, combination of local content and language (interface) [42]	• Positive attitude (positive perception and trust of new technology) [52] • Basic knowledge (about the technology) [52] • Fluency in language of locality [46, 54]	• Accessible location of technical support (in-country or local software developers) [52] • Understandable language of communication (among users and software developers) [52]
Need	• Disease severity and comorbidities [20, 51, 55] • Barriers to accessing care or information (not affordable, easily, promptly, quality and/or appropriate, limited, long-distance travel, travel cost, waiting time, delaying, presenting late) [20, 42, 45, 46, 48–50, 52, 53, 55]	-	• Lack of capacity to provide needed care (limited training/education, decision-making power/ support, point-of-care clinical information, specialized care, specialty referral systems) [36, 38–40, 47, 52] • Barriers to reporting and accessing supervision [37, 40–42, 47, 51] • Need to follow guidelines [50, 54, 55]	-	• Lack of human resources (limited specialists, trained or skilled personnel, unequal distributions of professionals, over-burdened workload) [20, 36, 38–41, 43, 45, 47] • Lack of necessary systems and infrastructure (health facility, referral system, transport) [38] • Lack of accurate information [46, 47] • Task shifting to achieve early intervention and low costs of care [42, 43, 49, 54]	• Characteristics of disease conditions (extent, severity) [36, 43] • Characteristics of diagnostic and treatment tasks (feasibly assess/examine, freely question patient, probe for additional information, conduct special tests) [43, 47, 49]
Enabling resources	• Access to mobile phone [37, 45, 46, 50, 53–55] • Access to mobile technology infrastructure [45, 48, 52, 55] • Affordability of services [50, 54, 55] • Convenience, privacy, autonomy, reduced time and travel cost [20, 43] • Service/program awareness [38, 40]	• Familiar and easy-to-use mobile technology (SMS, icons) [53, 55] • Maintenance (phone recharge, repair, durability, portability) [37, 55]	• Access to phone [41, 45] • Telecommunication networks (functioning, stable, accessible, available, low-cost) [36, 39, 42, 47] • Basic infrastructural resources (information, good roads, ambulance services) [41, 47, 52] • Operating funds and logistics (availability) [38, 40, 52]	• Easy portability and operability (direct, instant, immediate) [36, 39] • Phone features (quality camera, smartphones) [36, 41] • Maintenance support (equipment/ SIM card/mobile device failure, sporadic power	• Access to phone networks (in underserved communities) [20] • Tolerable burden of workload [46, 47] • Incentives (payment) [47, 55] • Policy (network or data protection, liability, consent, confidentiality, phone usage, staff job descriptions) [43, 45, 51, 52]	• Phone features (photograph, picture quality, video functionality, interface, text messaging, appropriate screen, zoom, long-lasting battery) [36, 41, 43, 45, 47, 51] • Suitability and equivalence to existing care processes (face-to-face care, assess nonverbal behaviors) [41, 49, 51, 54]

Table 2 Detailed classification of evidence supporting the framework for understanding why, for whom, and in what circumstances mHealth interventions work in sub-Saharan Africa *(Continued)*

• Assistance/support (spouse, partner, friend, family member) [51]	• Policy and sustainability (to avoid strike actions, staff turnover rate) [40, 52] • Continuous training (workshops) and sensitization [47, 52] • Tolerable burden of workload [40]	outages, battery power problem, software bugs, theft, medical technology) [45, 52]

[a](First-contact) provider = the referring/consulting healthcare provider, usually in a provider-to-provider mHealth consultation
[b]Specialized provider = the consultant specialist or experienced healthcare provider whose expertise is being sought in mHealth consultations
Source: authors' own compilation based on the findings of the included studies in this review

use the interventions, possibly because they found it easier to use the mHealth interventions rather than, for instance, walk to a provider [20, 51, 55].

The most important need contributing to (first-contact) providers perceiving mHealth to be useful was their self-reported lack of capacity to provide adequate care [36, 38–40, 47, 52]. Furthermore, (first-contact) providers reported that they needed support in order to follow guidelines [50, 54, 55] and that mHealth could contribute to overcoming barriers to accessing supervision [37, 40–42, 47, 51]. Also for (specialized) providers, several need factors contributed to the perceived usefulness of the intervention, including, for example, an over-burdening workload [20, 36, 38–41, 43, 45, 47, 50] and a lack of adequate referral and transport systems [38, 46, 47].

Studies did not report that the needs of patients and (first-contact) providers influenced their perceived ease of use. However, specialized providers found mHealth easier to use in the context of certain disease conditions, such as acne, herpes simplex, Kaposi's sarcoma, and flame burns in dermatology, than in others (scald burns, thickness wounds, and atopic dermatitis) [36, 43] and easier for certain diagnostic and treatment tasks (sharing feedback with patients, continuous clinical follow-ups) than for others (conducting physical examinations, special tests, and probing for additional information) [43, 47, 49, 51].

Enabling resources

For patients, unsurprisingly, the two most important enabling resources necessary for a mHealth intervention to be (perceived to be) useful were access to mobile phones [37, 45, 46, 50, 53–55] (also possible through borrowing [46, 50]) and the availability of a functioning stable telecommunications network [20, 36, 39, 42, 45, 47, 48, 52, 55]. Other enabling resources were assurance of privacy [43, 48], support from partners/relatives [51, 55], reduced costs of travel, and reduced time away from home or work [24, 50–53].

Enabling resources for first-contact providers were access to basic infrastructure, such as electric power and functioning medical technologies [49, 52], ambulance services and good roads [46, 47], as well as the affordability of telecommunication services and other operating costs [50, 54, 55] (see Table 2). For (specialized) healthcare providers, the most important enabling resources were a tolerable additional workload [40, 46, 47], the use of financial incentives [47, 55], and the availability of policy guidelines regarding data protection, phone usage, etc. [40, 43, 45, 52].

Enabling resources influencing patients' perceived ease of use of mHealth interventions included the durability and portability of mobile phones [37, 55] and the low complexity of the technology, for example, short message service (SMS) and icons [53, 55]. The same enabling resources — easy portability and operability [36, 39], using technologies from basic SMS to smartphones, built-in camera, and battery-saving apps [41, 43, 45, 52] — were also found to be associated with the perception among healthcare providers that mHealth was easy to use.

Discussion

Summary of main findings

This is the first realist review of mHealth interventions for patients with NCDs in SSA countries. It shows on the basis of a wide range of included studies how, for whom, and in what circumstances mHealth interventions contribute to improved access to (specialized) care for patients with NCDs in SSA. The review did not focus on specific interventions, specific diseases, or specific providers. Instead, it adopted a middle-range perspective to identify how contextual factors influence the outcome of mHealth interventions in terms of improved access to care; in other words, how to identify C-M-O relationships.

Our framework for understanding mHealth interventions illustrates the causal mechanisms that explain how, for whom, and in what circumstances mHealth interventions facilitate access to care (see Fig. 2). As to how mHealth interventions facilitate access to care, a mHealth intervention will ultimately contribute to improved access to care only if it is perceived to be useful and easy to use. The framework therefore shows that predisposing characteristics and needs of patients and healthcare providers as well as enabling resources influence the perceptions of patients and providers that mHealth interventions are useful and easy to use.

Considering for whom or how patients and provider characteristics influence mHealth interventions, the reviewed studies revealed that a positive attitude toward the mobile technology and the ability to communicate in a common language were the most important predisposing characteristics of patients and providers contributing to the perception that mHealth was useful and easy to use. In addition, needs of patients and providers, such as a high perceived burden of disease (e.g., in cases of reduced mobility) and the perceived lack of capacity of first-contact providers to provide adequate care, influenced the perceived usefulness and ease of use.

Furthermore, studies reported that certain circumstances of enabling resources, such as the availability of a stable communications network, accessible maintenance services, and regulatory policies (e.g., on data protection), contribute to the perception of patients and providers that mHealth interventions are useful and easy to use.

Strengths and implications for policy makers and program managers

This review has several strengths. Following a realist methodology, it has included a wider scope of evidence than previous reviews [6, 10], and it has focused on the policy-relevant questions of how, for whom, and in what circumstances mHealth interventions facilitate access to care. The framework presented in Fig. 2 and the more specific context factors summarized in Table 2 have major implications for policy makers and program managers.

Firstly, given that predisposing characteristics of patients and providers influence the success of mHealth interventions, it is important that these factors are taken into account during the planning stages prior to the introduction of a new mHealth intervention. For example, program managers should consider evaluating the cultural and social acceptance among patients and providers to use the mobile technology when selecting a particular setting for the intervention. In particular, healthcare providers should be recruited who are enthusiastic and motivated to use mHealth as part of their job. Furthermore, interventions should be designed in such a way that patients, providers, and technical support will be able to communicate in a common language; otherwise, interventions are unlikely to be perceived to be useful and easy to use.

Secondly, and similar to the first point, it is important for policy makers and program managers to consider the specific needs of patients and (first-contact) providers to access (specialized) healthcare providers when preparing for the introduction of an mHealth intervention. For example, mHeath interventions will be particularly useful for severely ill patients or patients who face barriers to access (specialized) care, e.g., because they have difficulties in walking. Similarly, those (first-contact) providers who have a particular need for advice and supervision for treating certain groups of patients will perceive mHealth to be particularly useful. In addition, the influence of need factors on the perceived ease of use of (specialized) providers should be considered when preparing the introduction of an mHealth intervention, e.g., that mHealth is better for sharing feedback and continuous follow-up than for special tests and for probing for additional information [43, 47, 49].

Thirdly, policy makers and program managers have to be aware that the availability of enabling resources is essential for the successful implementation of an mHealth intervention. Enabling resources include, for example, easy access to mobile phones/devices, a stable and accessible communications network, and access to basic infrastructural resources, such as roads and ambulance services, which are necessary for mHealth supported referral systems [20, 36, 37, 39, 41, 42, 45–48, 50, 52–55]. Furthermore, policies on data protection and policies limiting the extra workload of mHealth interventions for professionals, possibly providing additional financial incentives, can support the sustained use of mHealth. See the checklist for policy guidance in Table 3.

Limitations

This review has a number of limitations. First, it does not answer the question of whether mHealth interventions facilitate improved access to care for patients with NCDs. It therefore does not contribute to the debate of whether mHealth interventions should be scaled up. Second, given that this review included a broad range of studies with various study designs, the inclusion of a specific study's finding into the review depended on rather subjective judgments. Following guidelines for realist reviews [11, 12, 26, 27], it was necessary to make decisions about whether a study's findings were relevant for the development of the framework and whether inferences drawn by an original study were sufficiently supported by evidence. Third, despite an extensive literature search and the inclusion of a wide range of studies, the available evidence on mHealth interventions in SSA remains rather limited. Therefore, the contextual factors summarized in Table 2 are rather indicative. It is very likely that there are further predisposing characteristics, enabling resources, and needs that are relevant for explaining how, for whom, and in what circumstances mHealth interventions work beyond those identified in our review. Future research is needed to confirm the theoretical framework developed in this paper and to operationalize some of its categories. For example, concerning the interplay of predisposing characteristics and perceived usefulness (see Table 2), research is needed to confirm that cultural and social acceptance is a predictor of perceived usefulness. This requires an operationalization for measuring cultural and social acceptance and for quantifying its impact on the sustained use of mHealth. Similarly, more research is necessary to better understand the interplay between need and specialized providers' ease of use. For example, researchers should explore the suitability of mHealth applications for different diseases and concerning different diagnostic and treatment tasks. This could include an assessment of the ease of use of mHealth for sharing feedback with patients with different diseases or different levels of severity, e.g., diabetes versus hypertension or diabetes with and without complications, and the differential effects on health outcomes.

Conclusions

The implementation of mHealth interventions in SSA has great potential to improve treatment and care for

Table 3 A checklist for guiding the selection, development, implementation, evaluation, and policies regarding mHealth for treatment and care of non-communicable diseases in sub-Saharan Africa

Patient context factors

- The personal characteristics of patients, which predispose them to utilize the services provided by the intervention. For example:
  a. Enthusiasm to use mobile phone/device
  b. Educational/literacy level
  c. Age (may be more sustainable among middle/older age groups)
  d. Local content/language of locality
  e. Cultural and social acceptance
- The needs of patients to access the required healthcare services. For example:
  a. Disease severity and comorbidities
  b. Barriers to accessing care/information
- The necessary enabling (personal and community) resources to facilitate the implementation of the intervention. This includes:
  a. Access to mobile phone/device *(essential)*
  b. Stable and accessible communication networks and technology infrastructure *(essential)*
  c. Convenience and privacy *(essential)*
  d. Socio-technical support *(essential)*
  e. Affordable services *(critical)*
  f. Awareness raising *(for increased participation)*

Provider context factors

- The personal characteristics of healthcare providers, which predispose them to deliver health services through a mHealth intervention. For example:
  a. Experience and competence
  b. Positive attitude toward technology
  c. Basic knowledge of the technology involved
  d. Fluency in language of locality
  e. Understandable language of communication among users and technical support team *(software developers)*
- The needs of healthcare providers to deliver the required healthcare services. For example:
  a. Characteristics of disease conditions *(extent, severity)*
  b. Characteristics of diagnostic and treatment tasks
  c. Burden of workload
  d. Adequacy of referral and transport systems
- The necessary enabling (personal and community) resources to facilitate the utilization of the intervention. This includes:
  a. Access to mobile phone/device and stable networks *(in underserved communities)*
  b. Easy portability and operability *(features, apps, functionalities, etc.)*
  c. Available basic infrastructural resources *(good roads, ambulance services)*
  d. Suitability and equivalence to existing/alternative care processes *(attractive)*
  e. Tolerable burden of workload and incentives *(essential)*
  f. Maintenance-technical support *(essential)*
  g. Continuous training and sensitization
  h. Low operating costs and available funds/logistics
  i. Policy and regulation *(network/data protection, staff job descriptions, and contracts, etc.)*

patients with NCDs, but the causal mechanisms explaining why, how, for whom, and in what circumstances these interventions work used to be unexplored. Our realist review shows that the contribution of mHealth interventions to improved treatment and care for patients with NCDs is that they facilitate (remote) access to previously unavailable — and often specialized — services. In addition, our framework for understanding mHealth interventions illustrates that predisposing characteristics and needs of patients and healthcare providers as well as the availability of enabling resources in the community influence the perceptions of patients and providers that mHealth interventions are useful and easy to use — and these perceptions are essential for the successful implementation of an mHealth intervention.

The implication of these findings for policy makers and program managers is that predisposing characteristics and needs of patients and providers as well as the necessary enabling resources should be considered during the planning stages prior to the introduction of an mHealth intervention. In addition, researchers would benefit from placing greater attention on the context in which mHealth interventions are being implemented — as the context largely determines the predisposing characteristics and needs of patients and providers as well as the enabling resources — instead of focusing (too strongly) on the technical aspects of these interventions.

Additional files

Additional file 1: List of databases accessed and the search strategies used. (DOCX 20 kb)

Additional file 2: Theories included or excluded in review. (ZIP 28 kb)

Additional file 3: Description of the included articles providing the information for the synthesis and conclusions in this review. (DOCX 24 kb)

Abbreviations

C-M-O: Context-Mechanism-Outcome; mHealth: mobile phone-based health; NCD: non-communicable disease; SSA: sub-Saharan Africa; WHO: World Health Organization

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DO and WQ conceived and designed the study. DO and VS collected data. DO prepared an initial draft of the manuscript, which was subsequently revised by VS and WQ. All authors participated in data synthesis and analysis, and all read and approved the final manuscript.

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The authors declare that they have no competing interests

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2.3 Example from the field

What effect would mHealth interventions have at the diabetes clinic in Kumasi, Ghana?

Article under review in '*Ghana Medical Journal*' during submission of dissertation:

Stephani, V., Opoku, D., Otupiri, E. Determining the potential of mobile-phone based health interventions in sub-Saharan Africa: a study from Kumasi, Ghana

Full title: Determining the potential of mobile phone-based health interventions in sub-Saharan Africa: a study from Kumasi, Ghana

Running title: Determining the potential of mHealth

Abstract

Background: Numerous reviews have reported generally positive outcomes of mobile phone-based health (mHealth) interventions in the sub-Saharan African countries, also for people with non-communicable diseases.

At the same time the mHealth landscape is burdened by a lack of sustainability. It has been shown that several context factors influence a successful implementation. There is a need to analyse these context factors before the development and implementation of mHealth interventions.

Method: The clinical setting of the study was the 'Komfo Anokye Teaching Hospital' in Kumasi, Ghana. Patients attending the diabetes clinic were surveyed. Questions were derived from a recently published realist review, which identified important factors influencing the long-term success of mHealth in the sub-Saharan African region.

Results: One hundred and fifty (150) patients were surveyed. The survey revealed that patients at the diabetes centre had a positive attitude towards mobile phones, but also a low familiarity with its functionalities. Whereas patients faced several access barriers to care, most enabling resources for the successful and sustainable implementation of mHealth interventions such as the access to mobile phones and electricity were available.

Conclusion: It was successfully shown how a preliminary analysis of the potential for mHealth can be performed. There is a high potential for mHealth in the setting of the diabetes clinic in Kumasi, Ghana. In a next step, mHealth interventions should be developed and tested in a larger study.

Keywords: Ghana, mHealth, Diabetes, potential

Introduction

The rapidly growing mobile phone infrastructure in sub-Saharan African (SSA) countries has led to the emergence of mobile phone-based health interventions (mHealth interventions) over the past decade [1-3]. Numerous reports and reviews have reported that mHealth can have a positive effect on health outcomes, also for patients with non-communicable diseases (NCDs) [4-6].

While the body of evidence for the efficacy of such interventions is growing, the mHealth landscape is burdened by a lack of sustainability. Many interventions are not extended beyond the duration of the project-phase [7].

Publications in the last years have therefore increasingly analysed why some interventions are more successful than others [8-10]. It was illustrated that several contextual factors, e.g. the availability of a reliable electricity infrastructure, heavily influence a successful and sustainable implementation [11]. However, many interventions were implemented without an analysis being made as to whether the respective context would be ready for mHealth [12,13]. It is important that future projects are only implemented after a preliminary analysis of the local context has been carried out. Therefore, the aim of this study is to analyse whether a mHealth intervention would work in a particular context of an SSA country.

Method

Context

The clinical setting of the study was a diabetes clinic, located at the Komfo Anokye Teaching Hospital (KATH) in Kumasi, Ghana. Diabetes was chosen because prevalence rates are constantly increasing in SSA and it is recognized as a serious challenge to the health care system in Ghana [14,15]. The KATH is a thousand bed tertiary medical facility located in Kumasi (capital of the Ashanti Region) and serves a population of over 4.7 million. It is the second largest hospital in Ghana [16]. The diabetic centre of the KATH is situated in the middle of the hospital campus.

Designing the questionnaire

The questionnaire was designed based on the contextual factors from a recently published realist review, which has identified the mechanisms that explain why some mHealth interventions are likely to be more effective than others [11]. The review is primarily based on Andersen's healthcare utilization model and describes the utilization and/or success of mHealth as a function dependent on predisposing characteristics, need and enabling factors (PNE factors) [17].

Table 1: PNE-Factors contributing to the success of mHealth, derived from Opoku et al [11]

Predisposing characteristics	- patients' cultural/social acceptance - positive attitude towards mobile technology - age, language, education level - socio-economic background
Needs	- barriers to care - disease severity
Enabling resources	- access to mobile phones - availability of a functioning stable telecommunication network - assurance of privacy - support from partners/relatives

For instance, if the target population has a very negative attitude towards mobile phones (*predisposing characteristic*), if there is no access to mobile phones (*enabling resource*) or if the disease severity is low (*need*), it is likely that a mHealth interventions would fail. The PNE-factors identified by the realist review are depicted in table 1. For the questionnaire, all PNE-factors were translated into closed and open-ended questions, as well as statements with a 5-point Likert-scale. Questions were discussed among VS and DO. The final questionnaire (additional file 1) was reviewed by all authors. The Committee on Human Research, Publications and Ethics, of Medical Sciences, Kwame Nkrumah University of Science and Technology approved the questionnaire and the study protocol in September 2017 (Reference number: CHRPE/RC/229/17).

Recruitment and data collection:

Patients suffering from diabetes were interviewed using a structured questionnaire during September - October, 2017. They were recruited while they were waiting for their appointment at the clinic. The study was introduced and briefly explained in the local language (Twi) or English depending on the respondent's choice. After the introduction, patients were directly asked whether they are willing to participate. If they agreed, informed consent was obtained. The interview was either conducted in Twi or English, as the participant preferred.

Results

In total, 150 people with diabetes participated in the study; 72% were female and the majority (83%) resided in urban areas. Patients had been living with the disease on average for 11.5 years. Most did not know which type of diabetes they have: 17% knew that they are diagnosed with type 2 diabetes and 7% reported to have type 1 diabetes.

Predisposing characteristics:

The predisposing characteristics of the patients from the diabetes clinic are depicted in table 2. The results show that mobile phones were widely used in patients' communities, and that the attitude towards mobile phones was very positive. However, the familiarity with mobile phones appeared to be moderate. All patients knew how to make and receive calls, but only 22% were able to text with the phone, and only 9% were able to browse the internet. The average age of the patients was 58 years. The majority said that they received secondary school or higher level of education, but 43% stated that they could neither read nor write. English was spoken by two thirds of the patients; the other third spoke only Twi.

Table 2: Predisposing characteristics of patients with diabetes

Age (years)	58 (+/- 10.32)				
Speak English	105 (70%)				
Non-literate	64 (43%)				
Regular income	87 (58%)				
Education level:					
None	27 (18%)				
Primary	40 (27%)				
Secondary	71 (47%)				
Tertiary	12 (8%)				
Main functions of phone usage:					
Calling and receiving	145 (100%)				
Texting	32 (22%)				
Internet	13 (9%)				
Using apps	22 (15%)				
	1 Strongly agree	**2 Agree**	**3 Neither**	**4 Disagree**	**5 Strongly disagree**
"Mobile phones are very common and widely used in my community"	102 (68%)	43 (28%)	3 (2%)	2 (1%)	0 (0%)
"I am familiar with using a mobile phone"	30 (20%)	69 (47%)	30 (20%)	13 (9%)	6 (4%)
"I have a positive attitude towards a mobile phone"	122 (82%)	17 (11%)	5 (3%)	4 (3%)	1 (1%)

Needs

On average, the patients needed almost 100 minutes to get to the diabetes clinic. They strongly agreed with the statement that the cost of the treatment is too expensive, and that adhering to the treatment is difficult. Satisfaction with the availability of the health staff and overall treatment appeared to be moderate. Moreover, many reported that they suffer from complications due to their diabetes, and almost all (85%) stated suffering from other diseases in addition to diabetes. Hypertension was the most often mentioned co-

morbidity followed by eye-problems and diseases such as typhoid or asthma. All need factors are depicted in Table 3.

Table 3: Needs of patients with diabetes

Patients with co-morbidities	128 (85%)				
Distance between home and diabetes clinic	96.9 min				
	1 Strongly agree	**2 Agree**	**3 Neither**	**4 Disagree**	**5 Strongly disagree**
"The cost of the treatment is too expensive"	83 (56%)	32 (22%)	19 (13%)	10 (7%)	5 (3%)
"Following and adhering the diabetes-treatment is difficult"	60 (40%)	26 (17%)	3 (2%)	42 (28%)	18 (12%)
"I suffer from complications due to my diabetes"	60 (40%)	55 (40%)	14 (9%)	13 (9%)	7 (4%)
"The diabetes treatment is sufficient and satisfies all my health needs"	23 (15%)	53 (36%)	29 (20%)	28 (19%)	16 (11%)
"The health staff is always available when I need them"	61 (41%)	18 (12%)	21 (14%)	37 (25%)	13 (9%)

Enabling resources

Nearly 100% of the patients with diabetes had access to a mobile phone. The vast majority (91%) owned a mobile phone, while 5% shared the phone with their family members. Forty-two (42%) of the mobile phones were smartphones (phones capable of doing more than text messaging and making/receiving calls). Most agreed with the statement that there is always electricity to charge the phone. The mobile phone network was perceived as less reliable than the electricity network. In terms of the support by family and relatives, many patients assumed that they would receive their support when healthcare is delivered with a mobile phone. In case a phone is broken many reported that they would rather buy a new one than repair it. One third mentioned that they cannot assure privacy on their phone, e.g. because family members have access to their phone (Table 4).

Table 4: Enabling resources for patients with diabetes

Access to a mobile phone					
Personal mobile phone	136 (91%)				
Family mobile phone	8 (5%)				
No mobile phone	6 (4%)				
Access to a smartphone	62 (42%)				
Access to a cell phone	82 (58%)				
Recharging the phone					
Every day	44 (30%)				
Every couple of days	77 (54%)				
Every week	23 (16%)				
Repairing the phone					
Never	118 (82%)				
Once per year	21 (15%)				
More often	5 (3%)				
Health support from the family	137 (55%)				
	1 Strongly agree	**2 Agree**	**3 Neither**	**4 Disagree**	**5 Strongly disagree**
"There is a constant supply of electricity to charge the phone"	80 (55%)	50 (34%)	13 (9%)	2 (1%)	1 (1%)
"The mobile phone network is reliable and functioning stable"	35 (24%)	45 (31%)	45 (31%)	16 (11%)	5 (3%)
"I have convenience, autonomy and privacy on the phone"	82 (56%)	8 (5%)	9 (6%)	31 (21%)	17 (12%)
"Services on the phone (e.g. airtime) are affordable"	66 (46%)	31 (21%)	8 (6%)	25 (17%)	15 (10%)

Discussion

This is the first study which determined the potential of mHealth by using PNE factors.

In the case of the diabetes clinic in Kumasi, Ghana it turned out that the predisposing characteristics (e.g. high acceptance of mobile phones in the community, positive attitude towards mobile phones), the higher need (e.g. patients faced several access barriers to care, suffered from diseases beside of their diabetes) and the availability of the enabling resources (e.g. access to mobile phones, electricity) would translate into a high potential for future mHealth interventions.

The study provides important findings on several factors specific to the patients from the diabetes clinic in Kumasi and shows therefore the importance of such a preliminary analysis:

First, the subscription rate at the Diabetes clinic (meaning the share of people who have access to a phone) was nearly 100 %. This is higher than average subscription rates in Ghana (67%) [18]. A

mobile-phone based health interventions would therefore be able to include almost all patients from the clinic.

Second, 42% of the patients had access to smartphones (phones capable of using third party applications and browsing the internet). This is higher than the total average in SSA (34%) [18]. This bears opportunities for future mHealth interventions, since the ability to provide information via applications, in combination with voice calls or text messages, is perceived as a key to improving the situation of patients and their access to care [19].

Third, despite high cultural and social acceptance of the mobile technology, the familiarity with mobile phones turned out to be low. This could be due to the higher average age of the here analysed community. Elderly people tend to have a lower familiarity with the full spectrum of all mobile phone functions [20]. However, a low 'phone literacy level' needs to be considered when implementing an intervention. Providers need to ensure, that the patients are capable of using all, or at least most, functions of the intervention. This may require workshops or training-lessons which would also improve patients' overall ability to use the mobile phone as a tool to research, organize, evaluate and communicate information [21].

The analysis has implications for policy makers, researchers and industry representatives who are involved in the development of mHealth solutions. The approach could be adapted and utilized in order to identify regions with a higher potential for mHealth. If a region qualifies for mHealth (such as the diabetes centre at KATH), prototypes of particular interventions (e.g. an appointment reminder system via SMS) could be developed and tested. Furthermore, some aspects, such as the identified low familiarity with mobile phones, could be already considered during implementation-phase. This 2-step approach (feasibility analysis plus large-scale study with prototypes) could be used as a *cookbook* towards a more sustainable implementation of mHealth. And it would therefore counteract the widespread problem that many mHealth interventions have not moved beyond the pilot phase.

Strengths and limitations of the study

A major strength of the study is that the analysis and the questionnaire are scientifically grounded.[11] However, other factors such as an enabling legislation or the planning and funding of the project-stakeholders, might also have a significant influence on a successful implementation and were not considered in this analysis.

Another limitation of the study is its sample size. For a more representative sample more people would have to be interviewed over a longer period of time. A further limiting factor could have been that all outcome parameters are self-reported. Some parameters may be therefore biased, e.g. self-reported familiarity with mobile phones or the distance to the clinic. However, the interviewer tried to avoid this bias by explaining and repeating a question, when it was needed.

Finally, the study included only patients who have been diagnosed with diabetes and have already been to the diabetes clinic in Kumasi. It is estimated that two thirds of all people with diabetes remain undiagnosed and have therefore never attended a diabetes clinic [14]. The identified potential does therefore only count for the patients of the diabetes clinic at KATH and cannot simply be transferred to other population-groups.

Conclusion

It has been successfully demonstrated how the potential of mHealth can be measured in a particular environment. In the case of diabetes patients from Kumasi, Ghana, the potential was shown to be high. The use of mHealth would therefore most likely result in better treatment and care.

Abbreviations Chapter 2.3

KATH	Komfo Anokye Teaching Hospital
mHealth	Mobile health
NCDs	Non-communicable diseases
PNE factors	Predisposing characteristics, need and enabling factors
SSA	Sub-Saharan African

References Chapter 2.3

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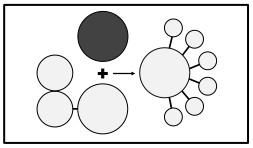
Chapter 3:
The need for mHealth



How do people from Sub-Saharan Africa who are diagnosed with Diabetes currently self-manage the disease?

Article:

Stephani, V., Opoku, D., & Beran, D. (2018). Self-management of diabetes in Sub-Saharan Africa: a systematic review. *BMC public health*, *18*(1), 1148.

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RESEARCH ARTICLE Open Access

Self-management of diabetes in Sub-Saharan Africa: a systematic review

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Abstract

Background: The prevalence of diabetes in sub-Saharan Africa has increased rapidly over the last years. Self-management is a key element for the proper management, but strategies are currently lacking in this context. This systematic review aims to describe the level of self-management among persons living with type 2 diabetes mellitus in sub-Saharan Africa.

Method: Relevant databases including PubMed, Web of Science and Google Scholar were searched up to September 2016. Studies reporting self-management behavior of people with type 2 diabetes mellitus and living in sub-Saharan Africa were included.

Results: A total of 550 abstracts and 109 full-text articles were assessed. Forty-three studies, mainly observational, met the inclusion criteria. The studies showed that patients rarely self-monitored their glucose levels, had low frequency/duration of physical activity, moderately adhered to recommended dietary and medication behavior, had poor level of knowledge regarding diabetes related complications and sought traditional or herbal medicines beside of their biomedical treatment. The analysis also revealed a lack of studies on psychosocial aspects.

Conclusion: Except for the psychosocial area, there is a good amount of recent studies on self-management behavior of type 2 diabetes mellitus sub-Saharan Africa. These studies indicate that self-management in sub-Saharan Africa is poor and therefore a serious threat to the health of individuals and the health systems capacity.

Background

Although the true burden of diabetes in sub-Saharan Africa (SSA) is unknown, it is recognized as a serious challenge to health systems [1, 2]. Current prevalence-estimates range between 2.1 and 6.0%, and the number of people suffering from the disease is likely to double within the next 25 years [3]. In order to reduce the burden posed to health systems and affected individuals, patients with diabetes need to adopt certain self-management behaviors. The American Diabetes Association (ADA) has therefore defined a list of essential self-care behaviors, which have been found to be positively correlated to good glycemic control and a reduction of complications [4, 5]. Diabetes Self-Management Education (DSME) is critical for informing patients about these essential self-care behaviors. Currently, DSME in most African countries is limited in scope, content and consistency and it is not clear how patients from SSA manage their diabetes [6–8]. Therefore, the aim of this systematic review is to assess the status of self-management of people with diabetes in SSA, and to analyze to what extent they follow the recommended self-management behavior.

Method

Search strategy and screening procedure

A preliminary search was performed in order to find appropriate terms. The final search strategy was discussed among the authors (VS and DO). Search term categories belonged to: "Diabetes", "Sub-Saharan Africa" and "Self--management". Databases included in the search were PubMed, Web of Science and Google Scholar. In addition, reference lists of screened studies were checked. An example of the performed search and the key words used is provided in Additional file 1.

The search-strategy yielded 741 publications (MEDLINE 436, Web of Science 232, Google Scholar 50). After removal of duplicates, 550 studies remained. VS and DO

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reviewed titles, keywords and abstracts independently and discussed the eligibility for full-text inclusion.

After discussing results and resolving disagreements, full texts of the remaining 109 publications were screened for eligibility. The overlapping rate of included and excluded studies was 87% between both authors. Disagreements were discussed and resolved by consensus, resulting in forty-three articles included in this review.

Inclusion criteria

Studies were included for this review if they met the following inclusion criteria:

- They took place in at least one country from sub-Saharan Africa, as defined by the World Bank [9]
- Participants were people living with type 2 diabetes mellitus (which accounts for 90% of all diabetes cases in SSA [10])
- The study analyzed self-management behavior of type 2 diabetes patients as defined by the American Diabetes Association (ADA) as described in Table 1. If a study analyzed both, type 1 and type 2 diabetes, it was only included if the outcome measures (or self-management behavior) for patients with type 2 diabetes were presented separately
- Published anytime before September 2016 (with no limit concerning the start date)
- The study was published in English or German

Table 1 presents all self-management related outcome categories and specifies them according to the recommendations given by the ADA [11].

Data extraction, analysis, and synthesis

Two data extraction templates (using Microsoft Excel) were developed to gather all data relevant for the analysis. One template was used for collecting characteristics of included studies (e.g. year of publication, country, number of participants, number of woman/man, age); study results and relevant information on self-management were collected in a second template. Qualitative and quantitative results were combined and summarized according to their specific area of self-management. Quantitative results were rounded to the nearest full percent and study-size-weighted arithmetic averages were calculated if eligible.

Risk of bias was assessed and information about the quality of the included studies were derived from the text using quality-assessment tools for cross-sectional studies [12], pre-post studies [13] and randomized controlled trials [14]. Additional file 2 contains the full details of a PRISMA checklist for this review and the full risk assessment of the included studies can be found in the Additional files 3, 4, 5.

Results

The final analysis included forty-three studies. Figure 1 illustrates the literature search and selection process. Common reasons for exclusion were: lack of results, reports from non-SSA countries, or focus on other diseases than type 2 diabetes mellitus. Publication dates were between 2002 and 2016. The majority of studies ($n = 33$) were published after 2010.

Description of included studies

Study characteristics such as the year of publication, sample size, study design and the measured outcome parameters of the forty-three included studies are summarized in Table 2. Most studies took place in Nigeria ($n = 13$) and South-Africa ($n = 11$), followed by Ghana ($n = 6$), Uganda ($n = 4$), Ethiopia (n = 3), Cameroon ($n = 2$), Tanzania, Kenya, Sudan, Zimbabwe (n = 1 each). Thirty-five studies were observational (mostly cross-sectional, only one longitudinal study [15]), while six studies were experimental (two studies described the same intervention [16, 17]).

Table 1 Specification of categories and included outcomes used for the analysis of self-management as given by the ADA [5]

Category	Specification	Included Outcomes
Healthy eating	General awareness of its importance, awareness of importance of measuring and portioning meals, adherence to an eating plan	Eating behavior, knowledge on diet recommendations, presence of and adherence to a diet plan
Being active	General awareness, existence of and adherence to an activity plan (with information on frequency, intensity, time and type of activity), glucose checking before and after sports	Knowledge on activity recommendations, presence of and adherence to an activity plan
Monitoring	General awareness, conducting SMBG (including information on frequency), keeping record of results, ability to analyze results	Awareness of SMBG, Availability of a glucose meter at home, frequency of SMBG
Taking Medication	Awareness of the kind of prescribed medicine, adherence to the medication plan	Prescribed medication, medication adherence, awareness that medication needs to be taken throughout the life-time
Reducing Risks	Awareness of possible complications, tobacco consumption, regular doctor appointments, taking care of feet	Awareness of consequences of uncontrolled Diabetes, consultations of specialists, self-care behavior, cigarette intake
Psychosocial Aspects	Environmental, social, emotional burden of diabetes	Support by relatives, emotional and environmental aspects

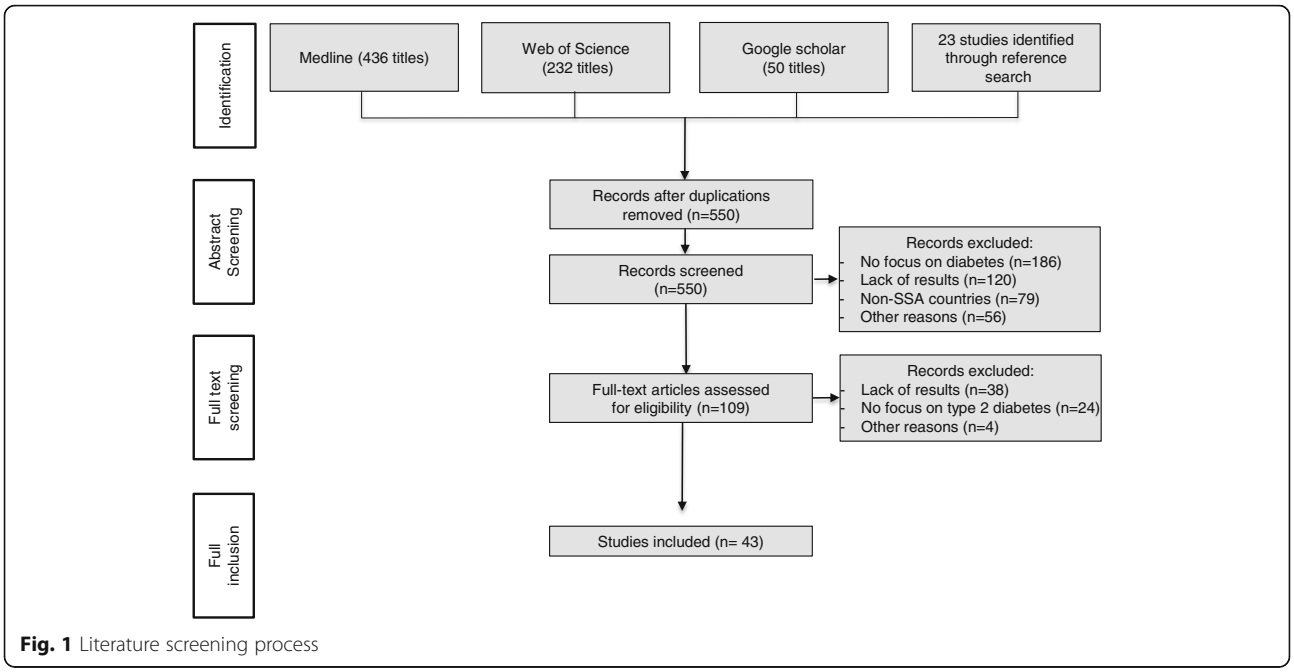

Fig. 1 Literature screening process

8281 participants with type 2 diabetes were included with an average age above 50 years, and out of which 4676 were women (3 studies did not indicate how many men or women were included). People had been living with their diabetes on average over 5 years. Most studies dealt with the self-management area of medication ($n = 26$), followed by the assessment of nutritional intake and the engagement in physical activity ($n = 21$ and $n = 20$). Fifteen studies were about risk reduction and self-monitoring of blood glucose, respectively. Only three studies considered psychosocial aspects of people with diabetes.

All experimental studies tested various forms of DSME programs, with either a pre-post design [18, 19], or a control group [16, 17, 20] study-design. One intervention was done by counselling and educating the patients on medication adherence at the beginning of the study [21]. In another study [18] patients attended a one-day education program. Two studies tested the impact of 4 one-hour group education sessions about the importance of nutrition, physical activity, adherence to medication and risk reduction [19, 20]. A more comprehensive intervention tested the outcome of weekly group education sessions on nutritional aspects, combined with monthly follow up sessions plus education in vegetable gardening [16, 17].

Study results on self-management

Healthy eating

Twenty-one studies included information on healthy eating self-care behaviors. Participants understood that unhealthy eating is a dominant cause of diabetes [16, 22, 23] and that it is important to take aspects such as the sugar-, salt- or fat-level of consumed food into consideration [19, 22, 24–26]. However, misconceptions and gaps of knowledge were present; particularly about the definition of high risk food [19], the sugar-level of food [24, 27] and the underlying diabetes related metabolic mechanisms [24]. As found in one study, respondents did not know the proportion of food they were allowed to eat [24]. And another study showed that mostly men talked about regular meals, while most women did not [28]. 'Positive dietary behavior changes' because of their diabetes were reported by 33% of Nigerian [29], 51% of Ghanaian [30] and most of South African [16] participants. Regarding the adherence to a certain diet plan, 60% [31], 70% [32] and 87% [33] stated that they 'followed an eating plan'.

Four experimental studies assessed the impact of counseling sessions on the adherence to diet plans. Two interventions assessed the impact of four one-hour group education sessions on nutritional aspects: One increased the level of adherence significantly from 4.8 to 5.9 days per week [19] and one decreased the adherence non-significantly from 4.8 to 4.6 days per week [20]. The third intervention, which combined weekly group educational sessions on nutritional aspects with monthly follow up sessions and education in vegetable gardening, significantly reduced the intake of energy and starchy food [17]. The fourth intervention, which consisted of weekly contacts among the patients over a period of four months, was found to improve the healthy eating habit of patients significantly from 11.5 points to 22.4 points (out of 25 total points on the 'Diabetes Self-Management Assessment and Reporting Tool') [18].

Table 2 Characteristics of included studies

	Author	Year	Country	Study Type	Sample characteristics				Reported outcomes					
					Sample size	Male	Female	Average age	Healthy eating	Being active	Monitoring	Medication	Risk Reduction	Psychosocial
Observational studies	Awah [57]	2008	Cameroon	cross-sectional	20	11	9	62.5				x		
	Awah [15]	2009	Cameroon	cross-sectional	65	30	35	–						
	Kassahun [43]	2016	Ethiopia	cross-sectional	309	189	120	50			x	x		
	Sorato [31]	2016	Ethiopia	cross-sectional	194	95	99	50.3	x	x	x	x		
	Wabe [42]	2011	Ethiopia	cross-sectional	384	186	161	48.3			x	x	x	
	Bruce [50]	2015	Ghana	cross-sectional	200	95	105	–				x	x	
	de-Graft Aikins [23]	2014	Ghana	cross-sectional	20	2	18	60	x		x	x	x	
	Doherty [27]	2014	Ghana	cross-sectional	30	10	20	48.7	x					
	Mogre [30]	2016	Ghana	cross-sectional	222	74	148	48.4	x	x				
	Obirikorang [54]	2016	Ghana	cross-sectional	630	243	387	55.2					x	
	Obirikorang [26]	2016	Ghana	cross-sectional	543	232	311	51.1	x	x			x	
	Matheka [44]	2013	Kenya	cross-sectional	187	–	–	–			x			
	Adibe [38]	2011	Nigeria	cross-sectional	314	136	178	43		x			x	
	Adisa [24]	2009	Nigeria	cross-sectional	121	60	61	–	x	x	x	x		
	Adisa [29]	2011	Nigeria	cross-sectional	114	51	63	61.3	x	x	x	x		
	Awotibede [37]	2016	Nigeria	cross-sectional	299	105	194	51.9		x				
	Ezuruike [48]	2016	Nigeria	cross-sectional	112	43	69	46				x		
	Iwuala [47]	2015	Nigeria	cross-sectional	100	38	62	59.9			x			
	Jackson [51]	2015	Nigeria	cross-sectional	303	171	132	54.5				x		
	Ogbera [40]	2011	Nigeria	cross-sectional	150	50	100	69.9		x	x	x		x
	Onakpoya [49]	2010	Nigeria	cross-sectional	83	32	51	57.5				x	x	
	Oyetunde [52]	2014	Nigeria	cross-sectional	102	35	67	59.6				x		
	Yusuff [46]	2008	Nigeria	cross-sectional	200	110	90	–				x	x	
	Jackson [36]	2014	Nigeria	cross-sectional	303	132	171	50		x	x	x	x	
	Adeniyi [22]	2015	South Africa	cross-sectional	17	6	11	58.5	x	x		x	x	x
	Haque [53]	2005	South Africa	cross-sectional	–	–	–	–				x		
	Matwa [55]	2003	South Africa	cross-sectional	15	5	10	61.4					x	
	Mendenhall [56]	2015	South Africa	cross-sectional	27	–	27	59				x		
	Nthangeni [33]	2001	South Africa	cross-sectional	288	133	155	62	x			x		
	Okonta [39]	2014	South Africa	cross-sectional	217	–	–	51	x	x				
	Steyl [35]	2014	South Africa	cross-sectional	26	11	15	58.9	x	x		x		

Table 2 Characteristics of included studies *(Continued)*

	Author	Year	Country	Study Type	Sample characteristics				Reported outcomes					
					Sample size	Male	Female	Average age	Healthy eating	Being active	Monitoring	Medication	Risk Reduction	Psychosocial
	Abdelgadir [45]	2006	Sudan	cross-sectional	193	95	98	50			x			
	Kamuhabwa [32]	2014	Tanzania	cross-sectional	469	171	298	54.9	x	x	x	x		
	Hijelm [34]	2008	Uganda	cross-sectional	25	10	15	–	x	x		x	x	
	Mayega [28]	2014	Uganda	cross-sectional	96	48	48	47.5	x	x				
	Nielsen [41]	2016	Uganda	cross-sectional	10	6	4	65.6	x	x	x			
	Hijelm [25]	2010	Zimbabwe	cross-sectional	21	10	11	48	x	x	x		x	
Experimental studies	Awodele [21]	2015	Nigeria	pre-post, quasi-experimental	152	47	105	65				x		
	Baumann [18]	2015	Uganda	pre-post, quasi-experimental	25	7	18	53	x	x		x		
	Mash [20]	2014	South Africa	RCTs	1570	411	1158	56.4	x	x		x	x	
	Muchiri [16]	2015	South Africa	RCTs	41	5	36	59.4	x					
	Muchiri [17]	2015							x					
	van der Does [19]	2013	South Africa	RCTs	84	68	16	51.6	x	x		x	x	x

Being active

Seventeen observational studies assessed physical activity behaviors and three interventional studies tested the impact of group educational programs.

The majority of participants in six studies were aware of the importance of being active and of doing regular aerobic exercises (such as brisk walking or climbing staircases) as part of their non-medical treatment [22, 25, 34–37]. However, respondents in three studies showed that a majority did not understand the relevance of physical activity as part of their glycemic control and therefore revealed gaps in knowledge on recommended type, frequency and duration of physical activity [24, 38, 39]. In addition, men and women were not always equally well-informed [34].

No study mentioned that participants had an activity plan or kept records of type, frequency, time and intensity of all exercises, or did glucose checking before and after doing sports.

Five observational studies indicated a low engagement in practicing exercises: 29% mentioned to 'practice exercise' [29], and only 25% [19], 27% [37], 33% [32] and 46% [40] said they were engaged in exercises on a regular basis. The most common type of exercise among participants was brisk walking [26, 37].

Less than half of the people who were engaged in regular exercises did their exercise daily [26] and only 39% at least in 30 min of duration [37]. In one study [31], 50.5% of respondents from Ethiopia reported to be engaged in at least 30 min of physical activity for total of ≥3 days per week.

Interventions with frequent group education sessions had mixed results based on the studies identified. One study found a significant increase in physical activity from 3 to 4.5 days per week [19], one found a non-significant increase from 4.1 to 4.5 [18], and one found a non-significant decrease from 4 to 3.9 days per week [20].

Monitoring

Fifteen observational studies reported on patients' behavior regarding monitoring of blood glucose. The vast majority of respondents from Nigeria [24] and Zimbabwe [25] reported to not be aware of SMBG. Thirteen studies observed how many of the study participants had the possibility to self-monitor their blood glucose level and had access to a glucometer at home (Fig. 2). The results indicate a very low degree of SMBG, ranging from a study from Uganda, where none of the patients had access to a glucose meter at home [41] to one study from Nigeria with 43% of all patients doing glucose testing at home [40]. On average only 15% of all patients were able to test his or her blood glucose level at home [23, 25, 29, 31, 32, 40–47].

Most patients, who had access to a glucometer at home, checked their glucose level only once a month or at no regular interval [21, 45, 47]. Only 1% [21] and 2% [45] of respondents measured their glucose level on a daily basis. One study mentioned that women did SMBG more regularly than men [47]. Another study reported that half of those people who performed SMBG, also kept records of their results [40]. Most importantly, no study reported patients' ability to analyze test results and whether they know what to do if their glucose numbers are off target.

Medication

Twenty-three observational and three experimental studies included information on peoples' awareness and adherence to prescribed medication. The most common type of medication prescribed were oral hypoglycemic agents (*OHA*): On average, 86% were on OHA alone, while 7% were on a combination of OHA and Insulin and the remaining 7% were on Insulin alone [29, 31–33, 40, 42, 46, 48, 49]. The fact that diabetes drugs need to be taken throughout the life-time was known by the majority of patients in Nigeria [24, 29, 36] and Uganda [34].

Study	Country	Sample	Value
41	Uganda	10	0%
42	Ethiopia	384	3%
25	Zimbabwe	21	4%
23	Ghana	20	5%
43	Ethiopia	309	10%
31	Ethiopia	194	10%
44	Kenia	187	20%
45	Sudan	193	25%
29	Nigeria	114	25%
32	Tanzania	469	26%
46	Nigeria	200	32%
47	Nigeria	100	40%
40	Nigeria	150	43%

Fig. 2 Percentage of people who are able to self-monitor their blood-glucose level at home

Six observational studies assessed patients' medication adherence by using the Morisky Medication Adherence Scale (MMAS). It entails (8 or 4, depending on the MMAS-version) questions about the self-reported medical adherence. A perfect medication adherence is having a full score on the MMAS (meaning 8 or 4 points). Setting a cut-off point at 75% of the MMAS (indicating a moderate level of adherence), the adherence rate is on average 64% (see Fig. 3) [29, 32, 43, 46, 50, 51].

Six other studies asked for the non-adherence (instead of adherence) without utilizing a standardized questionnaire. The results ranged from 20% of people who had a "lack of adherence" [52], to 21% who stated that they "missed the medication" [42], to 35% who were classified as having a "poor adherence" [22], to half of all participants who reported that they "forget sometimes" to take their medication [24] and who do not "take the drugs on time" [40].

One study [53] asked the responsible diabetes doctors about their perception on patients' adherence to prescribed medication. They concluded that the majority of all patients are non-compliant with the pharmacotherapy.

All three experimental studies improved medication adherence. A one-day education program in combination with weekly contacts among participants improved the frequency of 'missed medication' from 1.9 to 1.6 (1 never, 5 daily) [18], and the four one-hour group education programs about self-care behaviors improved the medication adherence from 6.3 to 6.5 days a week [19] and from 6.8 to 6.9 [20] days a week. However, all of these improvements resulted to be non-significant.

Risk reduction

Thirteen observational studies and two interventional studies dealt with risk reduction. Participants had various levels of knowledge about general consequences and complications of uncontrolled diabetes. All respondents from Ghana attributed complications to medical non-adherence [23] and most patients from a South African study [22] connected their already developed complications (e.g. foot problems, sexual dysfunction) to uncontrolled diabetes. However, only few participants were aware of the specific complications that could develop: the most frequently named complications were foot ulcers (on average named by 45%) and retinopathy (on average 36%) [42, 46, 50, 54, 55]. Other complications named were neuropathy (31%), sexual dysfunction (26%) [50, 54], or nephropathy (18%) [42, 50, 54]. The prevalence of cigarette smoking, which contributes to developing complications, appeared to be not very present and accounted on average for only 10% of all participants [18, 20, 31–33, 36, 43, 50, 54].

Having regular appointments at medical specialists (e.g. eye-doctor or dentist) is an important aspect of risk reduction. 77% of patients in one Nigerian study knew that they should go to the doctor when they have changes in their eyesight [38]. In another study 29% stated that they had previous dilated eye examinations [48]. On average, 80% [36, 38] of participants knew that they should take care of their teeth. No study assessed the frequency of visits at medical specialists.

Proper foot care is also critical for the reduction of risks. Most Nigerian diabetes patients knew that they have to take extra care of their feet [36]. In Zimbabwe only half of one group had been informed about foot care, and only with a limited content [25]. There was also a men-women discrepancy in one Ugandan study: women were better informed on how they should take care of their feet then men [34]. In one South African study all respondents reported that they adhered to the recommended foot care [55]. Two studies looking at group education programs about self-care behaviors, improved the foot care of participants non-significantly from 5.5 to 5.7 days per week [20] and significantly from 4.5 to 5.8 days per week [19].

Psychosocial aspects

Only three observational studies reported about the psychosocial aspects of having diabetes.

One study mentioned that the majority of patients received support from their family [22]. Stress and insufficient sleep due to the diabetes appeared to be below 1% among South African patients [19] and another study revealed a moderate level of emotional distress [40]. However, no study on environmental or other social aspects of living with diabetes was identified.

Alternative medicine

Although not included in the ADA framework (Table 1), alternative medicine was seen as an important component in

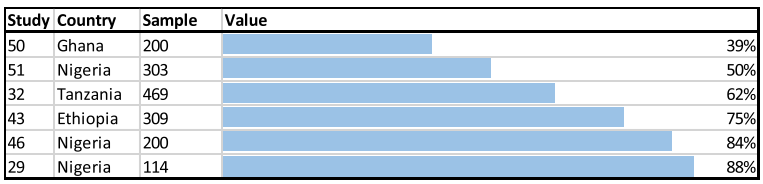

Fig. 3 'Morisky Medication Adherence Scale' results showing the percentage of people with a moderate medication adherence (> 75% of adherence)

SSA for self-management: Eleven studies addressed the utilization of alternative medicine by study participants. This shows that the western based model of self-management fails to describe the entire self-management behavior of diabetes patients in SSA. 11% of South African patients sought traditional healers [56] and many respondents from Cameroon stated that they used traditional diagnostic tools, such as tasting their urine for glucose [15]. Herbal medicine was equally valued with biomedical therapy [57] and frequently used [25]. The use of herbal medicines as part of the diabetes treatment was on average 32% [21, 34, 46, 48]. For some participants, it was grounded on their negative feelings and dissatisfaction towards biomedicine [15] or the belief that diabetes is a supernatural problem caused by witchcraft or fate [23, 25, 55]. To others, the willingness to treat diabetes took them to a 'modern' health facility but the willingness to cure diabetes took them to a traditional healer [15, 33, 56].

Discussion

Main findings and recommendations

This is the first systematic review which analyzes the self-management behavior of people with diabetes in SSA. Studies which analyzed **nutritional** aspects ($n = 20$) revealed a moderate level of adherence to recommended diet plans, with adherence rates ranging from 33 to 87% [16, 29–33]. Moreover, patients demonstrated a basic understanding of the right eating habits [16, 19, 22–26], but also revealed several gaps in their knowledge (e.g. regarding the sugar-level of food) [19, 24, 28]. Those which analyzed **physical activity aspects** of self-management behavior (n = 20) found that most patients were aware of the importance of aerobic exercises [22, 25, 34–37]. However, adherence rates to exercise plans varied between 29 and 46% [19, 26, 29, 31, 32, 37, 40]. Studies with information on the **medication** ($n = 26$) showed that Medication-adherence, measured by the MMAS questionnaire, was on the average 64% [29, 32, 43, 46, 50, 51]. Other studies, which utilized other (non-MMAS) methods confirmed these moderate results [22, 24, 40, 42, 52]. **Risk reduction** was assessed by 15 studies. Patients connected complications to uncontrolled diabetes, but only few were aware of the specific complications that can be developed [22, 23, 42, 46, 50, 54, 55] and how they can be prevented [25, 34, 36]. There was no study assessing the frequency of visits at medical specialists (such as an eye doctor or dentist) and only one study mentioned that all patients adhered to the recommended foot care [55]. Only three studies reported on **psychosocial aspects**. They indicated that people with diabetes seem to have a very low emotional distress level [19, 22, 40]. Although not part of the ADA self-management guidlines the use of **herbal medicine** and traditional healers was frequently mentioned [21, 25, 34, 46, 56–58]. Lowest adherence rates were assessed for patient's ability to **self-monitor their blood glucose**. On average, only 15% were able to test the blood glucose at home [23, 25, 29, 31, 32, 40–47] – and only very irregularly [19, 21, 45, 47]. Studies which tested **DSME programs** ($n = 6$) showed significant improvements for eating and activity habits [16, 18, 19], medication adherence [21] and risk reduction behavior [19]. Improvements were ascertained for the adherence to activity and medication plans [18–20] and risk reduction behavior [20], but without significance. Also without any significance, negative effects were shown in only one study for eating and activity behaviors [20].

This review is important because it shows that self-management of diabetes in SSA is insufficient. Particularly, the lack of physical activity, the inappropriate risk reduction knowledge and behavior, and the missing ability to self-monitor blood glucose are a serious threat to good glycemic control. Medication and nutritional adherence appeared to be better but are still sub-optimal. By comparing the results with results from other countries outside SSA, we observe a similar 'ranking': The three elements 'physical activity', 'risk reduction' and 'SMBG' are also the most critical parts of self-management outside SSA (adherence rates of 45–54%), while the adherence to medication and nutrition plans is better: outside SSA medication plans are followed by 87% (vs 64% in SSA). And diet plans are followed by 76% outside SSA (vs 72% in SSA) [59].

Second, the review revealed that the (western-based) ADA model of self-management fails to describe all self-care activities in SSA. One third of all patients sought alternative medicine beside of their biomedical therapy (in non-SSA countries this is done by 8% [59]). For many people it is therefore part of the self-management. Future research should focus on the (unknown) ingredients of herbal medicines and their interactions with other taken medicines, such as OHA.

Third, the provision of structured DSME programs in SSA is found to be effective. Most of the measured self-management behaviors, such as the adherence to medication or diet plans, were significantly improved by DSME programs. This supports the existing literature, which has proven that DSME is effective in non-SSA countries [60]. Therefore, we recommend to improve the current distribution of structured context-adapted DSME programs in SSA. Important factors, such as the low access to blood glucometers or the utilization of alternative medicines, need to be considered when conceptualizing these programs. Other factors, which have not been addressed in this review, need to be considered as well, e.g. the shortages of healthcare workers [61] or the lack of medicines [62]. Moreover, the implementation of structured DSME programs could be supported by technology. So called mobile health (mHealth) solutions, which have

shown to be effective against non-communicable diseases [63], could be used to guide health professionals through the education process and to follow up with patients.

Last, our results showed that there is only very limited research on psychosocial aspects in SSA. In contrast to all other self-management factors, we identified only three studies on psychosocial aspects (e.g. 21 studies on nutritional behavior or 15 studies about SMBG). Therefore, future research should put a higher emphasis on the assessment of the psychosocial situation, because factors such as stress or the missing support by the family can have a highly negative impact on people with diabetes and are associated with non-adherence to medication regimen and other self-management behaviors [64].

Limitations

An important limitation of this review is that it combines studies from 10 countries, which are culturally and economically diverse. The generalizability of the results is therefore problematic, because it was not always clear whether the individual study results were representative (see risk of bias assessment, additional files 3-5). The studies also differ in their objective, e.g. while some evaluated DSME programs, others measured the adherence to OHA. However, combining studies from various countries with heterogeneous objectives is not unusual for reviews on diabetes in SSA [65]. Furthermore, methods applied to measure outcome-parameters varied among included studies. One example is the medication adherence: in some studies people where simply asked whether they "missed medication" or "forget sometime" to take their medication, while other studies used the standardized MMAS scale. Moreover, the analysis considers only patients who have been diagnosed with diabetes. It is estimated that around two thirds of all people who suffer from diabetes in SSA remain undiagnosed [3]. Another limitation concerns the method used by all included studies: most of the measured outcomes were self-reported. The use of self-reported measures, such as the medication adherence may underestimate the non-adherence of patients [52]. Multiple methods may be required to detect those who report adherence but who may in fact be non-adherent.

Conclusion

There is a good amount of recent studies on self-management behavior of type 2 diabetes in SSA. These studies indicate that self-management in SSA is poor and a serious threat to glycemic control. Particularly, self-monitoring of blood glucose, physical activity and risk reduction behavior are insufficient. More research on the psychosocial situation is needed. Future efforts and resource investments in public health systems need to strengthen the distribution of strucutred DSME programs which need to be adapted to the SSA-context.

Additional files

Additional file 1: Search strategy used. (DOCX 12 kb)
Additional file 2: PRISMA checklist. (DOCX 26 kb)
Additional file 3: Risk assessment for cross-sectional studies. (DOCX 21 kb)
Additional file 4: Risk assessment for pre-post studies. (DOCX 14 kb)
Additional file 5: Risk assessment for RCTs. (DOCX 13 kb)

Abbreviations

ADA: American Diabetes Association; DSME: Diabetes Self-Management Education; MMAS: Morisky Medication Adherence Scale; NCD: Non Communicable Diseases; OHA: Oral Hypoglycemic Agents; SMBG: Self-Monitoring of Blood Glucose; SSA: Sub Saharan Africa

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Availability of data and materials

The datasets supporting the conclusions of this article are included within the article and its Additional files 1, 2, 3, 4, 5.

Authors' contributions

VS conceived the idea, collected data, participated in analysis and drafting of manuscript. DO collected data and participated in analysis. DB participated in analysis. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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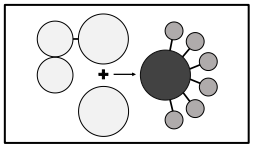
Chapter 4:
The implementation of mHealth



What are current drivers and inhibitors for the implementation of mHealth in African health systems?

Article:

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Victor Stephani

Effective and needed, but not used: Why do mobile phone-based health interventions in Africa not move beyond the project status?

Universitätsverlag der TU Berlin

Abstract

Introduction: Reviews have shown that mobile phone-based health interventions (mHealth interventions) are capable of improving health outcomes of patients in Africa. Particularly patients with chronic diseases such as non-communicable diseases (NCDs) benefit from mHealth interventions. But the current African mHealth landscape suffers from the problem of the so called pilotitis: Most projects are stopped after the pilot and the funding of the donors has ceased and do not become part of the health systems. Therefore, the aim is to assess the process of implementation and to identify the reasons for the lacking integration of mHealth interventions against NCDs in sub Saharan African health systems.

Method: 10 countries from Sub-Saharan Africa (SSA) were selected for the analysis. For the assessment a catalogue of indicators was developed. The catalogue and its indicators were derived from the 'health system building blocks framework' by the World Health Organization. Data for the indicators was gathered from various sources: databases, literature reviews and expert interviews.

Results: Inhibiting factors for the further uptake of mHealth are the lack of specific action points by the governments, the missing attention paid to the rising burden of NCDs, the non-utilization of the full potential of mHealth, the lack of financial incentives and standardized workshops/guidelines and lack of good governance. The access to mobile phones is also inhibited by the poor electricity infrastructure.

Enabling factors in many countries are numerous published eHealth strategies, constantly improving legislative frameworks (such as data protection laws) and a growing technology start-up ecosystem.

Conclusion: mHealth against NCDs is still in its infancy. The SSA mHealth landscape lacks steering and monitoring. The rapidly growing technology start-up environment in some countries could lower the problem of donor-dependencies and lacking sustainability.

Contents

Tables

Figures

Abbreviations

CCC	COMESA Competition Commission
CIA	Central Intelligence Agency
CMHI	Center for Health Market Innovation
COMESA	Common Market for Eastern and Southern Africa
CR Score	Consumer Readiness Score
EU	European Union
GDPR	General Data Protection Rule
GSMA	Global System for Mobile Communications Association
HDI	Human Development Index
HHD	High Human Development
ITU	International Technology Union
IXP	Internet Exchange Points
LHD	Low Human Development
LTE	Long Term Evolution
MHD	Medium Human Development
mHealth	Mobile Health
NCD	Non Communicable Diseases
NMRA	National Medicines Regulatory Agency
SDGs	Sustainable Development Goals
SELFIE	Sustainable intEgrated chronic care modeLs for multi-morbidity: delivery, FinancIng and pErformance
SSA	Sub-Saharan Africa
USA	United States of America
USAID	U.S. Agency for International Development
WHO	World Health Organization
WTO	World Trade Organization

1 Introduction

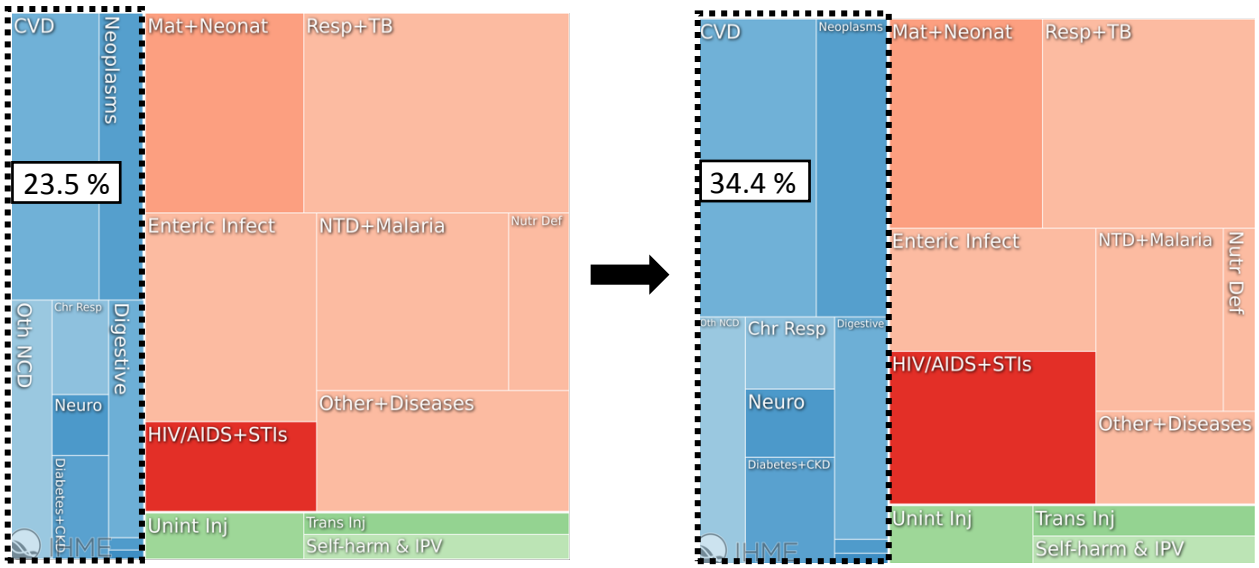
Health care systems in Africa face many challenges.

This applies particularly to the poorest region of the continent: Sub-Saharan Africa (SSA). First, health facilities are sparsely distributed, limited in their access to clean water and electricity and often poorly equipped. This is primarily caused by a lack of money: health expenditure in 2015 was only 84 Dollar per capita – much lower than spending in other regions of the world (e. g. the European Union (EU) spends 3,183 Dollar and the United States of America (USA) 9,535 Dollar per capita) [1]. Second, there is an extreme shortage of health-workers. In 2015, the SSA Region had an average of 1.30 health workers per 1,000 citizens – far below the 4.45 per 1,000 required for reaching the United Nations Sustainable Development Goals (SDGs) [2, 3]. And third, there is a serious lack of *good governance*, which increases the challenges through an inadequate legislation enforcement, corruption in the procurement system and an inefficient resource allocation [4–6].

At the same time, there is a slowly growing middle class in SSA that brings socioeconomic and demographic changes: The life-expectancy increases, people migrate from rural to urban areas and they change their lifestyle (e. g. nutrition or physical activities) [7, 8].

This leads to a shift in the burden of disease. People get less infectious diseases and are more likely to get so-called *diseases of wealth*, also referred to as Non-Communicable Diseases (NCDs) [9].

Figure 2: Causes of deaths in SSA in 2000 and 2017 with % of death caused by NCDs (dotted boxes) [10]



In 2017 more than one third of deaths were already caused by diseases such as cancer, cardiovascular diseases or diabetes (figure 1) [10]. And it is expected that this trend will continue and NCDs will be the main cause of death in 2030 [11].
The shift from communicable diseases to NCDs has far reaching implications for the health-systems [12]. NCDs are mostly chronic diseases. They are defined by their long duration and their slow progression. In contrast to acute diseases, they necessitate long term management and provision of mostly life-long integrated care [13]. But current health systems in SSA are primarily built around acute events and are not yet prepared and aligned to manage and care for NCDs [12]. As a consequence, people with NCDs receive an even more inadequate care than those with communicable diseases. And they are also poorly educated in how to self-manage their disease [14].

Despite all these challenges, there are glimpses of hope.
In the last years an almost invisible infrastructure has spread over the continent: the mobile phone infrastructure. Mobile phones have become one of the dominating ways of communication. In SSA, it is estimated that there are almost 500 million people having access to mobile phones, equivalent to a 'unique mobile subscriber' rate of 43 % [15]. As a result, people in many African countries have better access to mobile phones than to paved roads or sanitary facilities [16].
Through the access to technology and the easier exchange of information, mobile phones have started to change many areas of people's daily live [17, 18].
Particularly in the area of health, mobile phones have been used in many ways, such as for the provision of information (e. g. informing patients about a certain disease/condition). This mobile phone supported delivery of health care and management is also referred to as 'mobile health' (mHealth) [19]. Several systematic reviews have shown that mHealth is capable of improving patients' health outcomes, particularly for patients with chronic NCDs [20–22].

The potential of mHealth has been widely recognized and therefore many mHealth pilot projects have been implemented in SSA in recent years. But despite the enthusiasm, the African mHealth-landscape suffers from the problem of the so called *pilotitis*: most projects are stopped after the pilot and the funding of the donors has ceased [23]. mHealth

interventions usually don’t make the leap into standard care of the healthcare systems. Most mHealth projects, which have proven their efficacy, *vanish in beauty*.

This raises the question of ‘Why?’.

Why do mHealth interventions not move beyond the project status – although their efficacy has been proven and although the need is very high?

The aim is to identify the reasons for the lacking implementation of mHealth in sub Saharan African health systems. Therefore, the current level of the system implementation of mHealth in Sub-Saharan Africa is analyzed. The focus of the analysis is on mHealth interventions against NCDs.

2 Method

2.1 Selection of Countries

For the analysis of Sub-Saharan Africa, 10 sample countries were selected. The selection was discussed with Verena Struckmann (VeS)[1]. Final decisions on inclusions were made jointly among Victor Stephani (ViS) and VeS.
Included were countries that use English as their official language. In addition, emphasis has been placed on a balanced mix of countries at different stages of development. Therefore, the Human Development Index (HDI) classification system was used and countries with a low, medium and high human development (LHD, MHD, HHD) were included [24].
Based on these criteria, the following countries were finally chosen for the analysis: Botswana (HHD), Ghana, Namibia, South Africa, Zambia (all MHD) and Nigeria, Rwanda, Sierra Leone, Uganda, Zimbabwe (all LHD).

2.2 Framework and Indicator Selection

For the analysis of the health systems, a catalogue of indicators was developed.
The catalogue and its indicators were derived from two frameworks: the 'health system building blocks framework' by the World Health Organization (WHO) and the SELFIE framework.

2.2.1 The Health System Building Blocks Framework

The health system building blocks framework (also referred to as 'WHO Building Blocks') was proposed by the WHO in 2007 [25]. The framework consists of all organizations, people and actions whose primary intent is to promote, restore and maintain health. It organizes health systems into six functions (also called building blocks):

- Leadership & Governance
- Information & Re search
- Workforce
- Financing
- Service Delivery
- Technologies & Medical Products

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The blocks of *Leadership & Governance* and *Information & Research* provide the basis for the overall policy and regulation of the health system. Inputs to the health systems are given by the blocks *Financing* and *Workforce*. And the outputs, e. g. the availability of care, are reflected by *Service Delivery* and *Technologies & Medical Products* [26].

2.2.2 The SELFIE Framework

For the analysis, the WHO Building Blocks were combined with a framework developed as part of the SELFIE project ('Sustainable intEgrated chronic care modeLs for multi-morbidity: delivery, FinancIng, and pErformance'), an EU-funded project (PHC-23-2014) [27]. The project aims at the provision of policy advices on integrated care for persons with multi-morbidity. As part of the project, a framework was developed which captures relevant elements which need to be considered when reviewing integrated care models for patients with multi-morbidity. The elements are categorized according to the WHO Building Blocks. Furthermore, the elements are divided into a micro-, meso- and macro-level. While the micro level adopts a patient perspective, the macro-level considers institutional and the macro-level the system aspects.

2.2.3 Indicator Selection

Since a system view was carried out, only indicators from the macro perspective of the SELFIE framework were considered. Based on macro-level indicators in combination with the WHO Building Blocks descriptions, final indicators for the analysis were derived.
The selection of the indicators was discussed with VeS. The catalogue of all final indicators in combination with the underlying explanation of the WHO Building Blocks and the explanation of the macro perspective of the SELFIE framework is provided in table 1.

2.3 Data sources

Data for the selected indicators was gathered from various sources: (1) Databases provided by international organizations were used and (2) mHealth databases were systematically searched. In addition, (3) peer-reviewed literature and grey literature was used, and mHealth experts from the respective countries were contacted and interviewed. The indicators and their associated primary sources are listed in table 2.

Table 5: Indicator selection based on the WHO Building Blocks and the macro level perspective of the SELFIE framework

WHO Building Blocks	SELFIE-Macro Level	Selected Indicators
SERVICE DELIVERY: The service delivery depends on e. g. close-to-client care and the provision of required clinical and public health interventions that respond to the full range of health problems	Service availability & access	Access to cellular infrastructure
		Disease-focus of mHealth interventions
	Market regulation	Collaboration between providers while ensuring consumers choice
LEADERSHIP & GOVERNANCE: The authorities steer the health sector and deal with future challenges. They define health policies, strategies and plans with a clear direction	Policy & action plans, political commitment	eHealth strategy
		mHealth strategy
		Focus on non-communicable diseases in the strategies
WORKFORCE: The health workforce is responsive to needs and expectations. Furthermore, the workforce is fair, efficient and achieves the best outcomes possible	Education & workforce planning	Incentives for using mHealth
		Workshops/Guidelines
	Workforce-demography match	Mobile phone literacy
FINANCING: This is a key instrument to reduce health inequalities and to remove financial barriers by e. g. raising funds for health fairly among the population and pooling financial resources across population groups	Stimulating investments in innovative care models	Governments involvement in mHealth interventions
	Financial system for health & social care	Affordability of mHealth interventions
	Equity access	Affordability of mobile services
TECHNOLOGIES & MEDICAL PRODUCTS: This considers the situation regarding technologies and medical products, which includes e. g. the existence of a regulatory system for medical products and ensures access to technologies.	Policies fostering technological innovation	Innovation friendliness
	Access to technologies & medical products	Regulatory system for medical devices
		Access to electricity
INFORMATION & RESEARCH: Good information on health challenges and the environment, e. g. on the progress of meeting health challenges and social objectives of the consumption of and access to technologies	Privacy & data legislation	Legislative framework for protection of data
	Policies that stimulate research	mHealth related research activities
		Access to information

2.3.1 International Databases

Data on the 'cellular infrastructure', the 'affordability of mobile services' as well as the 'mobile phone literacy' was obtained from the 'Mobile Connectivity Index 2018 – Global Scores' (data from 2017). The data is regularly published by the 'Global System for Mobile Communications Association' (GSMA), which is the umbrella organization for mobile network operators. Data on the 'access to electricity' was taken from 'World Fact Book' database, provided by the Central Intelligence Agency (CIA) (data from 2016).

Table 6: Data sources for selected indicators

Building Block	Indicator	Primary Data Source
Service Delivery	Access to cellular infrastructure	'Infrastructure Index' by GSMA
	Disease-focus of mHealth interventions	mHealth databases
	Collaboration between providers while ensuring consumers choice	Literature / Experts
Leadership & Governance	eHealth strategy	Literature / Experts
	mHealth strategy	Literature / Experts
	Focus on NCDs in the strategies	Literature / Experts
Workforce	Incentives for using mHealth	Literature / Experts
	Workshops/Guidelines	Literature / Experts
	Mobile phone literacy	'Consumer Readiness' Index by GSMA
Financing	Governments involvement in mHealth interventions	mHealth databases
	Affordability of mHealth interventions	mHealth databases
	Affordability of mobile services	'Affordability Index' by GSMA
Technologies	Innovation friendliness	'Ease of Doing Business Report' by Worldbank
	Regulatory system for medical devices	'Global atlas of medical devices' by WHO
	Access to electricity	'Access-to-electricity Index' by World Fact Book
Information & Research	Legislative framework for protection of data	Literature / Experts
	mHealth related research activities	MEDLINE Database
	Access to information	Literature / Experts

For assessing the 'innovation friendliness' of the countries, the 'Ease of Doing Business' Report, published by the Worldbank was used (data from 2017). The presence of an agency responsible for implementing and enforcing regulations on medical devices was retrieved from the WHOs 'Global Atlas of Medical Devices' (data from 2015 and 2016).

2.3.2 mHealth Databases

Information on name, type, disease focus, business model and, if applicable, donors of the mHealth interventions, was systematically retrieved from various databases.
mHealth specific databases were screened: (1) the 'mHealth database' from the U.S. Agency for International Development (USAID), (2) the 'mHealth Working Group Inventory of Projects' by the Johns Hopkins University and (3) the 'mHealth Deployment Tracker' provided by the GSMA.
In addition, non-mHealth specific databases which collect innovative projects from all over the world were screened: (4) the 'Center for Health Market Innovation' (CMHI) database and (5) the database of 'Global Innovation Exchange'.
The sources of the databases can be found at the section 'Availability of data and materials'.
A web-search was also conducted and webpages of the Ministries of Health in each country were screened.
After the mHealth projects were collected, information on name, type of intervention (classified according to the classification system introduced by Labrique et al [28]), disease-focus, description of intervention, primary source of funding and involved organizations when possible, were retrieved.
Screening of databases was conducted in summer of 2018. The full list of included mHealth interventions (n=343) can be provided by the author upon request.

2.3.3 Literature / Experts

Furthermore, published peer reviewed literature (using google scholar and the MEDLINE database), grey literature (using conventional websearch) as well as legislative texts (e. g. for the analysis of data protection laws) was used.
Moreover, experts from the countries were identified and contacted. The identification was made primarily through published peer-review papers on mHealth (which had already been identified as part of the literature search). The identified persons were then contacted electronically and asked whether they were willing to answer questions about the mHealth

activities in their country and, if not, whether they could recommend someone in their country who could. If someone agreed, a questionnaire with a short introduction and aim of the study was sent electronically (the questionnaire is provided in additional file 1). The questionnaire served as a basis for further correspondence. Any ambiguities about the respective mHealth landscape were iteratively clarified with the experts.

3 Results

3.1 Service Delivery

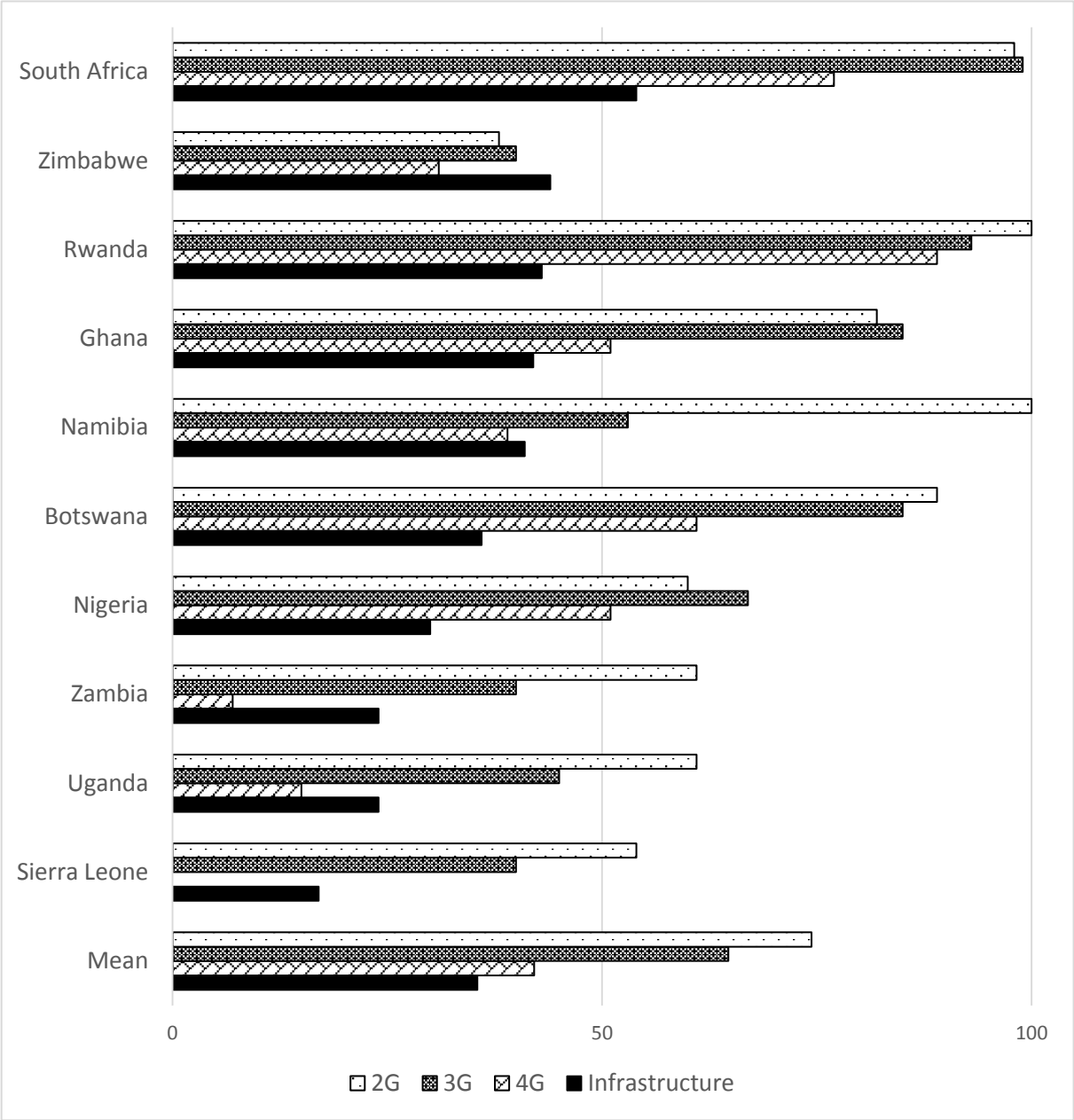
A healthcare system is only as effective as the services it provides. Provided services must respond to populations' health problems and the population must have access to these services. Also, in competitive environments, market regulation is needed that ensures competition while protecting consumer's choice.
Therefore, the following section analyses people's *access to the cellular network,* the *type of mHealth services* offered and the existence of a *competition law*.

3.1.1 Access to cellular network

The most basic form of access to the mobile network is access to the second generation of the cellular network (2G). It allows users to use basic functions (mainly voice calls and SMS) but does not allow fast data transmissions. The 2G coverage is good in most SSA countries and is, according to the 2G-coverage indicator provided by the GSMA, well over 50 (out of a maximum of 100). The average is 74 (figure 2). Some countries have almost complete 2G coverage (Namibia, South Africa and Zimbabwe). The coverage with the third generation of the cellular network (3G), which allows faster data transmissions, is on average lower the than the 2G coverage (65 vs 74). Interestingly, in some African countries the access to 3G is better than access to 2G (Nigeria, Ghana, Zimbabwe and South Africa). The lowest coverage rate has the fourth generation of the cellular network (4G, also known as 'Long Term Evolution' (LTE)). Some countries, e. g. Sierra Leone and Zambia, have just started introducing 4G and therefore have no or very low coverage rates. Other countries have a very high coverage (Rwanda and South Africa). The average 4G coverage in SSA has risen sharply in recent years, from 11 in 2014 to 42 in 2017.

The 'Infrastructure Index' (provided by GSMA) summarizes various parameters that include not only coverage, but also the quality (e. g. stability and reliability of the signal) of the cellular network. Of the countries selected here, Sierra Leone (17) and Zambia (24) have the lowest values, while South Africa (54) and Zimbabwe (44) have the highest. The average is rather low (36), but has continuously improved since 2014.

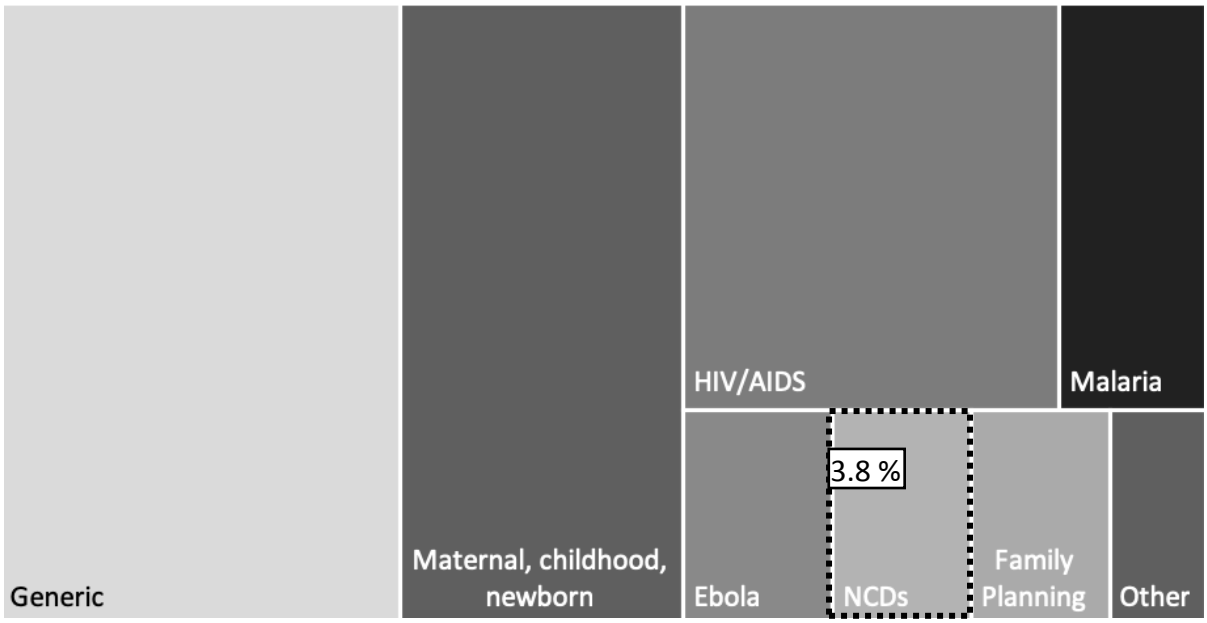
Figure 3: 'Infrastructure Index' (GSMA) and 4G, 3G and 2G coverage in SSA (scored within a range 0-100; higher score represents stronger performance)



3.1.2 Provided Services

The focus of most mHealth interventions in the past has not been on NCDs (figure 3). Only 4 % of interventions can be classified as exclusively NCD-related interventions. A large proportion (46 %) can be classified as reproductive health, which includes maternal, child and neonatal health (22 %), HIV/AIDS (20 %) and family planning (4 %).
However, there are many generic interventions that do not belong to a specific disease group and that can potentially be used to combat NCDs (e. g. generic mobile phone-based communication tools).

Figure 4: Disease focus of mHealth interventions in SSA (n=343)



Looking at the type of intervention instead of the targeted disease, the vast majority of mHealth interventions (48 %) have been used to provide information to patients. 11 of the 12 possible intervention types have already been used (table 3). The only type of intervention which has not been used so far is the 'electronic decision support'.

Table 7: Type of mHealth interventions in SSA (n=343)

Type of intervention	Number of interventions	%
Client education and behavior change communication	164	47.8
Data collection and reporting	34	9.9
Provider training and education	33	9.6
Provider-to-provider communication	30	8.8
Registries / vital events tracking	27	7.9
Supply Chain Management	22	6.4
Financial transactions & incentives	12	3.5
Electronic health records	6	1.8
Human resource management	6	1.8
Sensors and point-of-care diagnostics	5	1.5
Provider work planning and scheduling	4	1.2
Electronic decision support	0	0.0

3.1.3 Competition law

For maintaining market competition, many SSA countries have started to implement competition laws over the past years [29]. Currently, 6 out of the 10 analyzed countries have

an own competition-law in place: Zambia (since 1994), Zimbabwe (1996), South Africa (1998), Ghana (2000), Namibia (2003) and Rwanda (2010) [30–35].
Uganda is still awaiting approval by the parliament for its competition law [36]. The same accounts for Nigeria, where a federal competition law is underway (since 2016) [37]. Botswana is in the process of introducing a new competition law, since the old law has been regarded as flawed (e. g. there were no criminal liability for cartel conducts) [38]. Sierra Leone does not have a competition law, but it is expected that there will be a law very soon [39].
Furthermore, four countries (Rwanda, Uganda, Zambia, Zimbabwe) are members of the COMESA (Common Market for Eastern and Southern Africa), which is the largest free trade zone in Africa and has a competition law regulation for its members since 2013. The COMESA Competition Commission (CCC) regulates mergers and acquisitions and business malpractices on a supranational level. Therefore, countries still need to have a national competition law with national competition authorities [40]. However, despite all regulatory efforts which have been undertaken in the last years, the effectiveness of competition laws in the countries has to be questioned [41].

3.2 Workforce

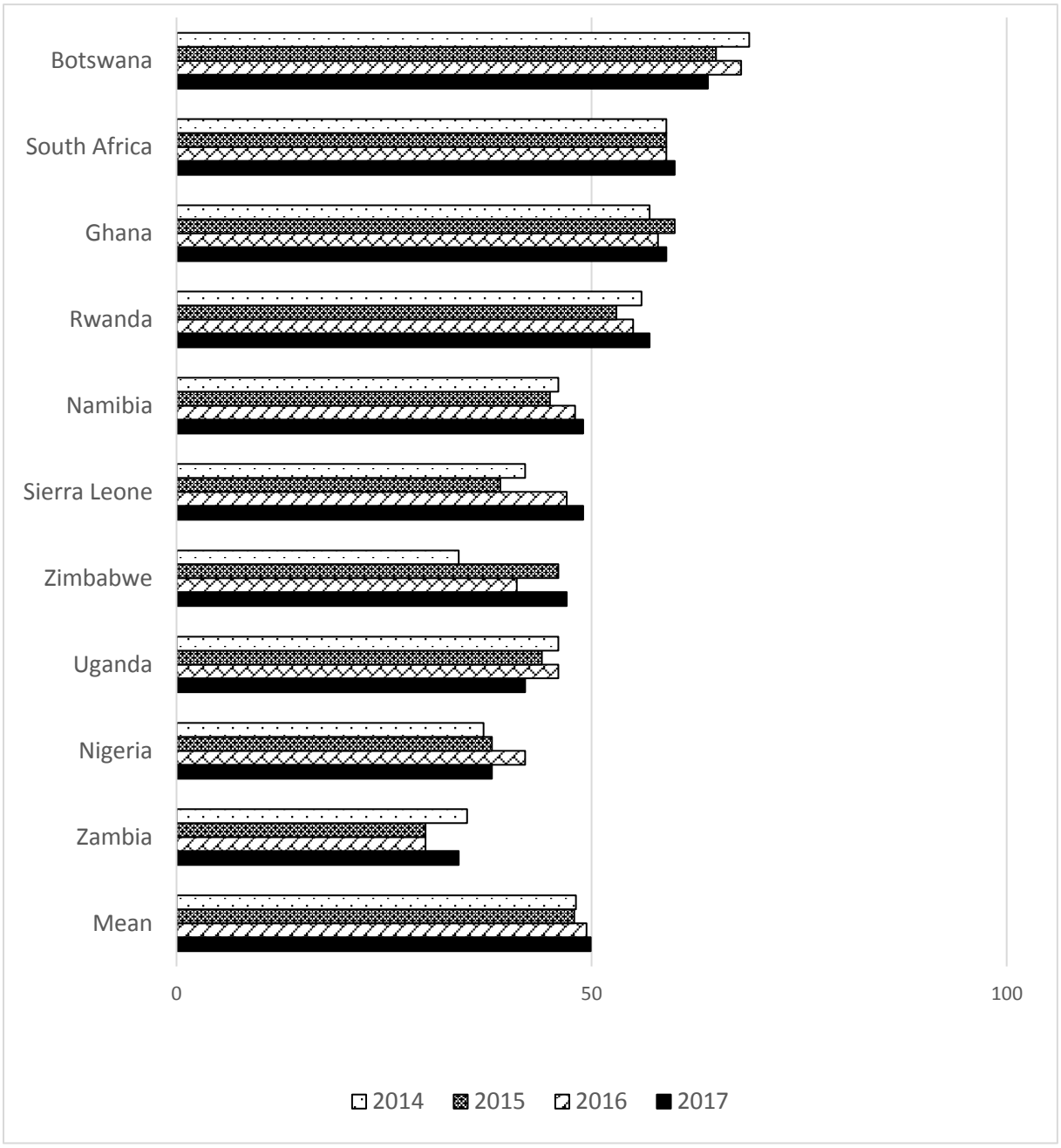
This building block ensures the ability of the health-workforce to provide and use procedures and services. The workforce must match with the requirements for providing health service and the system should support the utilization of these services.
Therefore, the following section will address the *population's familiarity* with mobile phone services, as well as the existence of national *workshops/guidelines* and *financial incentives* which guide/standardize and promote the use of mHealth.

3.2.1 Consumer Readiness

According to the Consumer Readiness score (CR score), which measures citizens skills to use mobile phone and its services (and also includes gender-related aspects that can influence the access to mobile phones) the countries average score is moderately high at 59 (out of a maximum of 100). Sierra Leone (38) and Botswana (44) are the only analyzed countries with a CR score of below 50. The highest scores were measured in Namibia (72), Ghana (73) and

South Africa (75). The development of the average score has been very low within the last years and improved by only one point since 2014 (see figure 4).

Figure 5: 'Consumer Readiness' from 2014 – 2017 (scored within a range 0-100; higher score represents stronger performance)



3.2.2 Workshops and guidelines

In terms of nationwide workshops and guidelines, there is currently no country that provides standardized and centralized workshops for the use of mHealth. It is rather common to train the user of an intervention within a specific project. However, the importance of workshops on the use and implementation of eHealth applications is recognized and mentioned by

various eHealth strategies (Uganda, Nigeria, Zambia, Sierra Leone, Botswana) – but has not yet led to a result.

3.2.3 Incentives

It is analogous with the financial incentives: None of the countries surveyed currently have system-wide remuneration for mHealth. In Nigeria and South Africa, the importance of creating an incentive system is taken into account in their eHealth strategies, but this is not specifically related to mHealth but to all digital applications in the health care system.

3.3 Leadership & Governance

The health systems benefit from governmental and political guidance. National strategies provide important orientations for all stakeholders involved in healthcare [42]. This section analyzes whether there are nationwide strategies for the digitization of the health care systems (e. g. *eHealth strategy*) as well as whether there are specific plans for the integration of mobile phones (e. g. *mHealth strategy*). In addition, it will be examined whether mHealth is regarded as a potential instrument for combating *NCDs*.

3.3.1 eHealth strategy

All countries except two (Namibia and Sierra Leone) have or had a digital Health strategy/eHealth strategy/ICT for healthcare sector strategy, mostly published by the Ministry of Health (in Zambia in collaboration with a development aid agency). However, most strategies are not up-to-date and date back up to 2004 (Botswana) [43–47]. Only 3 countries (Nigeria, South-Africa and Zambia) have a current digital health strategy [48–50]. In Botswana, the eHealth strategy was only part of a larger digitization strategy (eGovernment strategy).

3.3.2 mHealth strategy

With the exception of Botswana, mHealth and mobile phones are mentioned in all eHealth strategies. It is presented as an important tool to remotely educate and support health professional and community health workers (Uganda, Zimbabwe, Nigeria, Rwanda, Nigeria, South Africa), to provide information to patients (Ghana, Uganda, Zimbabwe, Nigeria, Zambia) or to use it for telemedicine (Uganda, Nigeria, Rwanda, Ghana, South Africa). It is also mentioned as a national disease surveillance tool (Zimbabwe, Ghana), as a tool for the collection of patient data (Uganda), for improving the supply chain management (South

Africa) and as an important instrument to reach the goal of a universal health coverage by 2020 (Nigeria).

One country (South Africa) has an independent mHealth strategy beside of the national eHealth strategy [51]. The mHealth strategy contains a comprehensive view on purposes and challenges of mobile phone based health care. In addition to the points already mentioned, the South African mHealth strategy points out the opportunity to re-engineer the primary healthcare system with mHealth (by an improved health delivery at household level).

In addition, many country strategies lack precise, quantifiable targets. Only 3 countries strategies have set (non-NCD specific) target parameters for mHealth.

Nigeria sets target groups (e. g. % of pregnant women and new mothers who receive mobile messages) but does not mention any values for the planned evaluation year 2020. Ghana and South Africa have rather qualitative goals and plan to support further pilot projects but without quantifiable targets.

3.3.3 Inclusion of NCDs

Most strategies do not mention the increasing prevalence of NCDs and the fact that mHealth could reduce the NCD-burden on health systems. Only three countries (South Africa, Uganda, Nigeria) have linked mobile phones to the prevention of NCDs in their strategies. In these strategies it is stated that mHealth could be utilized to educate patients on how to manage their disease. Another countries eHealth strategy (Zimbabwe) recognizes the increasing burden of NCDs but doesn't connect it with mHealth. In most strategies, mHealth is mostly connected with benefits in maternal, newborn, child health care and infectious diseases.

3.4 Financing

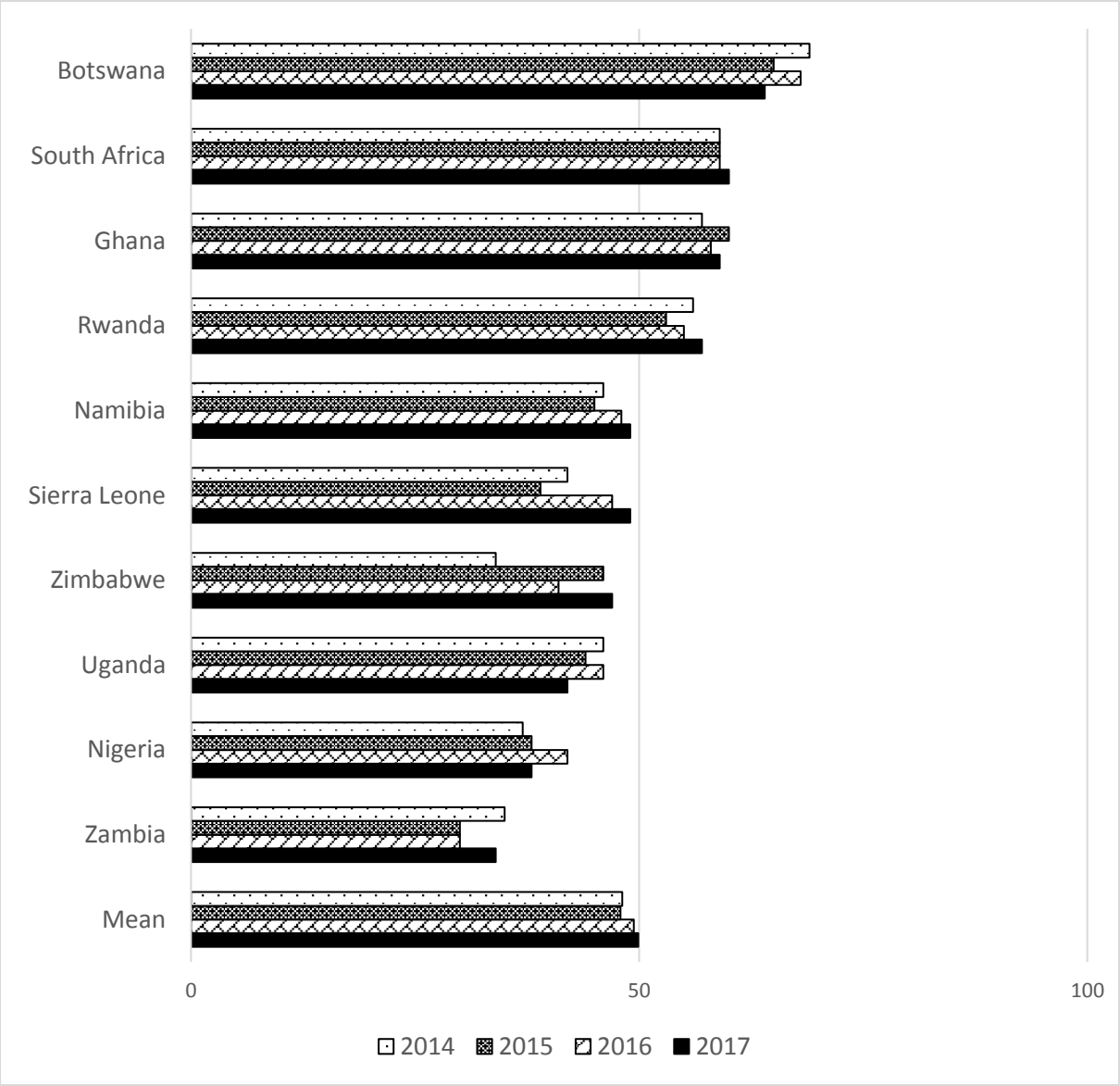
Inequalities and barriers to access to the health system and its services should be kept to a minimum. Governments can also promote and stimulate innovative care models.

Therefore, the *affordability of mobile services* (telephone, tariffs, etc.) and the *affordability of mHealth interventions*, as well as *government participation* in mHealth projects are analyzed below.

3.4.1 Affordability of mobile services

The affordability of mobile services is reflected by the 'affordability' score provided by the GSMA. The score includes local prices for entry-level phones, costs of mobile tariffs, average income, inequalities in income and cost of taxation and mobile-specific taxation. The analyzed countries achieve a value of only 50 on average (figure 5). This shows that the

Figure 6: Affordability of mobile services (GSMA) (scored within a range 0-100; higher score represents stronger performance)



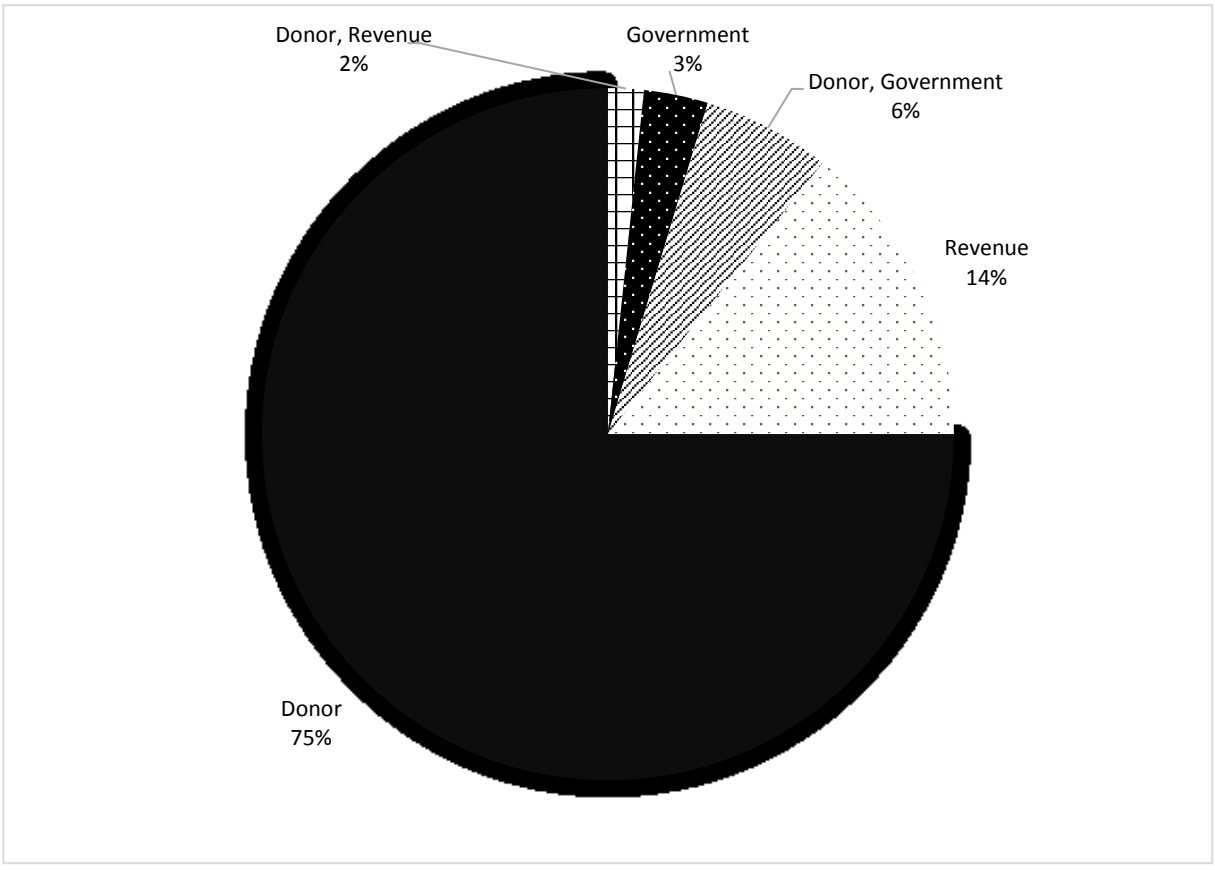
affordability of mobile phones and its services is limited for many parts of the African population. In six countries mobile services are even less affordable (meaning a score of below 50). In Zambia the score is the lowest (34). Highest scores were measured in Botswana (64) and South Africa (60) indicating a moderate affordability for most citizens.

Overall, the score has only slightly improved in recent years (by 2 points since 2014). In some countries, however, the situation has even worsened (Nigeria, Botswana, Uganda, Zambia)

3.4.2 Cost of interventions

The vast majority of the mHealth interventions is free of charge. Currently, 84 % of the interventions are donor and/or governmental-driven and therefore generally free of charge for users. However, in recent years, there has been an increase in the number of new mHealth related companies (e. g. start-ups) being set up. These do not function with the help of donations or NGOs but have a business case as a basis and thus are revenue and sales-driven. Some of these interventions run as freemium models (i.e. that the basic functionality of the intervention is free, but the full version must be purchased). At present, 16 % of the interventions are revenue-driven (see figure below) and may therefore include costs for end-users.

Figure 7: mHealth interventions funding sources (n=300)



3.4.3 Governmental involvement

The governmental involvement in mHealth is very low. Among the included countries, the governments are involved in less than a tenth of all interventions. And in many government-

backed interventions, additional donors are involved. As stated above the mHealth landscape is very much donor driven: Currently 75 % are purely financed through donation, many come from foreign countries (developing aid agencies, private donations).

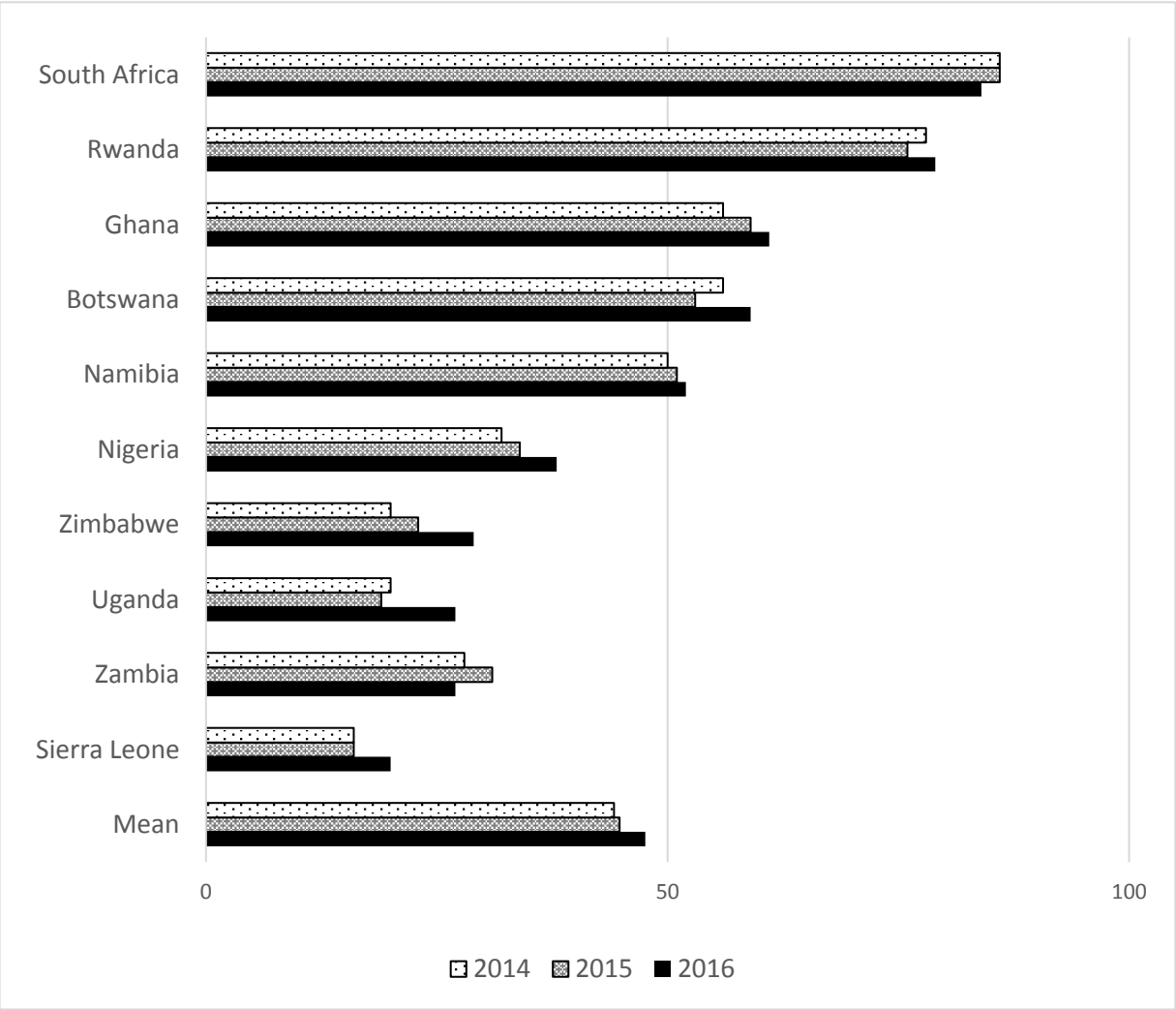
3.5 Technologies & Medical Products

A well-functioning health system ensures the equal access to technologies needed and ensures their quality and safety. Policies are also needed to promote technological innovation that benefits people with chronic diseases.
The access to mHealth is (beside of the access to the cellular network and the affordability of mobile services) determined by the *access to electricity*. Furthermore, in order to ensure the quality and safety of medical technologies, the existence of a *regulatory system for medical devices* will be analyzed and, in order to promote innovation, the *ease of doing business* will be discussed.

3.5.1 Access to electricity

Access to electricity varies widely among African countries. In few countries, the supply of electricity is good, for example in South Africa or in Rwanda (84 % and 79 % respectively of all citizens are supplied with electricity). But in most other countries the access is poor or very poor. In Sierra Leone only one fifth, and in Uganda and Zambia only a little more than a quarter of the population has access to electricity. In total, less than half of the population is connected to the electricity grid and therefore able to charge a mobile phone.

Figure 8: Access to electricity in SSA [%]



3.5.2 Regulation and Safety

mHealth solutions can cover a wide spectrum of functions and bear different levels of risks for the users. Therefore, sound and effective regulatory systems are needed to ensure the quality, safety and efficacy of medical products and for the promotion of trade and socioeconomic advancement [52]. National Medicines Regulatory agencies (NMRA), similar to the FDA in the US or the EMA in the EU, are needed, which provide guidance and regulation for the distribution of medical devices [53].

According to the 'Global Atlas of medical devices' (published by the WHO) most countries, except for Botswana have a NMRA, which is responsible for the regulation of medical devices. But the NMRAs have varying degrees of capacities. Many are under-resourced and lack of qualified experts to perform critical regulatory functions [54]. This leads for example to long delays before medical products become available to the population, or to an increasing circulation of substandard and falsified medical products. Furthermore, most

countries (except for Ghana, Rwanda and South-Africa) do not have a risk class classification system for their medical products, which indicates a rather low development level of medical device regulation.

3.5.3 Policies fostering technological innovation

Innovations, particularly developed by private investments, depend on the regulatory environment. The 'Doing Business report 2018', published by the World Trade Organization (WTO) compares business regulations for domestic firms and is based on parameters such as the ease of getting credits, paying taxes, or how much time it takes to start a business.
The various scores show that the SSA countries differ widely from each other. The SSA region has the widest gap worldwide between the country with the friendliest and the worst business environment.
The average regulatory climate for businesses in SSA is moderate (69 points). But it has steadily improved over the last years, showing that the region is becoming more business friendly.
The SSA region has also introduced many reforms in the last years in order to accelerate business investments. The number of reforms in the year 2017 was the highest worldwide: 31 % of all reforms globally (which were meant to make it easier to do business) were implemented in SSA [55].

3.6 Information & Research

Health systems should ensure correct processing of health-related data and also facilitate the availability of the data necessary for decision-making. Research also contributes to a functioning health system.
Therefore, the existence of *data protection laws* as well as *access to information* on mHealth interventions and cellular network coverage will be considered below. Finally, the scope of existing *research on mHealth* will be analysed.

3.6.1 Data Protection

Of the 10 countries, 5 have currently a data protection law (Botswana, Rwanda, Ghana, South Africa, Uganda) [56–60]. These laws have been introduced since 2012. All laws explicitly take into account the handling of health-related data and how such data has to be processed. 3 countries are right now in the process of introducing a law on data protection

(Namibia, Nigeria, Zambia) and 2 countries (Sierra Leone and Zimbabwe) have currently no actions planned to introduce a data protection law. The protection of data in these countries is therefore mostly regulated through the constitutional law.

However, the African continent is making efforts in the area of data protection. The African Union adopted a framework on cyber security and data protection in 2014 [61]. Member states are now free to declare their agreement with the convention. But currently only 10 countries have signed the convention – and before agreed countries need to translate the convention into domestic law, at least 15 of the 54 member states need to declare their agreement.

Moreover, it is worth pointing out that most mHealth projects, which are funded by western donors and development aid agencies, have adopted western-based standards of data protection and thus go beyond local data protection regulation. For example, mHealth projects funded by an EU developing aid agency, usually follow data protection principles given by the General Data Protection Rules (GDPR).

3.6.2 Information access

Currently, there is no centralized database that lists all available mHealth interventions. Online available databases are not comprehensive and not patient-oriented.

Since mHealth usually remains in a project status, information is only given to the respective project participants. However, in some countries (e. g. Ghana and South Africa) governments have started to advertise few of their governmental mHealth interventions. Regarding information on the available infrastructure – which is also important for developers, such as electricity or mobile cellular network, most countries don't have a detailed database on e. g. dead spots of cellular network coverage in the country. The only country where this already exists is Nigeria. A detailed 'mobile coverage maps' platform provides high resolution layers of who is covered and who is not covered.

3.6.3 Research

All countries except one (Zimbabwe) have published peer-reviewed papers on mHealth (according to MEDLINE). The bandwidth of the number of published articles is very high. South Africa has by far the most published articles (n=118). The second and third most frequent publications on mHealth were from Ghana (n=28) and Uganda (n=26). The number of published articles has steadily increased over the past year (see table 4).

Table 8: Number of published papers about mHealth according to MEDLINE (*published until 10/2018)

	1st author		**Total**	2018*	2017	2016	2015	2014	≤ 2013
Zimbabwe	**0**		**0**						
Namibia	**0**		**2**		1	1			
Sierra Leone	**1**		**4**	1	2	1			
Zambia	**2**		**4**		3			1	
Rwanda	**4**		**5**	3			1		1
Botswana	**4**		**7**	1		3		1	2
Nigeria	**7**		**22**	8	5	6	2	1	
Uganda	**8**		**26**	11	8	2	3	1	1
Ghana	**13**		**28**	8	8	6	4	1	1
South Africa	**75**		**118**	35	33	25	10	9	6
Total	**114**		**216**	**67**	**60**	**44**	**20**	**14**	**5**

South Africa (n=75) and Ghana (n=13) have the highest share of 1st authorships on all publications. The vast majority has been published by researchers from the universities within the countries. Only few were published from non-academic institutions or governmental bodies (e. g. MoH).

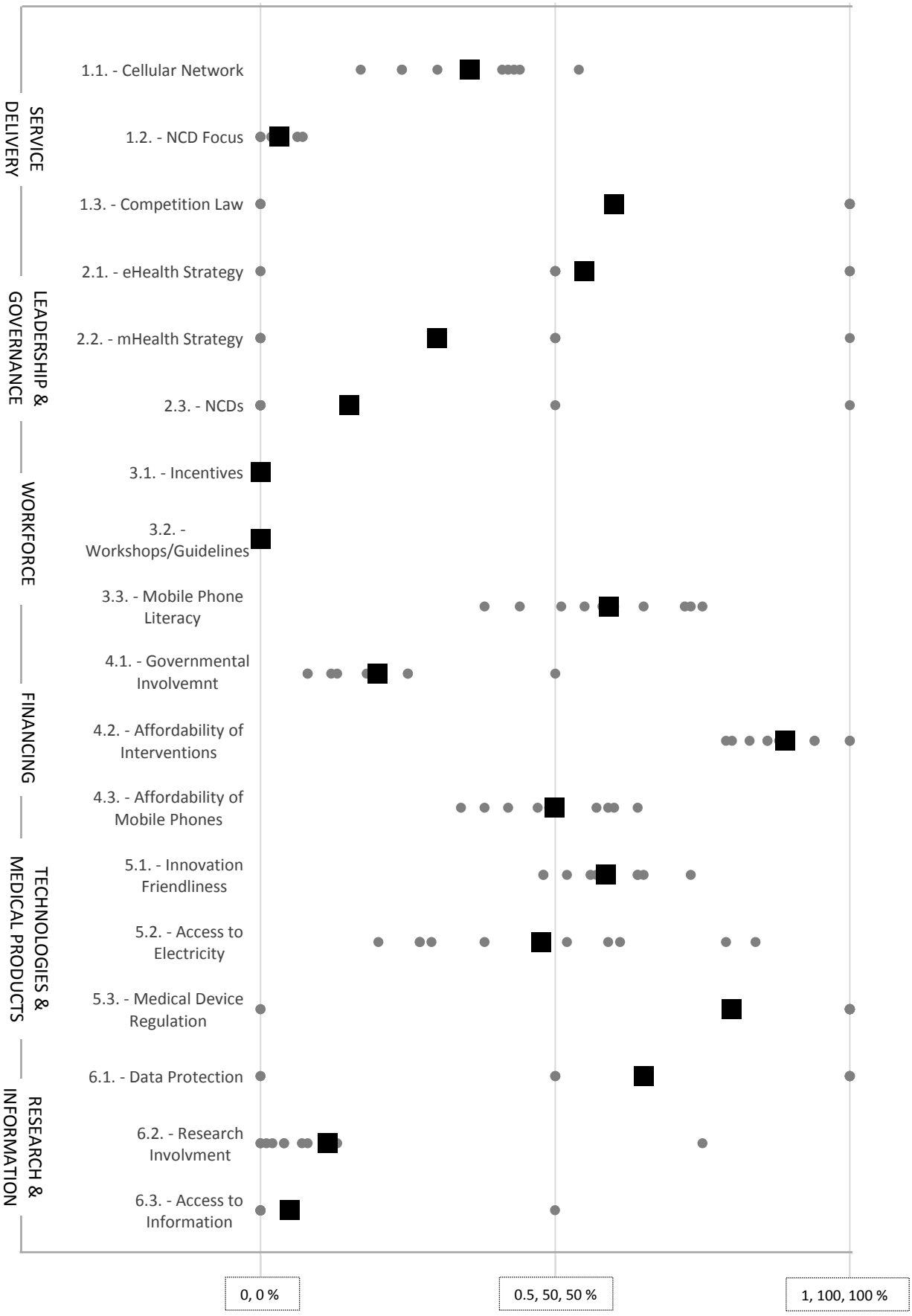
4 Summary & Discussion

This working paper has analyzed the current implementation status of mHealth in African health systems in order to identify inhibiting and enabling factors. The focus was on the area of mHealth interventions against NCDs, as the burden of NCDs is constantly increasing and is therefore a growing challenge for the continent and its health systems.
For the analysis, 10 benchmark countries were selected. The health systems were evaluated based on the Building Block concept developed by the WHO. Indicators for evaluating the implementation were primarily derived from the SELFIE framework, a framework for evaluating integrated health care models. Extracted data for the parameters came largely from international databases, the systematic analysis of mHealth projects, literature research and expert surveys.
The most important indicators are summarized and depicted in the *scorecard* below (figure 8).

4.1 Service Delivery

Although cellular coverage with the rudimentary 2G network is good and, in some countries, even 100 %, the quality of the networks (including not only coverage but also e. g. the latency rates of data transmissions) is rather low (score of less than 50 out of 100 in most countries). However, the spread of 4G, a newer network-standard with faster download and upload speeds, has strongly increased in the last few years and could therefore contribute to significant improvements of the cellular network in the next years.
Looking at the type of provided mHealth services, most attention has been paid to interventions in the field of reproductive medicine. So far, mHealth interventions against NCDs have not received much attention (they account for only 4 % of all interventions).
In most countries there is also a competition law, which ensures competition in markets. Thus, the law could e. g. contribute in the long term to a user-oriented improvement of mobile networks.

Figure 9: Scorecard of the degree of implementation of mHealth in the SSA health care systems. Squares indicate the average values. Circles represent individual country values. A higher value (in the figure going to the right) means a stronger performance. Explanation of indicators and values below



1.1 - Cellular Network	Quality and coverage of mobile network according to the 'Infrastructure Index' (scored within a range 0–100; higher score represents stronger performance)
1.2 - NCD Focus	% of interventions against NCDs
1.3 - Competition Law	Availability of a domestic competition law (0=no; 1=yes)
2.1 - eHealth Strategy	Published eHealth strategy (0=no; 0.5=yes, but not current; 1=yes, current strategy)
2.2 - mHealth Strategy	Published mHealth strategy (0=no; 0.5=yes, but only part of eHealth strategy; 1=yes, separate mHealth strategy)
2.3 - NCDs Addressed	Focus on NCDs in the strategies (0=NCDs are not addressed within the strategies; 0.5=NCDs are addressed by eHealth strategy; 1=NCDs are addressed by eHealth and mHealth strategy)
3.1 - Incentives	Financial incentives for the utilization of mHealth (0=no; 1=yes)
3.2 - Workshops/Guidelines	Guidelines for the utilization of mHealth (0=no; 1=yes)
3.3 - Mobile Phone Literacy	Citizens ability to use a mobile phone and its services, according to the 'Consumer Readiness Score' (scored within a range 0–100; higher score represents higher performance)
4.1 - Governmental Involvement	% of interventions with governmental involvement
4.2 - Affordability of Interventions	% of interventions free of cost (non-revenue driven)
4.3 - Affordability of Mobile Phones	Affordability of mobile phones and its services, according to the 'Affordability Index' (scored within a range 0–100; higher score represents stronger performance)
5.1 - Innovation Friendliness	Innovation friendliness according to the 'Ease of Doing Business' Index (scored within a range 0–100; higher score represents stronger performance)
5.2 - Access to Electricity	% of citizens having reliable access to electricity
5.3 - Medical Device Regulation	Availability of a regulatory agency for medical devices (0=no; 1=yes)
6.1 - Data Protection	Availability of a legislative framework for the protection of health-related data (0=no; 1=yes)
6.2 - Research Involvement	Number of published MEDLINE-indexed articles with first author coming from the country
6.3 - Access to Information	Availability of information on cellular coverage and/or mHealth interventions in the countries (0=no; 0.5=one or the other; 1=yes)

4.2 Leadership/Governance

All countries except one (Namibia) have recognized the importance and potential of mHealth and provided some guidance for its implementation – mostly within the framework of an eHealth strategy. South Africa is the only country with an independent mHealth strategy. However, many strategies are outdated and lack of quantifiable goals which want to be achieved. In most strategies, the potential of mHealth is not directly linked to the increasing burden of NCDs, but rather as a useful tool to support providers or to provide patients with information.

4.3 Health Workforce

The population's ability to handle mobile phones and services/applications running on them is moderate and has been relatively stable in recent years at around 60 points (out of a maximum of 100).

At present, there is a lack of guidelines and standardized incentive systems for mHealth. There are no guidelines for the health workforce or to patient groups that explain how mobile-assisted interventions should be used. There are also no system wide incentive systems - although the importance of an incentive-system has been identified as a goal in some eHealth strategies. So far, workshops/guidelines and incentive systems for the use of mHealth have been only given within the individual projects.

4.4 Financing

Not everyone can afford to own a mobile phone. The costs for mobile phones and the operating costs are sometimes high. The average-affordability score is 50 (out of 100 maximum points).

The government is only very infrequently involved in mHealth projects and thus leaves the field to the free market and donors from abroad. Since the mHealth landscape is heavily based on donors, most interventions themselves are free of cost. But in recent years the share of revenue-driven interventions has increased (now they account for approx. 15 %), and several business ideas have emerged in the area of mHealth. This development could lead to higher financial hurdles for the use of mHealth in the future.

4.5 Technologies

Access to electricity, which is as necessary for the use of technology as access to cellular network or access to mobile phones, is poor (an average of just under 50 %) – in some countries only about a quarter of the population has access to electricity.
The business environment has improved in recent years. Although the range of business friendliness in the different countries is very wide, the average business climate (e. g. the time it takes to start a business) can be described as moderate.
A regulation system for companies or the products that emerge from such medical technology companies is in place in most countries, but it is questionable whether they have sufficient resources to fulfil all their tasks.

4.6 Research/Information

Currently, 5 of the 10 countries have a data protection law. But most countries, which do not have their own law yet, are currently in the parliamentary process of implementing such a law. It is also important to note that many mHealth projects funded from other countries often follow the data protection standards of the respective funding countries.
In the area of access to information (databases with information on all available mHealth interventions, detailed information on cellular coverage) there is still a lot of catching up to do. There is no centralized database with all available information on mHealth projects in any country. Except for Nigeria, there is no country offering a map with detailed information on the cellular network coverage.
In terms of conducted research, there are considerable differences: in some countries research about mHealth is almost non-existent (Zimbabwe or Namibia) while a country like South Africa has already published much about mHealth.

4.7 Enablers

First, in many countries the mHealth landscape is huge. Some countries hosted up to 80 mHealth interventions over the last years. The importance of mHealth has been therefore mostly **recognized** and all countries except for Namibia have published a digital health strategy (eHealth strategy) and included the importance of mobile phones somehow in the strategy. The existence of such strategies, even if it usually does not receive much public attention, can be seen as an important milestone [62].

It is also positive that some strategies include very **ambitious goals**, e. g. establishing a new model of primary care with support of mobile phones (as proposed in the South African mHealth strategy) or the goal of achieving comprehensive health coverage with the help of mobile technologies (Uganda eHealth Strategy).
In addition, the **regulatory framework has continuously improved** in recent years. Many laws have been or are currently being implemented (data protection law or competition law) and thus constitute important elements for the future patient-oriented development of mHealth.
The regulatory framework has also improved for companies, as shown by the 'Ease of Doing Business' Indices and the legislative initiatives in the various countries. As a result, some countries in the SSA region host a rapidly growing **technology start-up ecosystem** that is playing an increasingly important role in the development of digital services [63]. This correlates with the observed increasing landscape of revenue-driven mHealth interventions. The increasing share of revenue-driven interventions could have a very positive effect and solve one of the main problems of the mHealth landscape: lacking sustainability.

4.8 Inhibitors

On the other hand, many factors can be observed that inhibit the expansion of mHealth. Although there are official strategies in most countries, these strategies are mostly afflicted with the problem of **a lack of precise action points** and objectives. Also, there is usually a lack of plans on the continuous monitoring of the implementation and related processes. The WHO has acknowledged these flaws in such strategic papers and has therefore in collaboration with the International Technology Union (ITU) developed and published guidelines (or toolkit) on how to establish such a digital strategy and emphasizing the importance of monitoring and supervision of the implementation process [62].
In addition, there is **not much attention paid to NCDs**. Neither in the various strategies (NCDs are usually not mentioned) nor in the numerous identified interventions. One reason for the lack of mHealth interventions could be that donor-funded health projects do not always fully respond to health populations needs [6].

In addition, the potential of mHealth is not fully explored yet and only a fraction of possible **types of interventions** are currently used. Almost half of all interventions have a focus on

interventions that provide patients with information (e. g. frequently sent SMS for pregnant women with information on the course of pregnancy). But 'Client Education' is only one of 12 different ways to use mHealth [28]. Other important ways of improving healthcare through mobile phones, by e. g. helping in the decision making for health care providers, are not targeted yet by any of the identified interventions. This could be due to the high prevalence of rather simple mobile phones, which offer usually the most basic functionalities (SMS, voice). However, the mHealth landscape will probable become more diverse in the near future, since the increasing adoption of smartphones and so-called feature phones in SSA could make it easier to distribute more complex tools [63].

Another issue is the **lack of financial incentives.** Without incentives it will be difficult to establish certain highly new procedures and interventions into standard care, since the adaption of new technologies is time and resource consuming [64]. A simple provision of such interventions is not sufficient. This could heavily influence the sustainable utilization of mHealth services in the future. Of course, the lack of incentives has to be seen in the light of the overall lack of money and resources in the health care systems.

Beside of the lack of financial incentive systems, there is also a **lack of standardized workshops and/or guidelines** on how to use such interventions (e. g. by recommending specific interventions for certain conditions). These could be developed by national medical associations. They could recommend e. g. how providers can implement mobile phone based tools into their processes. The lack of guidelines and its negative consequences in the widespread use of mHealth has been also acknowledged by the WHO [65].

Also, the **low governmental involvement** in mHealth is striking: in mHealth projects, in stimulation of research, provision of centralized registries/databases or other enabling factors (e. g. cellular network coverage maps). For example: centralized mHealth databases/registries would make it easier for all stakeholder to navigate through the system and also for developers to identify areas with higher needs and opportunities [66].

More governmental involvement could also help to steer the development of mHealth interventions and could accelerate the development of NCD-related interventions. It could further lower financial barriers to mHealth by offering the most important kind of interventions for free and as part of the benefit basket of public health insurance.

Last not least, **lack of good governance** is fostering the challenges. For example regarding the legislation: even those countries that have legislations in place (e. g. for data protection), have often too few regulators to enforce them [6, 67, 68]. Also, there are weaknesses in the enforcement and monitoring of the medical device market, because most NMRAs in SSA are understaffed and under resourced. Therefore, the medical device market is not properly regulated and the quality and safety of marketed medical devices can not be ensured. This has not been of great importance for previous mHealth interventions. But it is foreseeable that mobile phones and therefore mHealth interventions will be able to perform increasingly complex (e. g. diagnostic) functions, which could therefore pose a higher risk potential for its users.

4.9 Access to mobile phones

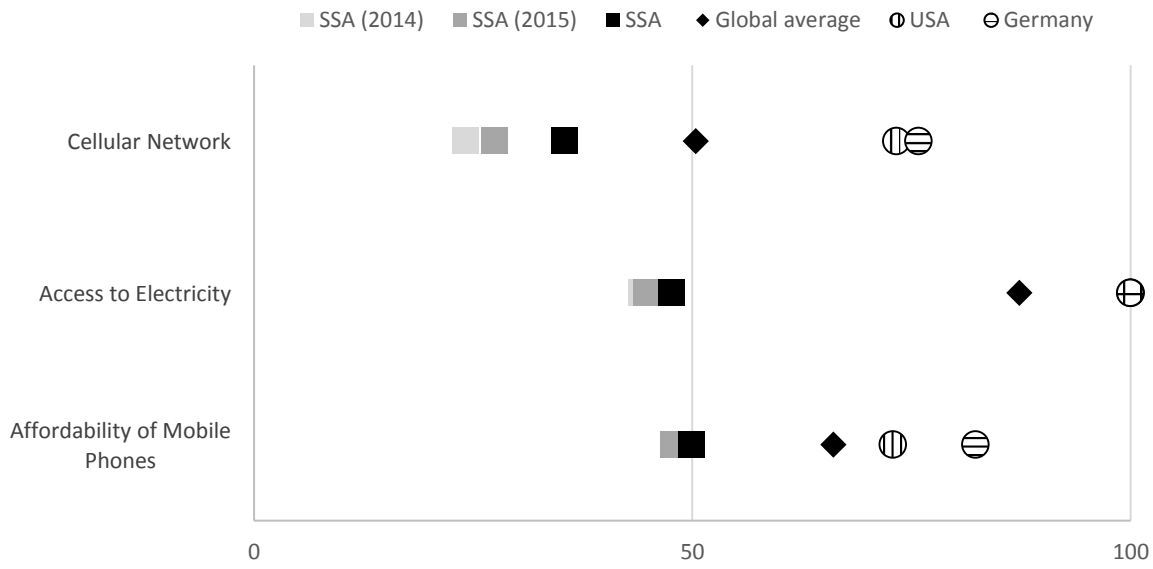
One of the most critical components for the adaptation of mHealth is the access to the technology [69]. The access to mobile phone technology is usually enabled by 3 factors: (1) the costs for buying a mobile phone and for using it, (2) the access to electricity in order to charge the phone, and (3) the access to the cellular network (2G, 3G or 4G). Figure 9 shows the scores for these 3 factors for SSA (which were already presented in the scorecard above) and compares them with scores for Germany, the USA and the global average. It further depicts the development of the indicators in SSA since 2014.

A direct comparison shows that the scores for SSA in all three areas are far lower than the global average. And compared to highly developed countries such as the USA or Germany, the access to electricity and the quality of the cellular network are only half as good in SSA.

The biggest gap is in the area of **access to electricity**. In many SSA countries, less than half of citizens have a reliable access to electricity. And since 2014 this situation has improved only slightly. This poor access to electricity is considered as one of the major prerequisites for a further uptake of mobile phones [70–72]. However, this limitation may not be as important as it has been assumed so far. There are creative solutions which have been developed to bypass this shortage: One example is the use of car batteries for charging phones [73]. Another example is the use so called feature phones. Feature phones are a mixture between smartphones and conventional cell phones, but less complex than smartphones, more affordable and, especially, more durable [74]. These *African solutions* (e. g. using more

durable and less complex phones, bypassing shortages) demonstrate that it is not always necessary to adopt Western standards to ensure access to a technology.

Figure 10: Factors influencing the access to mobile phone technology in SSA, Global Average, Germany and the USA (a higher score represents stronger performance; explanation of indicators and values below)



Cellular Network	Quality and coverage of mobile network according to the 'Infrastructure Index' (scored within a range 0–100; higher score represents stronger performance)
Access to Electricity	% of citizens having reliable access to electricity
Affordability of Mobile Phones	Affordability of mobile phones and its services, according to the 'Affordability Index'

Compared to other regions in the world, the **cellular network** is not as good as it may be assumed (considering the increasing subscription rates in the region). The quality and reliability of the mobile network is significantly driven by the backbone telecommunication infrastructure in Africa. This includes e. g. the international connectivity, the national telecommunication backbone and the last mile. Although there have been enormous investments over the last years to this infrastructure (e. g. in submarine cables and Internet Exchange points (IXPs)), many infrastructure components continue to pose a challenge to access, and African countries are required to make more investments. [75, 76].

The **affordability** is the best of all measured scores and moderate. Financial barriers prevent people particularly from rural areas of owning a mobile phone. But not owning a mobile phone does not necessarily mean to not have access to a mobile phone. In SSA it is not uncommon to share mobile phones among the communities or families [77].

If all factors (the cellular network, access to electricity and affordability of mobile phones) will continuously improving over the next years, an essential requirement for the uptake of mHealth will be ensured. Once access is ensured, the services offered must also be user-friendly designed and adapted to cultural conditions of the users (cultural factors and the inertia of the users must be taken into account) [69].

4.10 Strengths and limitations

The major strength of this research is its holistic view. It combines and analyzes several important factors that are crucial for the system implementation of mHealth. The framework is able to easily depict inhibiting and enabling factors. It could be further very useful for conducting longitudinal analyses and to observe and monitor the implementation-process of mHealth in SSA.

Another strength is the method used for the framework development. Indicators were systematically discussed and reviewed together with a WHO building block expert (VeS). However, a limiting factor could be that the framework might be non-comprehensive and does not cover all relevant indicators.

Also, the underlying parameters which have been identified as part of the SELFIE framework were developed for assessing integrated care models for patients *with multimorbidity*. But the focus here is not on multimorbidity but on NCDs. This was kept in mind when indicators were discussed and chosen.

Moreover, it was difficult to identify experts who had a comprehensive overview of the mHealth landscape in their country. However, answers by the experts were always crosschecked with grey literature and other available published sources. Therefore, most results presented rely on databases or literature.

Furthermore, the framework and the analysis subsume all analyzed countries under one region. Although it is quite common to generalize and to use terms such as ‘Sub-Saharan Africa’, the region is not very homogenous. SSA subsumes 48 countries (for comparison: the EU has 27 countries). Some countries have a low HDI, other countries have high HDI. These discrepancies can be seen in the scorecard and some indicators (e. g. research involvement).

5 Conclusion

First, the African mHealth landscape lacks steering and monitoring.
In some countries the number of implemented projects is extremely high. But these are usually donor driven and the governments are not involved. There is no support for the utilization of mobile phones for health, e. g. by providing guidelines or incentives. In addition, only few governments have formulated a mHealth strategy with tangible goals.

Second, mHealth against NCDs is still in its infancy.
Although the burden of NCDs is increasing and already accounts for more than one third of all deaths in SSA, there are only very few mHealth interventions targeting NCDs. Moreover, the published eHealth or mHealth strategies do not address NCDs.

Thirdly, access to mobile phones and the cellular network is moderate.
The cellular infrastructure and especially the poor access to electricity inhibit the access to mobile phones and therefore the uptake of mHealth. However, the quality of the cellular infrastructure has increased considerably in recent years and the poor access to electricity could be bypassed with *African solutions*.

Last but not least, the rapidly growing technology start-up ecosystem in some African countries is promising. mHealth solutions developed by private companies play an increasingly important role in the development of digital services. Their participation in mHealth could lower the problem of donor-dependencies and lacking sustainability.

6 Availability of data and materials

'Mobile Connectivity Index 2018 – Global Scores' by the GSMA:

https://www.mobileconnectivityindex.com/

'World Fact Book' database by the Central Intelligence Agency:

https://www.cia.gov/library/publications/the-world-factbook/

'Ease of Doing Business' Report, by the Worldbank:

http://www.doingbusiness.org/content/dam/doingBusiness/media/Annual-Reports/English/DB2018-Full-Report.pdf

'Global atlas of medical devices' by WHO:

https://www.who.int/medical_devices/publications/global_atlas_meddev2017/en/

'mHealth database' by the U.S. Agency for International Development:

http://www.africanstrategies4health.org/mhealth-database.html

'mHealth Working Group Inventory of Projects' by the Johns Hopkins University:

https://www.mhealthknowledge.org/resources/mhealth-compendium-database

'mHealth Deployment Tracker' by the GSMA:

https://www.gsma.com/mobilefordevelopment/m4d-tracker/mhealth-deployment-tracker/

'Center for Health Market Innovation' database: http://healthmarketinnovations.org/

'Global Innovation Exchange' database: www.globalinnovationexchange.org/innovation

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Chapter 5: Conclusion

Victor Stephani

5.1 Summary

In this cumulative dissertation it was analyzed whether and how mobile phone-based health interventions (mHealth interventions) would be able to improve treatment and care for people suffering from chronic Non-Communicable Diseases (NCDs) in Sub-Saharan Africa (SSA), one of the poorest regions in the world.

The **first part of the work** (chapter 2) focused on the efficacy of mHealth and the mechanisms behind it. A systematic review of Randomized Controlled Trials (RCTs) in Low and Middle Income Countries (LMICs) showed that mHealth is able to improve clinical outcome parameters of people with NCDs in low-resource settings (e.g. patients with asthma had a significantly better Peak Expiratory Flow Rate (PEFR) when receiving remote monitoring and care support with a mobile phone instead of those treated without).

The analysis also revealed that there are mixed effects and that mHealth does not necessarily lead to a better health-outcome of patients with NCDs. Since the systematic review did not allow to uncover the causal pathways that explain why and how interventions might work, a realist review was conducted which illustrated these casual pathways. It was shown that so called PNE factors - **P**redisposing characteristics (e.g. users' attitude to mobile phones), **N**eeds (e.g. patients' severity of disease) and **E**nabling resources (e.g. users' access to power supply) - influence the perceived ease of use and usefulness of mHealth against NCDs in SSA.

As a conclusion of the realist review, it was suggested that future policy makers and mHealth-program managers need to consider these PNE-factors within a certain context before they introduce mHealth interventions.

To demonstrate how this pre-analysis could be done, a field study was subsequently carried out (third publication of the first part). The PNE factors were used to test the potential for mHealth interventions at the diabetes clinic of the Komfo Anokye Teaching Hospital (KATH) in Kumasi, Ghana. Based on a questionnaire, 150 patients from the diabetes clinic were interviewed. The results showed that a mHealth intervention is most likely to have positive effects on the treatment and care of patients at the KATH diabetes clinic in Kumasi.

In the **second part** (chapter 3) the current self-management behavior of people suffering from diabetes were analyzed. The results of the systematic review showed that the current self-management behavior of people suffering from Diabetes in SSA is poor (particularly in the

areas of blood glucose monitoring, physical activity and risk reduction behavior). Therefore, the need for additional supportive measures for the care of people with NCDs (Diabetes in this example) is high. It was concluded that this could be addressed with mHealth (e.g. by sending recommendations on dietary behavior to patients with diabetes).

Since it has been shown that mHealth against NCDs is effective (chapter 2) and needed (chapter 3), the **last part of the dissertation** (chapter 4) analyzed how such interventions could be implemented into the health systems.

Therefore, on the basis of the World Health Organization (WHO) Building Block concept for describing health systems, a framework was created to analyze the degree of current implementation of mHealth in SSA. A comprehensive analysis of each WHO Building Block was conducted using 10 representative SSA countries. According to this analysis there are currently many inhibitors for the scale-up of mHealth, e.g. the lack of steering and monitoring, lack of financial incentives and lack of good governance. However, some positive developments have also been identified that could enable the implementation of mHealth, e.g. the growing start-up ecosystem in some SSA countries.

5.2 Implications for research

The body of published scientific literature on mHealth in SSA has steadily increased over the last years. Studies reported about positive effects on physical activity and healthy diets [1], on the successful utilization of mHealth as part of the data collection of Community Health Workers (CHWs) [2], on mHealth' capabilities to improve the medication adherence [3] or the clinical attendance of patients [4]. Even in specific fields such as palliative care it has been reported that mHealth could be a useful tool (e.g. as part of the pain management and better communication with health professionals) [5].

However, most of the evidence of the published studies on mHealth in SSA relies on observations from pilot studies or small-scale implementations. There is still a lack of high-quality evidence, particularly in the area of NCDs. This was also shown in the systematic review presented here (chapter 2): Out of the 8 included RCTs on mHealth interventions against NCDs in LMICs, not a single one was conducted in Africa.

So far, there are only few RCTs on the efficacy of mHealth in Africa, e.g. regarding HIV/AIDS or maternal and neonatal care (there, mHealth improved outcome measures such as the

perinatal mortality, delivery with skilled attendance, or attendance at the 7-day post-operative clinic visit following adult male circumcision [6, 7]).

Additionally, there is a lack of studies investigating the use of mHealth in the long term. This is problematic, since there is some evidence that adherence to mHealth interventions decreases with time of use [8].

While the evidence presented supports the conclusion that mHealth is capable of improving treatment and care for people with chronic NCDs in the SSA countries in a variety of ways, there is a strong need to conduct long-term prospective RCTs in order to generate more high-quality evidence for mHealth interventions in SSA. This would help to derive more robust implications for the scale up of mHealth and could ultimately contribute to the creation of an 'evidence map' that would help to understand exactly where mobile phone use in health care is most effective.

Furthermore, potential hazards of mHealth in general were not part of this dissertation. These, of course, need to be carefully tackled and analyzed in the future. In particular, personal health-data protection is of central importance. Most likely, any mHealth interventions lacking a rigid data protection management will not receive public as well as legislative support. Also, the contribution of mHealth to climate change (the electricity consumption of the worldwide ICT infrastructure accounts for already 2% of the global Carbon Dioxide footprint [9]) may receive increasing attention and should fuel efforts to find ecologically sustainable solutions.

5.3 Current boundaries of mHealth in SSA

SSA faces fundamental challenges inhibiting its development in general, but also the development of mHealth in particular. These are:

- **Weakness of the health systems**

  One approach to assessing the performance of health systems is the analysis of the 'cascade of care'. The 'cascade of care' concept is a summary of the sequential stages of medical care for people living with a chronic disease. In the case of Diabetes for example, only 37% of the people who live with the disease in SSA are currently aware of the diagnosis. 17% receive advice on how to live with the disease and only 11% get the needed medication [10]. In addition, chapter 3 has shown that only 5% are able to self-monitor their blood glucose level at home. Hence, lack of medical education and

limited resources are fundamental barriers for mHealth interventions. Therefore, it is important that such cascade gaps are closed.

- **Deficits of electricity infrastructure**

  Electricity is the fuel for technologies. Without it, technologies such as mobile phones can not be used. However, with a current access to electricity of below 50% the situation in SSA (chapter 4) is among the worst in the entire world. Furthermore, it is expected that the entire ICT infrastructure (e.g physical infrastructure such as data centres) and consecutively energy-consumption will increase within the next years. In order to provide a reliable access to mHealth a resilient electricity infrastructure is essential.

- **Political instability**

  Democracies in SSA are often relatively new and develop only very slowly [11]. Trust in the governmental structures, however, is necessary for sustainable project planning, such as those related to mHealth. Besides that, a stronger democracy obviously could also help to govern in the interest of all citizens. This could, for example, also regulate more strictly the marketing of alcohol by multinational alcohol producers (a determinant of chronic diseases) [12].

- **Education exclusion**

  Education is one of the central issues for the sustainable development of Africa, affecting many areas - including health. Many African countries have low school attendance rates. Over one-fifth of children between the age of 6 and 11 and one-third of those between the age of 12 and 14 are not going to school [13]. With regard to mHealth, a more comprehensive education can lead to more sophisticated mHealth interventions being rolled out in the future (e.g. those that require literacy) - which would multiply mHealth' functionalities.

- **Population growth**

  Population growth poses another major challenge to the entire continent. The population in SSA was about 1.1bn in 2018 and it is expected to double by 2050 and may even reach about 4.0bn in 2100 [14]. The larger the population, the higher the demands on the health system which may decrease investment in areas such as the scale up of mHealth (e.g. incentive system for doctors to use mHealth). Therefore, measures of birth control, e.g. mHealth solutions which provide information on

contraceptive methods and increase knowledge on family planning, are of great importance and could contribute to the reduction of the population growth. Currently, approximately 4% of all mHealth solutions can be attributed to family planning (Chapter 4).

- **Poverty**

  Due to the rapid population growth, the number of people living in extreme poverty (less than 1.9 $ per day) has even increased in recent years (from 387 million in 2005 to 413 million in 2015 [15]). This has direct effects on the adoption of mobile phones and mHealth and the affordability of this technology. Therefore, the financial situation of the population in SSA must be considered if mHealth programs are to be rolled out. Models of sharing or renting may be a way to account for these problems.

These points demonstrate: As long as the health- and education systems remain weak, as long as there is no reliable electricity infrastructure, the population continues to grow so rapidly, poverty remains so high and as long as the democracies remain unstable, it will be difficult for mHealth to reach its full potential. It will require a major effort in the coming decades to overcome these challenges, both by African countries as well as the international community.

5.4 Outlook

It became clear that mobile phone-based health interventions could be one answer to the growing burden of chronic NCDs in SSA countries – the need for such supplementary care and treatment is in any case very high. Still, the implementation and scale-up of mHealth interventions require fundamental improvements: within the health systems, but also in many areas outside the health systems.

Finally, the transfer and the exchange of knowledge should guide and accompany these processes: the current developments offer many opportunities to improve global health.

Abbreviations chapter 5

CO_2 footprint	Carbon Dioxide footprint
ICTs	Information and Communication Technologies
KATH	Komfo Anokye Teaching Hospital
LMICs	Low- and Middle-Income Countries
mHealth	mobile phone-based interventions
NCDs	Non-Communicable Diseases
PEFR	Peak Expiratory Flow Rate
PNE	Predisposing characteristics, Needs, Enabling resources
RCTs	Randomized Controlled Trials
SSA	Sub-Saharan Africa
WHO	World Health Organization

References chapter 5

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Appendix

Chapter 2.1 Appendices

Additional file 1: Search method conducted with the CENTRAL-database

ID	Search
#1	MeSH descriptor: [Telemedicine] explode all trees
#2	MeSH descriptor: [Developing Countries] explode all trees
#3	#1 and #2
#4	(”m-Health” or ”mHealth” or mobile or SMS or tele*)
#5	”developing countries” or ”developing world” or ”rural areas” or ”low-resource” or ”low-income” or ”mid-income”
#6	”non-communicable” or noncommunicable or chronic or cancer or neoplasms or diabetes or mental or neurological or ”sense organ” or ophthalmology or cardiology or cardiovascular or heart or digestive or genitourinary or skin or dermatology or musculoskeletal or congenital or oral or pathology or psychiatry or “chronic respiratory disease”
#7	#4 and #5 and #6
#8	#7 or #3

Additional file 2: Risk of bias of the included studies

	Sequence generation – Selection bias	Allocation sequence concealment – Selection bias	Blinding of participants and personnel – Performance bias	Blinding of outcome assessment – Detection bias	Incomplete outcome data	Selective outcome reporting – Reporting bias	Other bias
Balsa and Gandelman [24]	+/-	+/-	+/-	+/-	+	+	+
Liew et al. [29]	+	+	+	+	+	+	+
Liu et al. [27]	+/-	+/-	+/-	+/-	-	+	+
Osotjic et al. [28]	+	+/-	+	+	+	+	+
Piette et al. [22]	+	+/-	-	+/-	+	+	+/-
Shahid et al. [26]	-	+/-	+/-	+	+	+	+
Shetty et al. [25]	+	+/-	+/-	+/-	-	+/-	+
Tian et al. [23]	+	+/-	+/-	+	+	+	-

Chapter 2.2 Appendices

Additional file 1: Search strategy for four databases as at May 31, 2015

Search		Items found
	PubMed QUERY	
#1	mHealth[MeSH Terms]	16186
#2	Sub-Saharan Africa [MeSH Terms]	144985
#3	#1 AND #2	150
#4	((((("mHealth") OR ("m-health") OR ("mobile health") OR ("telemedicine") OR (“mobile device”) OR (“mobile phone”) OR (“cellular phone”) OR ("phone") OR ("text messaging") OR ("SMS") OR (“messaging”) OR (“call”) OR ("App") OR ("Handheld Computers") OR (tele*))))	110330
#5	((((“sub-Saharan Africa”) OR (“Africa”) OR (“developing world”) OR (“developing count*”) OR (“low income”) OR (“middle income”) OR (“low and middle income”) OR (“LMICs”) OR (“LAMICs”) OR (“low resource”) OR (“resource poor”) OR (“limited resource”) OR (“tropical”))))	256139
#6	#4 AND #5	2427
#7	#3 OR #6	2491
	WEB OF SCIENCE QUERY	
#1	TS=(mHealth OR m-health OR mobile health OR telemedicine OR mobile device OR mobile phone OR cellular phone OR phone OR text messaging OR SMS OR messaging OR call OR App OR Handheld Computers OR tele*) Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years	903,138
#2	TS=((“sub-Saharan Africa”) OR (“Africa”) OR (“developing world”) OR (“developing count*”) OR (“low income”) OR (“middle income”) OR (“low and middle income”) OR (“LMICs”) OR (“LAMICs”) OR (“low resource”) OR (“resource poor”) OR (“limited resource”) OR (“tropical”)) Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years	435,172
#3	TS=(("non-communicable disease") OR ("noncommunicable disease") OR ("chronic disease") OR (“NCDs”)OR ("diabetes") OR ("cardiovascular disease") OR ("respiratory tract") OR ("neoplasms") OR ("cancer") OR (“congenital”) OR (“digestive”) OR (“respiratory”) OR (“hypertension”) OR (“sickle cell”) OR (“oral”) OR (“ophthalmology”) OR (“eye”) OR (“ear”) OR (“mental”) OR (“psychiatry”) OR (“depression”)) Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years	3,809,025
#4	#3 AND #2 AND #1 Indexes=SCI-EXPANDED, SSCI, A&HCI Timespan=All years	1,836
	COCHRANE QUERY	
#1	MeSH descriptor: [Telemedicine] explode all trees	1302
#2	MeSH descriptor: [Africa South of the Sahara] explode all trees	4032
#3	#1 and #2	3
#4	(("mHealth") or ("m-health") or ("mobile health") or ("telemedicine") or ("mobile device") or ("mobile phone") or ("cellular phone") or ("phone") or ("text messaging") or ("SMS")	18107

	or ("messaging") or ("call") or ("App") or ("Handheld Computers") or (tele*))	
#5	(("sub-Saharan Africa") or ("Africa") or ("developing world") or ("developing count*") or ("low income") or ("middle income") or ("low and middle income") or ("LMICs") or ("LAMICs") or ("low resource") or ("resource poor") or ("limited resource") or ("tropical"))	14841
#6	#4 and #5	1504
#7	(("non-communicable disease") or ("noncommunicable disease") or ("chronic disease") or ("NCDs") or ("diabetes") or ("cardiovascular disease") or ("respiratory tract") or ("neoplasms") or ("cancer") or ("congenital") or ("digestive") or ("respiratory") or ("hypertension") or ("sickle cell") or ("oral") or ("ophthalmology") or ("eye") or ("ear") or ("mental") or ("psychiatry") or ("depression"))	378526
#9	#7 and #6	1186
#10	#9 or #3	1188
	GOOGLE SCHOLARS QUERY	
	(("mHealth") OR ("mhealth") OR ("mobile health") OR ("telemedicine") OR (“mobile device”) OR (“mobile phone”) OR (“cellular phone”) OR ("phone") OR ("text messaging") OR ("Handheld Computers")) AND ((“sub-Saharan”) OR (“Africa") OR ("LMIC))	684

Additional file 2: Theories included or excluded in review

Theory/Model	**Brief description [Inclusion/Exclusion]**
1) Middle-Range Theory of Self-Care of Chronic Illness [28]	Describes self-care as the process of maintaining health with health promoting practices within the context of the management required of a chronic illness. [***Excluded*****:** the theory treats access to care not necessarily as an outcome/output measure but rather as a factor that can impact on self-care]
2) Theory of Reasoned Action/Theory of Planned Behaviour [29]	Predicts and understands individual behaviour as a function of a formed intention based on beliefs, norms, attitudes and self-efficacy. [***Exclusion:*** Technology acceptance model was preferred and deemed fit because it has been based on reasoned action approach and directly relates to the assessment of technology-based interventions]
3) Rosenstock’s Health Belief Model [30]	Considers a person’s actions to treat and prevent disease because of the individual’s perceived susceptibility to disease, threat of disease, costs-benefits and cues to action. [***Excluded:*** the model concentrates partly on disease prevention which falls outside the scope of this review]
4) Andersen’s Behavioural Model of Health Services Utilization [31, 32]	According to Andersen’s original model, peoples’ decisions to use (or access) healthcare services are determined by three main factors: (1) predisposing characteristics (e.g. age, health beliefs), (2) enabling resources (e.g. availability of providers) and (3) need (e.g. burden of disease). [***Included:*** it could potentially provide insights into the mechanisms linking contextual and individual level factors with improved access to care]

5)	Young's Choice-Making Model [33]	Considers that individual's health service choice is based on perceived gravity of illness, the knowledge of a home treatment, faith in treatment and accessibility of treatment. [***Excluded:*** access to treatment (care) is considered an important influential factor on health care utilization and not necessarily an outcome/output]
6)	Davis's Technology Acceptance Model [34, 35]	Posits that the use and acceptance of technology is determined by two factors: *perceived usefulness* and *perceived ease of use.* Thus, health professionals will perceive a technology to be useful if they belief that it will help them to do a better job; and they will perceive a technology to be easy to use if they believe that it can be used without effort. [***Included:*** provides additional insights into mechanisms that are important for explaining individual's behaviour towards the use of information technology and information systems]

Additional file 3: Description of included articles providing the information for the synthesis and conclusions in this review

Ref. No.	**Author (year)**	**Title**	**Country**	**Intervention**	**Study design**	**Disease indication**	**Modality of interaction**	**User - participants**
36	Azfar, R. S., et al. (2014)	Reliability and Validity of Mobile Teledermatology in Human Immunodeficiency Virus-Positive Patients in Botswana A Pilot Study.	Botswana	(inter-national) mobile phone teledermatology diagnosis and management evaluation	Cross-sectional pilot cohort	dermatology	provider-to-provider	4 providers 76 patients cases
20	Azfar, R. S., et al. (2011)	HIV-positive patients in Botswana state that mobile teledermatology is an acceptable method for receiving dermatology care.	Botswana	(inter-national) mobile teledermatology evaluation of patients with skin or mucosal complaints	Cross-sectional survey	dermatology	patient-to-provider	75 patients
37	Chindo, L. (2013)	Mobile phone use in Cameroon: an increasingly useful tool for the follow-up of children with Burkitt lymphoma.	Cameroon	(in-country) use of mobile phone to contact patients' parents	Record review (letter)	Burkitt lymphoma (BL)	patient (parent proxy)-to-provider	285 patient cases
38	Fiander, A., et al. (2013)	Results from 2011 for the transportMYpatient program for overcoming transport costs among women seeking treatment for obstetric fistula in Tanzania.	Tanzania	(in-country) mobile phone technology to transfer funds to cover patients' transport costs	Record review	obstetric fistula	provider-to-provider	286 patients 253 health workers

39	Fruhauf, J., et al. (2013)	Mobile teledermatology in sub-Saharan Africa: a useful tool in supporting health workers in low-resource centres.	Uganda	(inter-national) smartphone-based remote expert diagnosis of dermatology cases	Mixed methods	skin diseases: inflammatory, infectious, neoplastic, autoimmune and others	provider-to-provider	72 patients 4 health workers
40	Greisman, L., et al. (2014)	Feasibility and cost of a medical student proxy-based mobile teledermatology consult service with Kisoro, Uganda, and Lake Atitlan, Guatemala.	Uganda	(inter-national) smartphone-based dermatology consult service	Mixed methods	skin diseases: Biopsy	provider-to-provider	57 patients 1 student proxy
41	Holeman, I., et al. (2014)	Mobile health for cancer in low to middle income countries: priorities for research and development.	Malawi	(in-country) SMS exchange between CHWs and a nurse at a district hospital	Commentary	cancers, HIV or Tuberculosis.	provider-to-provider	75 health workers
42	Kingue, S., et al. (2013)	Efficiency of an intervention package for arterial hypertension comprising telemanagement in a Cameroonian rural setting: The TELEMED-CAM study.	Cameroon	(in-country) GSM mobile telephone communication between staff at health centers and the telecare center	Prospective interventional study	hypertension	provider-to-provider	5 cardiologists 268 patients
43	Kiser, M., et al. (2013).	Photographic assessment of burn wounds: a simple	Malawi	(in-country) cell phone-based cameras used for	Cohort study	burn injury	provider-to-provider	2 burn physicians/ clinicians

		strategy in a resource-poor setting.		photographing wounds for experienced clinician's TBSA estimations and examination.				39 patients
53	Kivuti-Bitok, L. W., et al. (2012)	Self-reported use of internet by cervical cancer clients in two National Referral Hospitals in Kenya.	Kenya	(in-country) use of eHealth tools in cervical cancer management	Cross sectional descriptive survey	cervical cancer	patient-to-(system) provider	199 patients
52	Littman-Quinn, R., et al. (2013)	Implementation of m-health applications in Botswana: telemedicine and education on mobile devices in a low resource setting.	Botswana	(inter-national/in-country) smartphone-based management of complex patient cases by collecting pertinent clinical history and associated images for specialist consultation	-	women's health (cervical cancer) radiology oral medicine dermatology	provider-to-provider	24 clinicians 643 cases
45	Ndlovu, K., et al. (2014)	Scaling up a Mobile Telemedicine Solution in Botswana: Keys to Sustainability.	Botswana	(inter-national/in-country) smartphone-based management of complex patient cases by collecting pertinent clinical history and associated images for specialist consultation	Pilot study	women's health (cervical cancer) radiology oral medicine dermatology	provider-to-provider	27 clinicians 696 cases

46	Odigie, V. I., et al. (2012)	The mobile phone as a tool in improving cancer care in Nigeria.	Nigeria	(in-country) phone-based consultation about medical care	Structured interview	cancer	patient-to-provider	1176 patients 1 oncologist
47	Opoku, D., et al. (2015)	Healthcare Professionals' Perceptions of the Benefits and Challenges of a Teleconsultation Service in the Amansie-West District of Ghana.	Ghana	(in-country) teleconsultation for treating patients in times of difficulties	Qualitative study	health-related outcomes	provider-to-provider	8 health workers 3 healthcare professionals
48	Osei-tutu, A., et al. (2013)	Mobile teledermatology in Ghana: sending and answering consults via mobile platform.	Ghana	(in-country and inter-national) mobile telephone-based images and data collected for teledermatological diagnosis	Pilot study	dermatology	provider-to-provider	5 dermatologists 34 patients
54	Pastakia, S. D., et al. (2011)	The evolution of diabetes care in the rural, resource-constrained setting of western Kenya.	Kenya	(in-country) cell phone-based support to patients on nonclinical days	-	diabetes	patient-to-provider	2100 patients >2 healthcare professionals
49	Qin, R., et al. (2013)	Reliability of a telemedicine system designed for rural Kenya.	Kenya	(in-country) store-and-forward mobile telemedicine system to collect and send vital statistics	Modified intraobserver concordance study	NCDs: diabetes, hypertension	provider-to-provider	102 patients 1 nurse 1 CHW
55	Rotheram-Borus, M. J., et al. (2012)	Diabetes buddies: peer support through a mobile phone buddy system.	South Africa	(in-country) mobile phone-based peer support intervention among women in	Pilot study	diabetes	patients-to-provider	22 patients 3 nursing sisters

				resource-poor settings				
50	Stewart, A. N., T.; Eales, C.; Shepard, K.; Becker, P.; Veriawa, Y. (2005)	Adherence to cardiovascular risk factor modification in patients with hypertension.	South Africa	(in-country) a once-a-month telephone call by healthcare practitioners to both the patients and a member of their famlies.	Randomized controlled trial	hypertension	patient-to-provider	83 patients 1 physiotherapist
51	Temmingh, H., et al. (2013)	The evaluation of a telephonic wellness coaching intervention for weight reduction and wellness improvement in a community-based cohort of persons with serious mental illness.	South Africa	(in-country) telephonically delivered life style and wellness program by lifestyle coaches	Cohort study	mental health	patient-to-provider	Lifestyle coaches 761 participants

Chapter 2.3 Appendix

Additional file 1 Questionnaire

Potential and acceptance level of mobile phone based treatment interventions: A survey among Diabetes patients in Ghana

The following questions are about your Diabetes:

1. What type of Diabetes do you have?
    - Type 1
    - Type 2
    - Don't know

2. For how many years have you been living with Diabetes: …….
3. What was your last HbA1c?
    - ……
    - Don't know

4. Do you have any diseases beside your Diabetes?
    - Yes
    - No

5. What did you first do when you were diagnosed with Diabetes?
    - Go to health facility
    - Consult (fetish) priest
    - Use herbs/natural remedies (at home)
    - Others (specify) …….

6. Do you have family members/friends/relatives who support you in managing your Diabetes?
    - Yes
    - No

7. Is anyone else in your family diagnosed with Diabetes?
    - Yes
    - No

8. How many minutes do your need from your home to the next Diabetes health facility?
    - …..

The next questions are about your mobile phone and how you use it:

9. Do you have permanent access to a mobile phone?
    - No
    - Personal ownership
    - Family phone
    - Borrowing
    - Others (specify) …….

10. Do you have to share the phone with someone else?

- Yes if yes, with how many: …
- No

11. How high is the percentage of your time, you carry your mobile phone with you?
    - ……

12. How long have you been using a mobile phone? …….
13. What type of phone do you use?
    - Smartphone
    - Cell phone
    - No phone

14. What are the main functions you use the phone for? (multiple answers are possible)
    - Calling
    - Texting
    - Surfing in the internet
    - Using apps
    - Others (specify) …….

15. In what language do you often communicate when using the phone?
    - English
    - Other

16. How often do you have to recharge your phone?
    - Every day
    - Every couple of days
    - Every week

17. How often do you have to repair your phone?
    - never
    - once per year
    - more often

18. Are you aware of the possibility to use your mobile phone for health care support? (e.g. using video calls for medical check-ups)
    - Yes
    - No

19. Do you think family members/friends/relatives would support you when healthcare is delivered with a mobile phone?
    - Yes
    - No If no, why? .....

20. To what extent do you think mobile phones can be easy to use in diabetes treatments?

……
……

How much do you agree or disagree with the following statements. Please circle the correct number to each question (1= you strongly agree; 5= you strongly disagree)?

		Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
Statements about your mobile phone						
21	Mobile phones are very common and widely used in my community	1	2	3	4	5
22	I am familiar with using a mobile phone	1	2	3	4	5
23	I have a positive attitude towards mobile phones	1	2	3	4	5
24	I have convenience, autonomy and privacy on the phone	1	2	3	4	5
25	The mobile phone network (2G,3G or 4G) is reliable and functioning stable	1	2	3	4	5
26	There is constant supply of electricity to charge the phone	1	2	3	4	5
27	Services on the mobile phone (e.g. air time) are affordable	1	2	3	4	5
28	I am willing to pay for a mobile phone supported treatment	1	2	3	4	5
Statements about your Diabetes treatment						
29	The cost of the Diabetes treatment is too expensive	1	2	3	4	5
30	Following and adhering the Diabetes-treatment is difficult	1	2	3	4	5
31	I suffer from complications due to my Diabetes	1	2	3	4	5
32	The Diabetes treatment is sufficient and satisfies all my health needs	1	2	3	4	5
33	The health staff is always available when I need them	1	2	3	4	5

The following questions are about your personal characteristics:

34. What is your age? …….
35. What is your sex?
    - Male
    - Female

36. What is your highest level of education?
    - None
    - Primary
    - Middle/JHS
    - Secondary/SHS
    - Post-secondary/Tertiary
    - Others (specify) ……

37. What is your literacy level?
    - Read and write
    - Read only
    - Cannot read and write

38. What is your language of locality? ……
39. What is your Ethnicity? ……..
40. What is your place of living?
    - Urban
    - Rural

41. What is your marital status?
    - Single
    - Married
    - Divorced
    - Widowed
    - Separated

42. What kind of employment status do you currently have?
    - Employed
    - Unemployed
    - Retired
    - Student

43. Do you have a regular income?
    - Yes
    - No, irregular
    - None

44. Do you want to comment or add anything?

……
……

Chapter 3 Appendices

Additional file 1: Search strategy used

Africa OR "Sub-Saharan Africa" OR Angola OR Benin OR Botswana OR Burkina Faso OR Burundi OR Cameroon OR Central African Republic OR Chad OR Congo OR Comoros OR Cote d'Ivoire OR Democratic Republic of the Congo OR Equatorial Guinea OR Eritrea OR Ethiopia OR Gabon OR Gambia OR Ghana OR Guinea-Bissau OR Kenya OR Lesotho OR Liberia OR Madagascar OR Malawi OR Mali OR Mauritania OR Mozambique OR Namibia OR Niger OR Nigeria OR Republic of Congo OR Rwanda OR Sao Tome and Principe OR Senegal OR Sierra Leone OR Somalia OR South Africa OR Sudan OR Swaziland OR Tanzania OR Togo OR Uganda OR United Republic of Tanzania OR Zambia OR Zimbabwe
AND Diabetes
AND "Self-Management" OR "self-care" OR "self-control" OR empowerment OR knowledge

Additional file 2: PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3-5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	3
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Additional file 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	4-5
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	5
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	4, Table1

Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	5
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	5
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	Additional file 3-5
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	-
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	5-6
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	7, table 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Additional file 3-5
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	8-14
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	10,
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	17, Additional file 3-5
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	7-13
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	15

Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	17
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	18
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	-

Additional file 3: Risk of bias assessment for cross-sectional studies

Author	Year	Response Rate	Sampling technique	Screening questions										
				1	2	3	4	5	6	7	8	9	10	11
Abdelgadir	2006	-	consecutive sampling	+	+	+/-	+	+	+	+	+	+	+/-	+
Adeniyi	2015	-	purposive sampling	+	+	+	+	+	-	+	+	+	+/-	+
Adibe	2011	78.50%	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Adisa	2009	100%	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Adisa	2011	81.40%	convenient sampling	+	+	+	+	+	+	+	+	+	+/-	+
Awah	2008	-	purposive sampling	+	+	+	+	+	-	+	+	+	+/-	+
Awah	2009	-	purposive sampling	+	+	+/-	+	+	-	+	+	+	+/-	+
Awotibede	2016	-	purposive sampling	+	+	+	+	+	+	+	+	+	+	+
Bruce	2015	89.30%	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
de-Graft Aikins	2014	-	consecutive sampling	+	+	+/-	+	+/-	-	+	+	-	+/-	+
Doherty	2014	-	convenient sampling	+	+	+	+	+	+	+	+	+	+	+
Ezuruike	2016	-	convenient sampling	+	+	+/-	+	+	+	+	+	+	+/-	+
Haque	2005	-	consecutive sampling	+	+	+	+	+	-	+	+	+	+/-	+
Hijelm	2010	-	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Hijelm	2008	-	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Iwuala	2015	-	convenient sampling	+	+	+	+	+	+	+	+	+	+	+
Jackson	2014	79.70%	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Jackson	2015	-	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Kamuhabwa	2014	94.40%	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Kassahun	2016	-	-	+	+	+/-	+	+	+	+	+	+	+	+
Matheka	2013	100%	convenient sampling	+	+	+/-	-	+	+/-	+	+	+	+/-	+

Author	Year	Response Rate	Sampling technique	Screening questions										
				1	2	3	4	5	6	7	8	9	10	11
Matwa	2003	-	purposive sampling	+	+	+/-	-	+	-	-	+	-	+/-	+
Mayega	2014	-	purposive sampling	+	+	+	+	+	+	+	+	+	+	+
Mendenhall	2015		convenient sampling	+	+	+/-	+	+	-	+	+	+	+/-	+
Mogre	2016	-	convenient sampling	+	+	+/-	-	+	+	+	+	+	+	+
Nielsen	2016	-	convenient sampling	+	+	-	-	+	-	-	+	+	+	+
Nthangeni	2002	-	convenient sampling	+	+	+	+	+	+	+	+	+	+/-	+
Obirikorang_BMC	2016	-	purposive sampling	+	+	+	+	+	+	+	+	+	+/-	+
Obirikorang	2016	-	convenient sample	+	+	-	-	+	+	+	+	+	+	+
Ogbera	2011	-	consecutive sampling	+	+	+	-	+	+	+	+	+	+/-	+
Okonta	2014	-	consecutive sampling	+	+	+	+	+	+/-	+	+	+	+/-	+
Onakpoya	2010	-	consecutive sampling	+	+	+	+	+	-	+	+	+	+/-	+
Oyetunde	2014	79%	consecutive sampling	+	+	-	+	+	+	+	+	+	-	+
Sorato	2016	-	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Steyl	2014	54.20%	consecutive sampling	+	+	+	+	+	-	+	+	+	+/-	+
Wabe	2011	90.45	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+
Yusuff	2008	-	consecutive sampling	+	+	+	+	+	+	+	+	+	+	+

(+): low risk of bias; (+/-): unclear risk of bias; (-): high risk of bias;

Screening Questions - 1: Did the study address a clearly focused issue?; 2: Did the authors use an appropriate method to answer their question?; 3: Were the subjects recruited in an acceptable way?; 4: Were the measures accurately measured to reduce bias?; 5: Were the data collected in a way that addressed the research issue?; 6: Did the study have enough participants to minimize the play of chance?; 7: How are the results presented and what is the main result?; 8: Was the data analysis sufficiently rigorous?; 9: Is there a clear statement of findings?; 10: Can the results be applied to the local population?; 11: How valuable is the research?

Additional file 4: Risk of bias assessment for pre-post, quasi-experimental studies

Author	year	Response Rate	Sampling Technique	Screening questions											
				1	2	3	4	5	6	7	8	9	10	11	12
Bauman	2015	-	convenient sampling	+	+	+/-	+/-	+	+	+	-	+/-	+	-	-
Awodele	2015	-	consecutive sampling	+	+	+/-	+/-	+	-	+	-	+/-	+	-	-

(+): low risk of bias; (+/-): unclear risk of bias; (-): high risk of bias
Screening Questions – 1: Was the study question or objective clearly stated?; 2: Were eligibility/selection criteria for the study population prespecified and clearly described?; 3: Were the participants in the study representative of those who would be eligible for the test/service/intervention in the general or clinical population of interest?; 4: Were all eligible participants that met the prespecified entry criteria enrolled?; 5: Was the sample size sufficiently large to provide confidence in the findings?; 6: Was the test/service/intervention clearly described and delivered consistently across the study population?; 7: Were the outcome measures prespecified, clearly defined, valid, reliable, and assessed consistently across all study participants?; 8: Were the people assessing the outcomes blinded to the participants' exposures/interventions?; 9: Was the loss to follow-up after baseline 20% or less? Were those lost to follow-up accounted for in the analysis?; 10: Did the statistical methods examine changes in outcome measures from before to after the intervention? Were statistical tests done that provided p values for the pre-to-post changes?; 11: Were outcome measures of interest taken multiple times before the intervention and multiple times after the intervention (i.e., did they use an interrupted time-series design)?; 12: If the intervention was conducted at a group level (e.g., a whole hospital, a community, etc.) did the statistical analysis take into account the use of individual-level data to determine effects at the group level?

Additional file 5: Risk assessment of Randomized Controlled Trials

Author	Year	Response Rate	Sampling technique	sequence generation	allocation sequence concealment	blinding of participants and personal	incomplete outcome data	selective outcome reporting	other bias
Mash	2014	-	consecutive sampling	+	+	+/-	+	+	+/-
Muchiri	2015 and 2016	-	convenient sampling	+	+	+/-	+	+	+
Van de doest	2013	-	snowball sampling	+	+	+/-	+	+	+

(+): low risk of bias; (+/-): unclear risk of bias; (-): high risk of bias

Chapter 4 Appendix

Additional file 1: Questionnaire sent to experts

Expert survey:

The implementation of mHealth in sub-Saharan African countries

The utilization of mobile phones for preventing and managing diseases has proven to be effective, especially in sub-Saharan African countries. At the same time the need for such a technology which supports the provision of healthcare is very high. This applies particularly for people with chronic and non-communicable diseases, which are expected to become much more prevalent over the next years. However, although the efficacy of mHealth has been proven and the technology is needed, African health systems are lacking to implement mHealth into their health systems. Most mHealth projects remain in a project-status and are not scaled to a national level. Therefore, this questionnaire wants to identify current gaps in the implementation process of mHealth in your country. As part of our literature review, we have identified several factors, which are necessary for a sustainable, nation-wide implementation of mHealth interventions. These factors have been translated into questions which are listed below. **Please feel free to answer the questions with short key points or either yes or no**. If you can recommend any literature (scientific, reports etc.) feel free to refer to it.

Thank you very much in advance,

Victor Stephani

Department of Health Care Management, Technical University of Berlin, Str. des 17. Juni 135, 10623 Berlin

(1/6) **Leadership & Governance**	
Is there a current national digital strategy/agenda (e. g. eHealth strategy)?	
Is mHealth specifically included in the strategy?	
If yes, what are the major aims regarding mHealth?	
Is the government committed to the achievement of their aims / Have they so far reached their goals?	
Are there currently any mHealth interventions which are funded and/or implemented by the Ministry of Health?	

(2/6) **Health workforce**	
How is the health personnel being paid for using mHealth / what are the incentives for the health personnel to use mHealth?	
Are there national guidelines/norms/workshops etc. on how to utilize mHealth?	

(3/6)**Health Care Financing**	
Is there any financial support for the implementation of mHealth interventions by the Ministry of Health?	
Who or which institution is the biggest funder of mHealth interventions?	
Are there financial barriers for using mHealth interventions?	
Are expenditures for mHealth programs reviewed (e. g. by an accounting control)?	

(4/6) **Service Delivery**	
Do all people in need have free access to the relevant mHealth interventions?	
Does the Ministry of Health has close links to the industry or the 'Ministry of Technology' (in order to stimulate integration and collaboration)?	
What disease-focus do most mHealth interventions in your country have?	
Do the mHealth programs use a patient-centred approach?	

(5/6) **Information and research**	
Is there a legislative framework for the protection of (health-related) data?	
Are current policies stimulating research on mHealth?	

(6/6) **Medical products, technologies**	
Is there an innovation-friendly environment for private companies/start-ups etc.?	
Is there a regulatory system for marketing mHealth? (e. g. is mHealth a medical product which needs to be certified by an independent institution comparable to the FDA in the USA)?	