Medication Adherence: A Review and Lessons for Developing Countries

Article *in* International Journal of Online Engineering (iJOE) · July 2019

DOI: 10.3991/ijoe.v15i11.10647

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https://doi.org/10.3991/ijoe.v15i11.10647

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Abstract—Most of the time, complete adherence to prescribed medication is a big step towards recovery from either chronic or acute diseases, but patients often are unaware of the adverse effects that could arise from inconsistency in adherence. The inability of patients to adhere to prescription can affect the potency of some effective therapies known to treat many conditions, and passive compliance may result in the development of resistant to the drug causing a need for treatment modification. Shockingly, more than half of the drugs prescribed for patients with chronic conditions like diabetes and hypertension were found not to be taken as recommended. Adherence is so important because it can assist clinicians in successful supervision of evidence-based treatment of patients; therefore this paper presents an overview of medication adherence, non-technology and technology-based approaches, and lessons for developing countries.

Keywords—Medication adherence; prescription; ehealth; developing countries

1 Introduction & Background

Medication adherence is an important step in the treatment of diseases, and patients' inconsistencies to the regimen could result in a poor state of health, unnecessary increased cost of care, and long recovery time. Nonadherence has been recognized as a public health issue in both developed and developing countries, although evaluating nonadherence could be expensive in countries with decentralized healthcare system [1,2]. Moreover, Africans and Asians have been found to be more non-compliant with medication regimens [3]. Due to different reasons, patients might decide against collecting their prescribed medications from the dispensing system, resort to overdose, and indulge in irregular intake frequency. These kinds of primary noncompliance which slow down recovery, though can be reduced to some extent by the use of technology in prescription, are very common in rural areas of developing countries [4]. Factors such as education, gender, and proximity and frequency of visit to healthcare facilities have been identified to be responsible for noncompliant behaviour towards electronic prescription in poor countries [4].

As stated in existing studies, low level of medication adherence is connected with many things such as the high possibility of demise and hospitalization of people with heart failure with reduced ejection fraction[5], exposure to a high risk of sudden fractures and deaths in osteoporosis patients[2], and several other casualties. Nonadherence is chiefly high among patients with chronic diseases, especially hypertensive patients who are responsible for close to 50% of nonadherence, and by the year 2025, the prevalence of hypertension is projected to go up by 30% [3]. The direct and indirect methods have been used for evaluating drug adherence It is however recommended that the use of direct methods for treatment of chronic disease, like resistant hypertension, is more accurate and less prone to patients' manipulation [6]. Direct methods make use of direct observation of the patient in the course of taking the prescription, and therapeutic drug monitoring. The indirect methods analyzing medication adherence include the use of adherence questionnaire, medical diaries, patient interviews, automated electronic pillbox, prescription registries, and manual counting of pills [1].

Using Morisky Green Levine Questionnaire, a study on adherence performed with 150 patients taking medication for at least two chronic conditions showed that 52% of the patients were non-adherent with associated causes including forgetfulness which occurred in 43.3% patients, carelessness (20%), discontinuing medication once patients felt better (14.7%) and stopping the medication once they felt worse (13.3%). It was also shown that 48.7% were unintentionally non-adherent, 24% were intentionally non-adherent, and 20.7% had mixed attitudes towards adherence [7]. In addition to the myriad of other factors such as medication intolerance, the need for support, the cost of treatment, and forgetfulness; insufficient motivation is equally responsible for non-adherence to medication exercise [8]. Inadvertent negligence of patients, probably arising from low motivation, is reported to be associated with about one-third of medication noncompliance, and a lot of smartphone apps have been designed to this effect, though with most focusing more on deliberate nonadherence, and with many lacking shreds of evidence that showed neither their effectiveness nor quality. There are indications that even many of the people who take their medication regimens seriously also fall victim of forgetfulness. Apart from gamifying adherence process by introducing game elements to add fun, and modify and train the psychology of the patients [8], one of the interesting general solutions to tackle this is the formalization of the guidelines for designing apps for reminding patients about their medication routine developed by [9]. Rather than relying solely on generic timer-based medication reminders, the amalgamation of daily routine actions and habits like breakfast, visiting the kitchen and other things done regularly into reminder apps was advocated for. This association is expected to reduce the burden of trying to catch up with ordinary difficult timer task and makes the process smarter and more personalized. Nonetheless, different forms of technologies to assist patients such as the reminder app have been proposed, however an evaluation of technology meditated interventions (TMIs) for supporting adherence from Cochrane review showed that, even though TMI has been used for providing patients with health education, professional advice, personal health management tools, and reminders, evidence supporting TMI for adherence is still limited and inconsistent [10].

Globally, the use of technology in healthcare service delivery (known as eHealth) has the potential to transform healthcare medications management, by providing important personalization and tracking– which can help to reduce the overhead cost associated with fluctuating abidance to medication instructions. [11,12,13]. [11] investigated the projected roles of eHealth systems in supporting and improving the general health of patients and the effectiveness of adherence as medication intervention. They concluded in order for low- and middle-income countries to benefit from the future eHealth solutions, there is a need for a context-based and adaptable transdisciplinary research approach that considers the multifaceted factors that can contribute to effective investment in eHealth at the macro, micro, and meso levels. Whether the pieces of evidence supporting technology usage are conflicting or not, it is difficult to categorically undermine the role of technology in improving medication adherence, and some studies have even stated that the use of telemedicine technology for medication adherence and the future exploration of artificial intelligence can also change the way medication regimens is addressed [14]. This paper performs a summary review of medication adherence, non-technology and technology-based approaches, and a lesson for developing countries.

2 Literature Review

Recapitulation of some of the related work pertaining to adherence in different groups of patients is presented in this section. Medication adherence issue is common among patients treating both chronic and acute diseases irrespective of their age group. Medication adherence challenges facing elderly patients were presented in [15] through the case report of a certain 80-year-old male patient who could not manage his 17 different medications at home. In their findings, the elderly are susceptible to several comorbidities requiring polypharmacy, and this may make them guiltier of medication nonadherence that younger patients. They are therefore likely to have a more frequent hospitalization, increased health spending, slow healing and so on. Similar to the hurdles in the way of older adults' commitment to medication regimens stated in [16], the authors divided the factors responsible for elderly nonadherence into five – patient, socioeconomic, healthcare system, healthcare provider, and medication. They concluded by emphasizing that the job of a physician does not stop at writing a prescription alone, but it also includes ensuring patients' adherence so that they can maximize benefits therapeutically. According to [2], the level of nonadherence in osteoporosis patient is comparable to what is found in other chronic diseases like diabetes and hypertension. Osteoporosis medication has been proven to work well, however, nonadherence could be dangerous because a noncomplying patient may show no symptoms until a fracture occurs. Similarly, they also stressed the need to understand some of the contributing factors to nonadherence mentioned in [15]. Healthcare system interventions such as pharmacist-directed interventions and fracture liaison service appeared to be successful. Patient-directed behavioural interventions such as behavioral interventions using counseling sessions, and behavioral interventions using prompts for taking medications (use of pillbox, calendars, alarm clocks, telephone calls and so on) did not give a good outcome. They concluded that the lack of awareness and poor education of patients on osteoporosis may have contributed to the failure of patient-directed behavioural intervention. The most frequently used interventions for enhancing medication compliance identified by [17], were classified as behavioral interventions (therapies and techniques to improve patients' attitude to treatment), educational intervention (patients' education on medication adherence techniques), integrated care interventions (collaborations between health care personnel and patients), self-management and risk communication interventions. It was also noted that many studies focused on short term adherence, and the adherence methods in place for chronic patients have not been very effective. The authors concluded that behavioral adherence interventions have been more successful than others, suggesting a need for more focus on improving health literacy. [18] carried out a review of medication adherence in patients with chronic heart failure (CHF). The search was performed using Medline and Cochrane database and incorporated all records accessible up until 2014. It yielded 17 studies that covered 162,727 patients. Ten studies which covered 33.7% of all participants showed no correlation between age and medication adherence, and the mean age of adherent patients was between 66 and 75 years of age. Only one study indicated a better medication adherence in older patients compared to youths and they then concluded that increased age alone is not connected to reduced medication adherence in patients with CHF. A cross-sectional study was carried out with 2445 adult patients on an anti-hypertensive medication by [19] in Hong Kong. A questionnaire was used and eight-item Morisky medication adherence scale was applied to evaluate the level of adherence in these patients. Results from their study demonstrated that about 55.1% of the patients had good medication adherence, with a score greater than 6. Age, employment status, illness perception, and self-perceived health state are viewed as basic factors in medication adherence. They concluded by suggesting the use of educational projects in promoting adherence in younger patients. Understanding the factors affecting adherence is still ongoing research because their comprehension can help to increase patient's compliance. In a recent study, [20] developed a new way to measure medication adherence which involves determining adherence levels as well as the specific factors that influence non-adherence in patients with inflammatory bowel disease. This new method called the medication adherence index was evaluated against the popular Morisky medication adherence scale-8. It was noted that specifying the reasons for non-adherence significantly increased adherence in patients, this is logical because if the causes of non-adherence are known, adequate solutions can be provided.

On the impact of mobile technology on adherence, [21] analyzed various mobile phone applications for medication adherence, available on Apple and Android devices. Out of the 70 applications identified, 20 applications were assessed through a web-based review, and a content analysis was done on the reviews provided by users of the applications. Apple had a total of 443 adherence applications and Android had 261 applications. It follows that 38.1% and 31.4% of the Apple and Android applications respectively had at least 2 medical adherence features. Also, 17.9% and 33.1% of applications on Apple and Android platforms had an alerting or reminder feature and over 90% do not require internet connectivity to be able to do so. In the reviews provided by users, 34.16% provided positive comments about the adherence applications and found them very helpful. In the same vein, [22] performed a review on technologies available for monitoring medication adherence and categorize them into sensor systems, vision-based, proximity-based and fusion based systems. Under sensor systems, there are wearable sensors and fixed sensors (which can be mounted on pillboxes) and ingestible sensors. Some applications in this category include Medtracker, Pillsense, and Medrem. MyTmed, which has ingestible biosensors, is an example of ingestible sensors. Proximity sensors include technologies that make use of RFID technology, vision-based systems include technologies that make use of the smartphone camera in detecting medication compliance, and fusion based systems blend multiple techniques. Challenges that affect the use of the technologies highlighted include, system and data accuracy, energy consumption, acceptability and user tampering. [23] identified the most popular technologies for medication adherence, in young adults with sickle cell disease through a survey carried out on 80 patients, and it was discovered that 79% of patients preferred daily text messages as reminders to take medication and other technologies that assist directly observed therapy. The major features in smartphones that boost adherence include medication reminders, medication logs, positive feedback and adherence text prompts. However, a review of 15 applications available for HIV management showed that while the majority of the applications had reminders, logs, resources and search functionalities, none of them had the self-management feature which is necessary for persons living with HIV.

Authors in [24] further investigated software solutions and computerized devices accessible for improving heart failure results by conducting a survey on mobile applications available for medication adherence. Key highlights of the applications were presented and many of the mobile applications have an interactive education module and social support networks which help enhance disease management. A precedent, Proteus Discover: a mobile application with a versatile sensor patch that reports the pulse, blood pressure and medication adherence of patients to sensor enabled pills was mentioned. Other applications include Medisafe, Pill monitor free, and Dosecast. The authors recommended the use of digital and patient management tools for a robust heart failure platform for enhancing adherence. [25] examined the perception of hypertensive patients to the use of smartphone applications in improving adherence in a study with 24 participants. The application analyzed, MiBP, is a self-management application for hypertension that helps remind users to take medication, monitors, and reports blood pressure of users. Interactions with users showed a willingness to use smartphone applications for self-management of hypertension though some users had doubts about the continued use of the application for a long period of time. [26] analyzed the level of adherence in patients using an electronic medication dispenser (EMD). A randomized study was carried out for a year, on patients' compliance in taking immunosuppressive medication. The EMD can relay video and audio signals to notify users of the prescription time to take the medication. The signal is repeated for over an hour and then a report is forwarded to the web portal whether the patient is compliant or not. Results showed the EMD achieved an adherence rate of 97.8% and missed doses was common in younger patients. The study also informed that 50% of patients tend to forget evening doses more often than a morning dose of medication.

Many of the proposed electronic detection monitoring devices (EMD) for inhaler adherence in asthma patients have only been implemented for clinical research and [27] investigated the impact of EMD's based on cost-effectiveness, feasibility, and barriers in a variety of settings to encourage the use of EMD in a larger population. Some EMDs for inhaler adherence considered are Asthmapdis (which has a mobile application and a tracking device on the inhaler), Doser (which records the total number of puffs per day), smart inhaler tracker, Akita, and so on. The major limitations of the devices are the cost of devices, data transfer and vulnerability to changes in the inhaler design. It was noted that EMD technologies for inhaler adherence by direct patient reminder or clinician to patient feedback are most promising and can improve medication adherence. The world's aged population is increasing rapidly; another study on medication adherence in the elderly was carried out by [28]. They proposed the use of a pervasive multimedia system that takes advantage of multimedia technology customization features to improve compliance in home health care. Multimedia system that can adapt to the surrounding of the elderly by rendering a context-aware prompt using audio, text, images or animations correctly and appropriately can support home care adherence. Services provided by their system include the ability to follow medication plan online, medication advice, identification of medication information and so on. The evaluation result of their developed system showed great promises in enhancing adherence among the aged.

In a nutshell, a lot of reminder apps existing in the market have been discussed elaborately in past works, but recently, [29] examined the effect of reminder devices on patients between 18 and 64 years taking more than 1 medication. The study was conducted for a 2-year period amongst 53480 patients. Medication possession ratio (MPR) was used to assess adherence; patients with MPR value greater the 80 were considered optimally adherent and MPR value between 30 and 80 are suboptimal adherent. It was shown that about 16% of patients were optimally adherent and the conclusion was that the reminder devices did not necessarily improve the level of adherence in non-adherent patients. On the contrary, [30] evaluated the use of mHealth in reminding patients with coronary heart disease to take medication. Using applications like Wechat and BBreminder, and a survey carried out on 50 patients for a 30-day period and finding showed that medication adherence was improved in the experimental group. Therefore, it is dicey to generalize either the effectiveness or non-effectiveness of reminder apps. Nevertheless, overall total compliance to medication regimens is beneficial, for example as of 2011, [31] analyzed the relationship between medication adherence and cost of healthcare including medications. Their study included data from 16,353 patients with congestive heart failure, 112,757 hypertensive patients, 42,080 diabetic patients and 53,041 patients with dyslipidemia. The MPR was used to measure adherence and medical costs obtained from patients claims. The patients with congestive heart failure had the lowest MPR value of 0.40 and the hypertensive patients had the highest MPR value of 0.59 while the total cost per patient was an average of $39,076 for patients with cognitive heart failure and $14,813 for hypertensive patients. It was shown that in the long run, the annual cost was smaller in adherent patients. They concluded that medication adherence though increases pharmacy costs reduces the total costs of healthcare and medications. Some of the specific recent technologies developed for adherence are described in Table 1.

Table 1. Some of the technologies used for adherence

Author	Application Description	Technology
[32]	TransplantHero: A mobile application with a smartwatch for medication adherence. The application is used to remind patients and provide helpful contents. Their evaluation focused on users > 18 years and was carried out on 108 patients. 19% of patients used both the smartwatch and application whereas 35% used the mobile application alone. It was concluded that the use of the mobile application or smartwatch did not increase medication adherence levels as compared to users who did not use either of them.	Smartwatch for medication adherence
[33]	WiseApp: A mobile self-management health application for patients living with HIV. The application monitors patients' adherence in real-time and contains features like medtrackers, push notifications, testimonial videos from persons with the same condition, health surveys and a schedule of health-related tasks for each day. WiseApp was evaluated amongst 20 users with a mean age of 51.3 years. The health information technology usability evaluation scale used to assess adherence level showed that the application is usable and useful	Self-management health app /HIV
[34]	A smart prescription packaging to combat issues with general pharmaceutical packages used. Some of the challenges addressed are the difficulties in gauging how much medication is left and an appropriate reminder to suit the elderly. The smart packaging system has key features that include a light sensor to detect when the medication pack is opened, a reminder application that also confirms if medication is taken, an alarm to warn finished medications which should be refilled and Bluetooth functionality that transfers prescription data to mobile devices. Evaluations reported positive feedback from users and the system can be combined with other packaging technologies.	Smart prescription
[35]	Smart Assist: a smartphone intervention based on augmented reality for propagating drug adherence in patients with special needs and the elderly. The application is user-friendly and makes use of the smartphone camera in detecting medications. It has a three-layer framework which namely - patient-drug interface with cloud integration, a pharmacy vendor management, and clinician site. The application connects to the patient medical record and then images of the drug, the drug dose frequency and a presentation on how the drug should be administered were shown on the users' device. The application also recognizes when the drug is taken, that is, after the user scans the drug with the computer vision feature, then the system updates the drug chart. The pharmacy vendor stage provides details of the drug and its vendors, and the clinical administration allows medical staff to access the application and set reminders or monitor their patients.	Smartphone intervention
[36]	MEDIBOX: a portable intelligent device for improving medication adherence. The device has sensors to track the temperature and humidity and avoid depreciation of the medication stored in the box. It also has a cooling system and power supply. It can store a patient's information such as discharge summary and other information on the cloud.	A portable intelligent medication monitoring device
[37]	A smart medication cabinet system to monitor adherence in elderly patients. This medicine cabinet has an alarm system that goes off when it is time to take the medication and a sensor that detects if the cabinet is opened which deactivates the alarm. The system is also able to send a report of medication compliance to friends and family members of the patient.	Smart medication cabinet/elderly
[38]	Ambupod: A mobile ambulance outpatient department in India. This technology is cost effective and capable of taking blood, urine, blood samples, checking sugar levels and pulse. It is a telemedicine device that is video-enabled and sends the patients medication details to their respective doctors. Though the Ambupod is not for e-prescription, it can be modified to perform medication adherence.	Mobile ambulance

[39]	A smart transportation IOT based system for transporting pharmaceutical medication. The system keeps cloud information on the transportation location through GPS, at regular intervals, has a transportation box with RFID which can read product data and a transportation box which can only be opened when the box is close to the customers' location earlier given. The system is also able to monitor and report traffic jam within every 2 kilometers and provide alternative routes. It also has the alarm feature to remind patients to take prescribed medication. The system is reported to be cheap and efficient, and it has an anti-fraud feature for security	Smart medication transportation
[40]	AICure: an AI platform installed on mobile devices, for monitoring medication adherence. Prior methods available for monitoring adherence include the use of pill counts and self-reported data, electronic monitoring packages - which are reliable but do not verify drug administration - and, the direct-observed-therapy (DOT) - which is a very intensive method for monitoring non-adherence but very effective. However, AICure visually identifies the patients using facial recognition and algorithms to confirm ingestion of the prescribed medication. The platform was evaluated in a six-month study on 53 subjects, out of 431 schizophrenia patients who were participating in a phase 2 clinical study of ABT-126 medication. Results showed that subjects using the AICure platform were 25% more adherent compared to subjects monitored with the modified DOT.	AI platform for monitoring adherence/ schizophrenia
[41]	Video / virtually observed therapy (VOT): a technology for monitoring medication adherence in tuberculosis patients. It takes advantage of the Internet connectivity and video conferencing capabilities of smartphones. Since smartphones are now readily available in low- and middle-income countries, therefore the VOT has great potentials. The VOT has been successfully deployed in London and eastern Europe.	Virtually observed therapy/ tuberculosis
[42]	ScanMed: an application for tracking medication adherence. The system has a web interface for the healthcare professional and a mobile interface for patients use. The health professional is able to input all medication details on the interface and a QR code which contains the information is printed on the medication container. The mobile application acquires the information after it is scanned and displays the information on the user's mobile device. The application reminds and notifies the user's when it's time to take the medication. However, the user is required to scan the medication each time he or she is compliant, as a proof of adherence but it is argued that this technique may not guarantee adherence.	Mobile medication tracker
[43]	A smartwatch-based medication adherence solution that measures a patient's adherence when using gel capsule medications. The watch utilizes sensors in capturing users' actions, a triaxial accelerometer and a gyroscope. The motions-captured-as-data in measuring adherence by the smartwatch were the cap of the bottle being turned and the wrist being turned with the palm facing upwards. The two motions must occur consecutively to affirm ingestion by the watch. The technology is evaluated on 12 subjects and the application had a 30% precision in the medication bottle opener gesture and 82.7% precision in detecting palm up gestures.	Smartwatch-based medication adherence system
[44]	A drug checker system based on IOT to monitor drug adherence and detect adverse drug reactions. The application can be installed on smartphones and PDAs. The drugs to be taken can be verified using a pharmaceutical intelligent information system (PIIS) and patient's information obtained from a personal health record, PIIS database or personal health card based on RFID. Once the information is acquired, an intelligent system detects and reports drug allergies, interactions, side-effects and optimized times for drug consumption.	Drug checker system
[45]	UbiMeds: a mobile application for improving medication adherence in the elderly and disabled with visual and cognitive impairment. It is easily accessible, provides details of medication to be taken, allows physician-patient monitoring, automated reminders, and text to speech features. It integrates with the patient's personal health record, tracks prescription intake, and notifies the patient's family and physician when the patient is non-compliant. However, the application was designed to run only on Apple devices.	Multimedia medication Adherence monitor

3 Methodology and Implications

Over 70 articles were used in this study and our articles were mainly downloaded from Google Scholar, Science Direct and PubMed databases. Our search emphasizes on technology in adherence and general medication adherence challenges. The distributions, by year, of some of the selected 65 articles considered in this study are shown in Figure 1. Since there are different schools of thought on the sustainability of technology supporting medication adherence, especially those involving reminder apps, we highlighted some of the technologies and applications found in our review. Data in Table 2 shows some of the Information and Communications Technology (ICT) applications that have been revealed to somehow influence medication adherence. Even though many of the studies were carried out and implemented outside the shores of Africa and the like, some of them are viable solutions that can be adopted. It goes without saying that technology has a promising potential at improving medication adherence but some of the limiting factors contributing to non-adherence can be a cog in the wheel, and some of those challenges found in our review are shown in Table 3, with the frequency of their appearance and some possible solutions. Since identifying reasons for non-adherence can significantly increase adherence, and therefore aid in providing adequate solutions [20]; forgetfulness and cost are still chief among the global leading factors.

Diseases such as cardiovascular diseases, asthma, and diabetes were the top ranking diseases largely referenced in many of the work we reviewed and are likewise prevalent in developing countries like Africa. The spread of these diseases in developing countries and implications are scary, therefore, use of existing technological solution supporting adherence is important.

Diabetes is a risk factor of cardiovascular diseases and when left untreated causes a lot of complications. In developing countries, between 1980 and 2015, there have been 88% increases in the number of diseases attributed to diabetes with over 90% cases associated with type2 diabetes. Also, within this period, the number of adults with diabetes increased drastically from 108 million to 422 million. Common causes of type2 diabetes are overweight and obesity, which can be associated with poor feeding habits by individuals in low middle-income countries [46]. Only 25.8% of countries have adopted guidelines for managing hypertension.

Hypertension is the most common cause of renal dysfunction and chronic kidney diseases which is a major health burden [47].

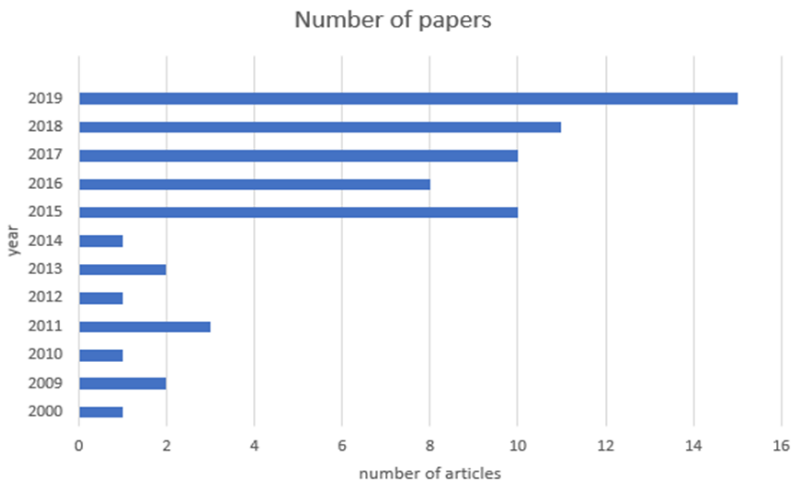

Fig. 1. Article distribution by year

Table 2. Some of the technologies used for adherence

Technology	Author	Impact
Asthma adherence pathway (AAP)	[48]	Positive
Medsimple (Medication management application)	[49]	Positive
Remotely monitored therapy	[50]	Positive
Tablet technology	[51]	Positive
TransplantHero (Mobile app for education and reminder)	[32]	Positive
Interwalk smartphone app	[52]	Positive
Self-management app	[33]	Positive
Mhealth technology	[53]	Positive
mKidney system	[54]	Not evaluated
99DOTS (digital patient management)	[55]	Not evaluated
Electronic pill bottles	[56]	Positive
Home-based telehealth group intervention	[57]	Positive
Medication monitors, video observed therapy, SMS reminders.	[58]	Positive
Medication Event Monitoring Systems (MEMS); Home telemonitoring	[59]	Positive
Digitally enabled heart failure management platform (proposed)	[24]	Not evaluated
Medibox (a portable intelligent device for pill storage with reminders and alerts the physician)	[36]	Positive
Smartphone app reminder and self-monitoring; Smart Assist	[25], [35]	Positive
Smart medicine cabinet monitoring system	[37]	Positive
Gamification	[8]	Not evaluated
Ingestible biosensor medication	[60]	Not evaluated
Smart medicine transportation and medication monitoring system	[39]	N/A
Reminder devices (Pillbox)	[29]	No effect
AiCure (Monitoring adherence)	[40]	Positive
Video-enabled devices for patient-healthcare professional interaction	[41]	Not evaluated
Apps with reminders, text prompts, education on medication and medication log features	[23]	Positive

E-prescription apps	[61]	Positive
ScanMed (Medication tracker and reminder)	[42]	Positive
Smartwatch based monitoring system	[43]	Positive
Electronic monitoring drug dispensing device	[26]	Positive
Smart pharmaceutical packaging with graphics e-paper	[1], [34]	Positive
Reminder and tracking app	[9], [21]	Positive
Personal health care device (Movital)	[44]	Positive
Electronic monitoring device	[27]	Positive
Electronic blister packs	[62]	Not evaluated
Health information technology using interactive voice recognition	[63]	Positive
Multimedia healthcare system (MHS)	[28]	Positive
E-health system	[64]	Positive
Daily text reminders	[65]	No effect

Table 3. Factors that affect medication adherence

	Factors	Occurrence	Possible solutions
1	Forgetfulness on the dose and time to take medication	15	Use of automated reminders and smart packages.
4	High out of pocket medication costs	11	Health insurance plans; Higher priority to low-income areas.
7	No follow-up by health physicians and family	9	Directly observed therapy and therapeutic drug monitoring; More supportive patient-provider relationships and frequent follow-ups.
14	Number of pill doses	7	Minimizing pill dose
10	Complexities (in drug dose)	7	Minimizing the number of pills; Reducing the frequency of drug administration
5	Harmful side effects	7	Enlightening patients through education on common side effects and ways to prevent them can help to attenuate the trepidation and concerns about adverse drug reactions; Emphasis on the need for treatment by physicians.
18	Age-related	6	Easy to use technologies and reminders.
9	Lack of awareness of available reminder technologies	5	Counselling and patient education
13	Changes in treatment schedule or drug dosage	5	Fixed-dose combination therapies; Minimizing changes in treatment schedule and follow-ups.
3	Gaps in medical knowledge	4	Involving pharmacist in medication management; Provision of clear medication knowledge by physicians.
12	Difficulty in transportation or pickup of medication from a pharmacy	4	E-prescribing
2	Lack of motivation	3	Pharmacist-delivered counseling; Risk communication; Video observed therapy.
8	Lack of digital competence or interest in using medication technologies	3	Education and coaching
11	Lack of income or health care insurance	3	Health insurance plans; Prescription of cost-saving generic medication.
19	Ambiguous medication technologies	3	Introduction of simplified, easy to use technologies.
15	Self-perceived health status	2	Telephone-based medication counselling
20	Sustainability (long term use of the technologies for self-	2	Integration of medical regimen into patients' routine daily activities;

	management)		
6	Low conscientiousness	1	Evidence-based interventions like educational programs.
16	Depression	1	Counselling; Providing physiological support.
17	Impaired cognition	1	Use of technologies with diverse sensors (e.g. text to speech)
21	Fear that reminders would become annoying over time Admitting to relatives that their memory is poor causes them to refuse medication reminders.	1	Pillboxes; Assistance from caregivers; Self-management technologies.

Chronic kidney diseases have been reported to be 13.9% overall prevalent in sub-Saharan Africa and primary hypertension is its major risk factor. Some hypertension related factors include alcohol and tobacco use, salt intake and lack of physical activity. For instance, in Uganda, alcohol is reported to be associated with a 64% increased risk of developing hypertension [66].

Cardiovascular diseases caused an estimate of 17.7 million deaths worldwide in 2015. Of these deaths, approximately 7.4 million were as a result of coronary heart disease and stroke was responsible for about 6.7 million. Also, three-quarters of the occurrence of this disease occurs in low middle-income countries and it is the leading cause of death globally occurring mostly in those aged greater than 70 years [67].

Heart failure is a growing issue in Africa and about 75% of heart failure patient cases where non-ischemic in origin and highlights hypertension as a rising cause of heart failure. The causes of heart failure such as rheumatic heart disease and endomyocardial fibrosis are more prevalent in Africa. Appropriate therapies and medicines for patients with heart failure are unaffordable by 60% of low-income countries as seen by the prospective urban rural epidemiology study [68].

Asthma [69] reported that about 235 million people are suffering from asthma and over 80% of deaths resulting from asthma occur in low middle-income countries. It was also shown that severe asthma is prevalent among 13-14 years old and the cost of asthma medication is out of reach for most patients. Asthma is most prevalent in South Africa with a 53% occurrence in children of 5-12 years. In Africa, over 94.8 million cases of asthma were reported in 2000 and this increased significantly to 119.3 million in 2010 [70].

According to [71] the top five causes of death in children are malaria, diarrhea, HIV/AIDs, lower respiratory infections, and neonatal disorders. In 2015 alone, over 212 million cases of malaria-causing 429,000 deaths were reported in Africa and the highest number of deaths occurred in children. Examples of lower respiratory tract infections are influenza, pneumonia, tuberculosis, and bronchitis Most rural areas do not have access to high-quality health facilities and delayed the diagnosis of these diseases cause it to be extremely severe. Pneumonia is the number one killer disease in African children and HIV/AIDS is the leading cause of deaths in African adults.

Developing countries like Africa still have a long way to go in managing medication and adherence but the use of technology in managing drug prescription and adherence is feasible, even if it is just a reminder app. An electronic prescription is an effective system for measuring adherence, it can reduce the frequency of visit and proximity issues, and the possibility of this has been demonstrated in some simulations [72, 73, 13, 74, 75] In developing countries, e-learning is also increasingly becoming popular, this platform can be adapted to solve some of the medication adherence problems, through re-education of patients on the importance of keeping to medication regimens. The remodeling of the health system into a centralized structure can greatly reduce cost in the long run [31], and lastly, there is a need for evidence-based research on the use of reminder apps and other technology in developing countries in order to understand the contextual issue [76]. Although the main focus of this work is not to design a framework, however, since total adherence is capable of catalyzing healing and recovery; based on the numerous factors identified in the previous sections, Fig 2 shows a few of the basic features – education, e-Prescription, and health care proximity – that can be achieved with using mobile technology to tackle some of the prevalent diseases that are already either controlled or on the decline in developed countries through leveraging the use of ubiquitous technology to support medication adherence.

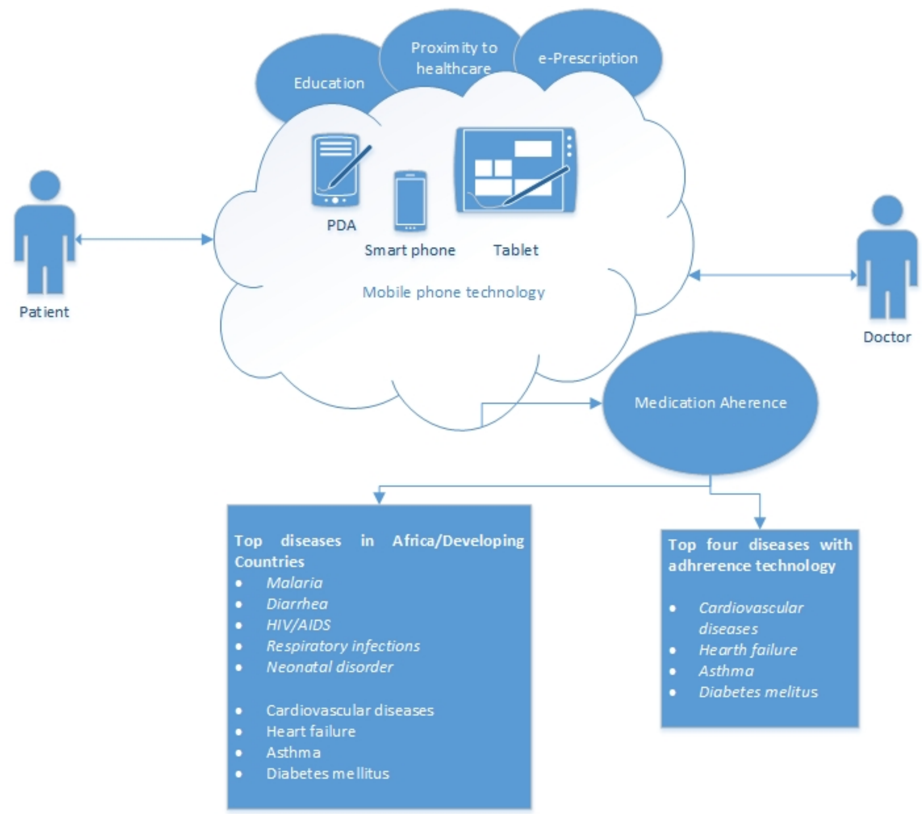

Fig. 2. Conceptual path to mobile adherence

4 Conclusion

This paper performed a detailed review of medication adherence and ICT, the challenges and the use of varieties of technology to support patients and prescribing physicians in providing complete healthcare, with respect to intervention based on abidance to medication regimens. The diseases that have received the most attention based on our review were identified and findings suggest that if low-income countries can adapt some of these technologies into managing patient's adherence, starting with health education of patients', breaking the barriers created by proximity, and cost of visits hospital visits, recovery from many of the prevalent diseases can be improved through electronic prescription and mobile reminders. Future work will explore the availability and evaluation of ICT solutions for endemic diseases in tropical countries.

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Article submitted 2019-04-11. Resubmitted 2019-05-18. Final acceptance 2019-05-19. Final version published as submitted by the authors.