Vrije Universiteit Amsterdam

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Literature Review

mHealth-based early detection for infectious diseases in low- and middle- developing countries

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Content

1. Introduction

Infectious diseases are a major public health issue and social problems, and the main cause of death and increase in economic burden of medical health care in the developing world, due to dissemination, regional characteristics and variability (21). Despite producing clinical applications including vaccines to prevent infection, there is still no specific treatment for some infectious diseases, such as dengue fever (22) and rabies (23). Up until now, research has consistently shown that early detection of infection is crucial for the prevention of emerging, reemerging, and the outbreak of novel infectious disease (24-27).

These early detection methods often involve the surveillance, rapid and accurate identification of dengue fever (25-27). Traditional surveillance of infectious diseases was done by transmitting standardized paper-based method (28). Especially in low resources environments, this method had been widely used due to poverty, imperfect equipment and low health literacy. In terms of infectious diseases identification, experienced physicians and nurses has been played a critical role. In addition, molecular scientists also are involved in detecting novel infectious diseases early by analyzing and discovering hosts and pathogens (29).

However, due to the lack of clinical laboratories and skilled technical personnel, and the high of the density of population, some of diagnostic tests or point-of-care diagnosis might not be available or treated timely for people living in low resources environments. The technique of rapid diagnostic tests (RDTs) (26) was developed and used widely as an alternative to diagnosis. However, the limitations of sensitivity (30) and lack of funding and clear regulatory policies (31), the development of RDTs has meet a number of challenges.

With the popularity of the mobile phone, mHealth was introduced to the public. mHealth is regarded as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices” (32). So far, mobile phone penetration has covered over 90 percent in almost every developed country in 2019 (33). Nearly all demands of com-medication tools are mobile or internet connectivity, which could facilitate and improve health care in low- and middle-income countries. Therefore, developing a mobile devise enabled electronic platform has been considered a feasible and usable intervention to change people's traditional medical methods of monitoring, medical treatment and health care. mHealth could reduce the occurrence probability of the error caused by paper-based reporting in surveillance system, reduce potential health costs and provide an assessment on disease identification.

This literature research primarily focuses on the mHealth based on early detection of infections This is done by examining the current practices for design approach, implementation and usability evaluation of mHealth based early detection systems for infectious diseases in low- middle income countries by researching their predominant functionalities and examine the approaches deployed for the evaluation of m-Health usability.

2. Method

The purpose of the study is to answer the main research question: “What are current practices for design approach, implementation and usability evaluation of mHealth based early detection systems for infectious diseases in low- middle income countries?”. To gain an in-depth understanding, the main research question is further divided into following sub questions (RQ):

-RQ1: What are the predominant functionalities used and techniques adopted by implementing the mHealth based early detection systems for infectious diseases, among the current practices?

-RQ2: What approaches have been employed to evaluate the usability of mHealth based early detection systems for infectious diseases?

-RQ3: What are the predominant characteristics of mHealth based early detection systems for infectious diseases in terms of local contexts, problem domains, targeted participants and outcome measures?

-RQ4: What are the predominant barriers and facilitators in the implementation of mHealth based early detection systems for infectious diseases in the community?

The study contributes a technical perspective on the main research question and there are two sub questions including RQ1 and RQ2, for this review. The rest of sub questions (R3 and R4), focusing on context analysis and implement factors, are answered in another review*” reference by lisanne”*.

2.1 Research Strategy

For the data collection and data extraction of the study, we organized a two-stage process to search relevant papers. Firstly, collaboration stage, both researchers made an effort on searching literatures based on the same searching string and did a title and abstract filter by using the same inclusion and exclusion criteria. The primary search terms identified are based on the primary subjects involved: *mHealth, Infectious diseases, low-middle income countries*. Meanwhile, we added synonyms for each term to ensure that the search querying is as many broad and general as possible to cover the period of recent five years, from the start of 2014 until the end of 2019 (See in Appendix A (1)).

Secondly, independent stage, to answer the sub questions for the study, two reviewers independently searched the full texts of the retrieved literature according to their own sub questions. The study answered main research questions from these two categories: (1) design and development; (2) usability evaluation.

To answer the main research questions, what are current practices for design approach, implementation and usability evaluation of mHealth based early detection strategies for infectious diseases in low- middle income countries, due to computer science and medical science involved in the main research questions, the search engines we selected are Web of Science (34), PubMed (35) and IEEE Xplore (36) accessed through Vrije Univeristeit

Amsterdam (37) and Univeristeit van Amsterdam(38). PubMed covers the publications from the perspective of life sciences, IEEE Explore is relevant to software aspect and Web of Science is also useful for both perspectives.

2.2 Inclusion and Exclusion Criteria

The studies are included and excluded in the review based on the following inclusion and exclusion criteria (I/E criteria). In the collaboration stage, we filtered relevant publications by title and abstract based on the inclusion (I1, I2, I3, I4) and exclusion criteria. As for independent stage, because two researchers contribute different perspectives on main research, the inclusion criteria (I5, I6, I7) are employed.

Inclusion criteria: satisfying all of the following

I1 Studies must focus on mobile phone, tablet -based digital responses to mosquito-related infectious diseases.
I2 Studies must discuss the development and/or implementation of digital solutions.
I3 Studies must consider early detection as a goal.
I4 Studies must consider community and/or health worker in ow- and middle-income countries.
I5 Studies discussing the functionalities of a mHealth system. This inclusion criterion is utilized to filter out studies considering design aspect.
I6 Studies providing information on the usability evaluation of mHealth system.
I7 Studies presenting results regarding user feedback on the application or discussing the usability issues.

Exclusion criteria

E1 Studies are not written in English.
E2 The full text of studies cannot be accessed.
E3 Secondary or tertiary studies (e.g. systematic literature reviews, surveys, etc.).
E4 Studies consider mobile microscopy and/or laboratory based mHealth solutions.
E5 Studies are duplicated.

2.3 Study Selection Process

After applying search querying in three searching engines, in total we identified the total of 755 publications, including 205 publications from PubMed, 505 publications from Web of Science, and 45 publications from IEEE Explore. Both of two reviewers conducted screening based on title and abstract on first 25 publications to keep judge consistency in the selection procedure, which could help reduce anomalies and heighten objectivity. The 6 conflicts generated were discussed. In order to meet with common agreement, two reviewers tailored the I/E criteria accordingly.

Then, we divided the workload to perform reviewing in collaboration stage, 342 publications and 260 publications separately. In particular, publications from IEEE Explore were screened and selected by one reviewer for this review instead of the combined study, because this review has higher concerns on the paper from the perspective of technique. The Figure 1 presents the whole process and the search results. After removing for duplicates 541 remained. Before performing an independent reviewing, two reviewers individually reviewed and confirmed the retrieved literatures by title and abstract-based screening. 32 conflicts were generated and needed to be discussed with two researchers. In the end, two researchers retrieved 45 articles and 14 articles were identified by one researcher for the further searching process. In total, there were 63 articles for full-text screening based on I/E criteria. To confirm the results and filter relevant publications based on sub questions, two reviewers screened the full text of the papers individually.

From the full-text filtering, there are 17 articles retrieved. We found that 16 of articles excluded do not provide information about usability evaluation for their system and 2 of articles excluded only involve evaluation but do not elaborate their system in terms of design and development. The reason might be the development of mHealth systems are delivered to technical experts, IT team or company (1, 2). Considering this situation, we took Pearl-growing method to search the relevant articles (3, 4).

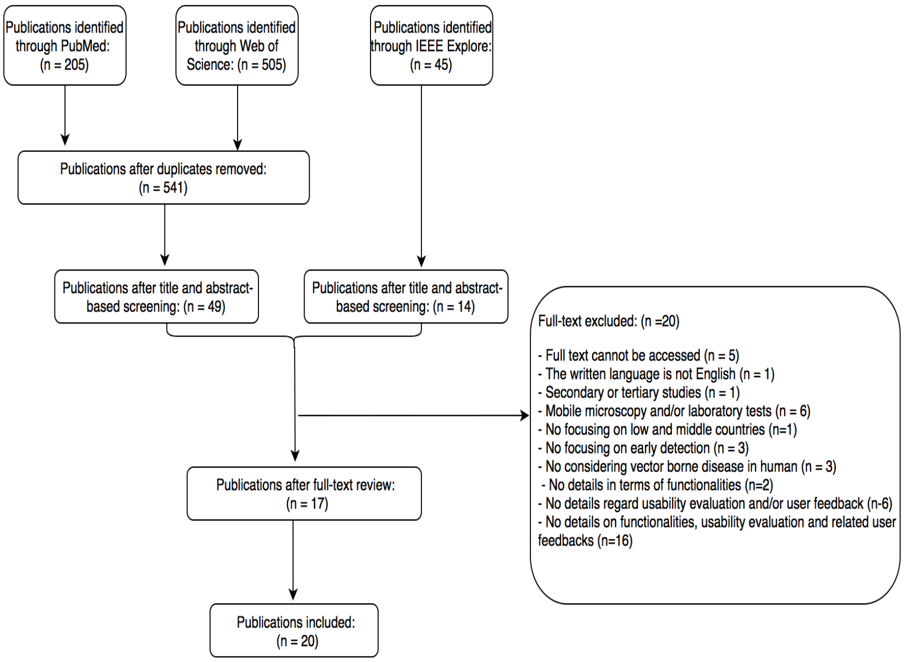

Figure 1. The whole review processes

2.4 Data Extraction

To gain a general understanding for the studies, the data were extracted according to themes include type of mHealth tools, types of initiative, target diseases and device types. The data that could answer sub research questions (RQ1 and RQ2) were identified through a full-text review. To investigate and analysis similarities and differences among the studies, the data were extracted and recorded in a data extraction form, according to relevant themes, including approaches for early detection, technologies adopted, methods conducted for usability evaluation and the corresponding usability issues and user feedbacks.

3. Results

By answering this research question, we aim at providing (i) the overview of the studies; (i) the categories of exists researches; (ii) a solid foundation for analyzing and classifying each category on functionalities and (iii) an understanding of current research trends and gaps in the state of the art of such approaches.

3.1 Overview of Studies

In total, there were 20 publications included for the literature review. By investigation and analysis, some publications discussed the same mHealth tool but with different purposes. More specifically, Lwin et al. (1,2) proposed mHealth solution for public health inspectors and public, and Lwin et al. (3,4) discuss usability evaluation and user feedbacks for different digital solutions. Similarly, Ibrahim et al. (12), and Mohammed et al. (20) also provide details on user perspective. In the end, there were 15 mHealth tools proposed among 20 studies.

Application or System name	No. of papers	Authors, Publication Year	Title	Goal	End user
Mo-Buzz PHIs: A passive dengue surveillance system for public health inspectors	1	Lwin *et al.* (2016)	A Social Media mHealth Solution to Address the Needs of Dengue Prevention and Management in Sri Lanka	The goal of the study is to reduce the time and effort on existing paper-based surveillance system.	Health workers
	4	Lwin *et al.* (2017)	Lessons from the Implementation of Mo-Buzz, a Mobile Pandemic Surveillance System for Dengue.	The goal of the study is providing feedback after implement and comparing two version of Mo-Buzz (one is for health workers; another is for public) and analyzing reasons of the success and unsuccess.	Public, Health workers
Mo-Buzz Public: A participatory and predictive dengue surveillance system	2	Lwin *et al.* (2014)	A 21st century approach to tackling dengue: Crowdsourced surveillance, predictive mapping and tailored communication	The goal of the study is to design a social media system to prevent dengue through interacting and engaging with the public.	Public, Health workers
	3	Lwin *et al.* (2016)	Baseline Evaluation of a Participatory Mobile Health Intervention for Dengue Prevention in Sri Lanka	The goal of the study is providing a descriptive analyzing for understanding the participatory behavior in diseases surveillance systems, which could give an implication of dynamic behaviors public evolved.	Public, Health workers
Epihack: A passive and predictive dengue surveillance system	5	Lwin *et al.* (2019)	Epihack Sri Lanka: development of a mobile surveillance tool for dengue fever	The goal of the study is to improve and solve the problem of Mo-Buzz.	The public, Health workers
SORMAS: Surveillance and outbreak response management system for health workers.	6	Fähnrich *et al.* (2015)	Surveillance and Outbreak Response Management System (SORMAS) to support the control of the Ebola virus disease outbreak in West Africa	The aim of the study is to design a system to support the control of the Ebola virus diseases and improve efficiency and timeliness	Health workers, field epidemiologists

	7	Tom-Aba *et al.* (2018):	User Evaluation Indicates High Quality of the Surveillance Outbreak Response Management and Analysis System (SORMAS) After Field Deployment in Nigeria in 2015 and 2018	The aim of the study is to improve the SORMAS 2015 and comparing two version of SORMAS and analyzing reason of the success and unsuccess.	Health workers, Epidemiologists
BFMIS: Bhutan febrile and malaria information system for health workers to passive case detection	8	Tobgay *et al.* (2016)	Performance and user acceptance of the Bhutan febrile and malaria information system: report from a pilot study	The aim of the study is to evaluation and user acceptance of a surveillance tool for malaria.	Health workers
SMS text message: Data collection by using specified format of messages	9	Dang *et al.* (2016)	Perceptions of the Feasibility and Practicalities of Text Messaging-Based Infectious Disease Surveillance: A Questionnaire Survey	The aim of the study is to evaluation the feasibility and practicalities of text message-based surveillance	Health workers
Bespoke app: Mobile phone-based Data collection	10	Ngor *et al*. (2018)	Smartphones for community health in rural Cambodia: A feasibility study	The purpose of the study is to investigate the feasibility of mHealth adoption in rural arears for frontline health workers	Mobile application
DES system: Collecting and analysis ovitrapping of dengue data	11	Ibrahim and Quan (2017)	The development of multi-platforms application for dengue-entomological surveillance system	The purpose of the study is to develop multi-platforms application for Dengue-Entomological Surveillance (DES) system to reduce the burden in manual interventions.	Health workers, Entomologist
	12	Ibrahim *et al*. (2017)	An Evaluation Study on Dengue-Entomological Surveillance System using Alpha Acceptance Test	The purpose of the study is to report on how to conduct an acceptance test for DES system based on System Usability Scale (SUS) method used in Alpha testing. Moreover, it could give an understanding on how the results contribute to validate the DES systems.	Health workers, Entomologist

Text Message-Based Participatory Surveillance	13	Lester *et al.* (2016)	Assessing Commitment and Reporting Fidelity to a Text Message-Based Participatory Surveillance in Rural Western Uganda	The purpose of the study is to identify a mobile phone-based participatory syndromic surveillance in low resources and observe users' behaviors.	Public
EasyDetectDisease: an application allows mothers to self-screening of diseases	14	Ponum *et al.* (2019)	EasyDetectDisease: An Android App for Early Symptom Detection and Prevention of Childhood Infectious Diseases	The study aims to help all level of literacy mothers to diagnose the early symptoms of infectious diseases in their children under 5 years old through a mHealth tool, which could reduce the morality of children and increase awareness of mother.	Mothers
MEDSINC ®: Frontline health workers are allowed to screening children by the application.	15	Finette *et al.* (2019)	Development and Initial Validation of a Frontline Health Worker mHealth Assessment Platform (MEDSINC ®) for Children 2–60 Months of Age	The study aims to provide a mHealth platform to perform clinical risk assessments of children under 5 years old and perform initial validation testing. Instead of using binary decision, the study considers Bayesian pattern recognition logic as an approach for decision making.	Health workers
MalariaConnect: A real-time reporting system	16	Craig *et al.* (2018):	Effectiveness of 24-h mobile reporting tool during a malaria outbreak in Mpumalanga Province, South Africa	The aim of the study is to learn about the benefits of mobile application on surveillance systems for infectious diseases, compared to paper-based approach.	Patients, Health workers
Vigilant-e app: community members are allowed to self-reporting their data	17	Olson *et al.* *(2017)*	Performance of a Mobile Phone App-Based Participatory Syndromic Surveillance System for Acute Febrile Illness and Acute Gastroenteritis in Rural Guatemala	The purpose of the review is to improve self-reporting by using the mobile phone-based solution for participatory syndromic surveillance systems.	Public
Web-based application	18	Luz *et al.* (2015)	Disease surveillance and patient care in remote regions: an exploratory study of collaboration among health-care professionals in Amazonia	The purpose of the study is to develop a mHealth intervention for supporting disease surveillance and	Frontline health workers

				patient care in remote regions for relevant health care workers.	
Electronic Health Information and Surveillance System (eHISS)：Interactive voice response facilitates a participatory surveillance and follow up.	19	Brinkel *et al.* (2017)	Mobile phone-based interactive voice response as a tool for improving access to healthcare in remote areas in Ghana – an evaluation of user experiences	The purpose of the study is to identify factors that enhanced or constituted barriers to the acceptance of an mHealth system.	Mothers
	20	Mohammed et al. (2018)	Feasibility of Electronic Health Information and Surveillance System (eHISS) for disease symptom monitoring: A case of rural Ghana	The aim of the study is to assess the feasibility of an mHealth system	Mothers

Table1. Overview of the reviewed studies

3.2 Characteristics of Studies

In Table2, it provides a general understanding of the categories of exists researches and multiple selection possible based on available information. Regarding the types of initiatives, in most recent studies, mHealth tool has been applied in two areas. There are a majority of papers (18/20, 90%) have made an effort to strengthen diseases surveillance systems, and only 20% papers contribute on screening to help health authorities monitor and control infectious diseases. Besides usage of basic functionalities in mobile phone, including voice call (2/20, 10%) and message (2/20, 10%), a majority of mHealth tools interact with users through technology platforms or web-based interfaces (16/20, 80%).

The third category in the Table2 shows the target diseases. There are almost one third of mHealth solutions (6/20, 30%) that can be applied to responding multiple diseases. Especially for intervention related surveillance systems, the half of the mHealth solutions have a limitation of the type of diseases (10/20. 50%). The minimum requirement for mobile devices is portrayed in the fourth category. The mHealth solutions involving mobile applications or web applications normally have a requirement on internet connection (16/20, 80%), which smart phones (12/ 16, 75%) or tablets (4/16, 25%) are proposed. The mHealth solutions using voice call and SMS do not have further limitations of mobile devices (4/20, 20%).

Classification category	Subcategories	N	Reference index of paper in Table
Types of initiative	Screening	2	14, 15
	Disease surveillance	15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17
	Combination	3	18, 19, 20
Types of mHealth tools	Voice call	2	19, 20
	Short message service (SMS)	2	9, 13
	Technology platform/web-based interface	16	1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14, 15, 16, 17, 18
Target diseases	Single disease	10	1, 2, 3, 4, 5, 8, 10, 11, 12, 16
	Multiple diseases	6	6, 7, 9, 18, 17, 13
	Children health	4	15, 14, 19, 20
Device requirements	Feature phone	4	9, 19, 20, 13
	Tablet	4	1, 4, 15, 18
	Smart phone	12	2, 3, 5, 6, 7, 8, 10, 11, 12, 14, 16, 17

Table2. Characteristics of the adoption of mHealth technologies

3.3 Predominant functionalities identified in studies

In Table 2, as we discussed before, the functionality of reviewed projects is organized into two parts: surveillance and screening. There are two forms of surveillance systems [30] supported through mHealth technology, which are traditional approach and participatory-based approach according to the different way of data collection. One project, for instance, not only designs a mHealth solution for frontline health workers to digital collection data and report, but also engaging general publication to collect 'unknown' data. The rest of projects related interventions allow patients to use mHealth tool to rapidly self-screening.

3.3.1 Surveillance

A total of 18 papers consider digital surveillance systems as a solution for early detection and there were 14 mobile tools proposed and elaborated about functionalities and features of digital surveillance for infectious diseases; in Table 3, the number of mHealth solutions supporting for traditional surveillance systems (10/14, 71%) is more than two times as much as for participatory based approach (4/14, 28%). Participatory-based approach is a way to strengthen traditional surveillance systems, the main difference between two approaches is the way of data collection. Participatory approach encourages the general public to regular and voluntary reporting health information. Alternatively, tradition approach is highly dependent on health workers and health seeking behavior from patients.

Types of Surveillance	**N**	**Reference index of projects in Table**
Traditional surveillance system	10	1 (2), 5, 6, 7, 8, 9, 10, 11 (12), 16, 18
Participatory-based surveillance system	4	2 (4), 19, 13, 17

Table3. Characteristics of surveillance

Regarding the process of surveillance in most recent studies, the predominant tasks of surveillance are divided into five categories, data collection (14/14, 100%), data analysis and interpretation (6/14, 43%), case management (5/14, 36%) and action (5/14, 36%). The details of functionalities are shown in the below table.

Tasks	Definitions	Functionalities Used in the Studies
Data Collection	To enable collect data and facilitate data transmission, storage. Data collected in such systems including demographic, socioeconomic and clinical	Digitized form, sending message, voice call, image processing, off-management, automatically synchronize
Data analysis and interpretation	Data analysis gives an indication of the performance of an immunization program	graphical-based data visualization, predictive high

	and for identifying gaps through transferring raw data into information.	risk arears, text-based data report
Case management	Supporting health workers to manage identified cases.	follow up, check list, remainder, treatment suggestion, public notification
Action	Interaction with general public	health information, treatment suggestion

Table4. List of sub functionality and their features in surveillance

a. Data Collection

More recent attention has focused on the provision of real time data collection. The traditional data collection is happened, when doctor identifies or detects a suspected case, relevant health workers will be notified to input all the paper-based information to surveillance system. A majority of mHealth tools (11/14, 78%) aim to reduce time and effort caused by paper form through online form. Compared to paper-based, text sending and voice call approaches, a major advantage of digitized approach is increases in the integrity of data collection. Digitized disease investigation forms combining with active input and passive input, which allows public health inspector record patient information (1-8,10,16,17) and ovitrapping information (11,12) by using manual data entry, such as multiple-choice questions, option list as well as photograph of mosquito–breeding sites (1,2,5,11,12) by in-built camera. In a passive way, accurate geographical coordinates are automatically recorded in the system by Global Positioning System (GPS) technology (1,2,3,4,5,6,7,8,10,11,12,16,17). But there was also an application used digital mapping to present location-based clustering to health workers, which could increase accuracy and efficiency of information sharing (2). The online form increases the variety, and veracity and hence reducing the effort on data collection. In terms of precision of data, although GPS technology improve the precision, there were less evidence that health data and photograph data that are freer of erroneous than paper-based approach. The speed of internet had could limit the breed-site image size, especially in the poor network connection regions, such as mountain areas. Photographical data with poor quality or repeatable for one site, the image processing has been adopted to filter most relevant photos (2).

Furthermore, poor internet connection is a common technical barrier in low resources context. To reduce the dependence on internet, the functionality of offline management, saving data temporarily and automatically synchronize at later, has been adopted (1,3,4,5,6,17). As for rural poverty with low mobile coverage, health information represented by using numbers and symbols was recorded through sending message with a fixed format (9, 13). Although this approach has lower requirements on the types of mobile devices, internet coverage and digital skills, the quality of data collected has becoming the most problems. Poor IT skill could lead to undesirable behavior, such as mistyping, typos, and repetitive data entry. To reduce these human errors, IT staffs are needed to make much unavoidable effort on checking records stored database (9).

Another proposed solution is to using voice call to allow community members to self-reporting through answering health questions step by step. By doing so, people with low literacy or low digital literacy are allowed to provide their data easily. But the main concern is that the scale of system is limited. In order to collect necessary information, a number of questions need to be answered, which leads community members to lose their patience.

Data collection approach	User skills	Requiremnets	Surveillance approach	Technology used	Advantage	Disadvantage	No. of paper
text message reporting	learning necessary syntax for reports	Training participants message process, managing database	Traditional surveillance, Participatory surveillance	Text message gateway,	The scope of application could access to hard-to-reach areas, and relevant low digital skill for adopting this approach. Ease to motification and extend and have a low requirements for mobile devices.	It has more errors than other two approaches, including typing error, double sending, fragmentary information, and incorredt formatting.	9, 13
completed online form	completing online form	Training participants, developing an online form and internet conntection is necessary.	Traditional surveillance, Participatory surveillance	Internet technology, Mobile computing, Web technology, In memory database technology, mobile cloud computing, location-based technology	The intergrity of data could be siginificantly improved by collecting location data and visual data. And it has well scalable for a large of users. The timeless of data compared to paper based approach also is improved	It highly rely on internet connection and has a higher requirements on mobile devices and user digital skill. This cause a limitation for implement such approach in such as mountain areas and poor people.	1(2), 3(4), 5, 6, 7, 8, 10, 11(12), 16, 17, 18
voice call reporting	calling to system and answering health questions	Answering questions steps by steps	Participatory surveillance	Interactive voice response,	The low requirements for mobile devices and user digital skills. The completeness of data collected could be quarientine.	It has poor scalable for collecting enough information if information is too much. And the fixed questionnaires could limit the intergrity of data.	19 (20)

Table5. The approaches of Data collection

b. Data Analysis and Interpretation

Around Half of mHealth tools (6/14, 43%) provide a data analysis and interpretation function, which gives an indication of the performance of an immunization program and for identifying gaps (WHO, 2008) through transferring raw data into information (2,3,5,8,11,12,18,19,20). All of these studies have utilized graphical-based data visualization for interpterion of data analysis as mosquito-based infectious disease naturally occur regionally. This allows users to alter the display by zooming in or applying filter conditions through mobile and tablet screen. By doing so, color-code map to alert user's possible dengue hotspots (18) and people who are at high risk areas (2,3,5). Moreover, the statistic report is also provided to frontline health workers to quickly gain a general understanding of diseases in their areas (11,12).

c. Case Management

Several studies (5/14, 36%) have attempted to manage cases through mobile application based on the information archived by data collection (5,6,7,8,11,12,19,20). For field workers, it is necessary to do active monitoring patient once a suspected case is identified as a confirmed case. The function of generating a follow up schedule (5,6,7,8,11,12,19,20) and remainder (5,6,7,8) has been carried out. Few applications also implemented a checklist function for health workers (6) and construction workers and managers, a high-risk group of

Dengue that facilitates the workers to early detect the potential mosquito-breeding sites and reduce the risk (5). For health authorities, it is critical to management and validity of cases detected actively. The multiple role of personal have integrated into surveillance systems, which requires to different functions for different personal (11, 12,).

d. Action

The studies focusing on general public used the results of data analysis to generate customized information to public. One of mobile solution provides personal alarm by consideration on the numbers of dengue cases into account and be aware of high risk arears such as school and construction sites (5) and provide an early warning for people who are close to high risk areas by sending messaging or system message (2,3,5). Few studies encourage public to information seeking behavior by displaying video-based health information (1,2,3,4,5). Furthermore, the function of treatment suggestion is also provided, which allow frontline health workers to help community members immediately (11,12,19,20).

3.3.2 Screening

A total of 4 mHealth tools offer a functionality to screen for infectious diseases. Most of studies described used closed questions to collect users' symptoms (3/4), the rest one study acquired images of the patient and then compared with positive and negative cases to make a decision (1/4). As for the screen frequency, only one of study supported to monitor the changes of patient's symptoms in a period time (19), others focused on on-demand momentary diagnosis (14,15,18). The results of screening normally are severity level or possibility (15, 18, 19), only one study using "yes verse no" answer (14).

Another interesting outcome, despite the benefit of personized information could serve as a public engagement factor that could increase attractiveness and support adherence, a majority of studies have failed to show any support such tailored recommendations for patients with particular issues but adopted predefined suggestions upon the results of screening (14,15,19).

Purpose	**No. of paper**	**End user**	**The results of screening**	**Frequency**	**Feedback upon the results**	**Input mode**	**Target Diseases**
Monitoring symptoms	15	Health worker	Severity assessment	Momentary	Triage, Follow up, treatment	Closed question	Multiple diseases
	18	Health worker	possibility	Momentary	Sending for specialist	Photo	Single disease
Self-diagnosing	14	Mother	"yes verse no" answer	Momentary	none	Closed question	Multiple diseases

	19	Mother	Severity assessment	Periodic	advice	Closed question	Multiple diseases

Table6. The overview of screening

3.4 Predominant technologies identified in Projects

The studies focusing on low resources setting prefer using text messaging to connect with health workers and public (7,9,10,13). The predominant domain of mHealth tools on mobile applications are internet technology, computing technology and web technology, which facilitate a real-time data collection and reporting system (1-8,11,12,16,17,18). Mobile cloud computing (6,7), location-based technology (1-8,11,12,16-20), as well as in memory database technology (6,7) also contributed to this field.

In terms of data analysis and interpretation, information visualization (1,2,3,4,5,6,7,18) and computer simulation (1,2,3,4,5, 6,7,18) have been widely used for generating an interactive map. In particular, Mo-Buzz for public adopted an advanced algorithm by considering weather vector and human data as well as computer simulation to predict dengue hotspots (2,5). Moreover, although health workers are allowed to capture the picture of breeding sites, it is unavoidable that the same breeding sites could be submit by several times. In order to avoid this problem, image processing in combination with machine learning technologies also have been adopted to analysis graphic data (2) and even to screening patients (18).

Besides picture-based screening, some studies using advance algorithms technology to allow users to do self-diagnosis (14, 15, 19, 20). More specially, decision tree has been proposed to determine the following questions in the interactive voice response (19, 20). Some other algorithms also contribute to decision making, such as Naive Bayesian classifiers using feature weighting (15) as well as evidence-based clinic data (14, 15). In order to facilitate the adoption of mHealth tools among low literacy mother, text to speech (14) and animated gif illustrations (15) were considered as solutions for improving mother to better understanding the content of mobile application.

3.5 Usability evaluation

According to the ISO 9241-11, usability describes that goals related to effectiveness, efficiency and satisfaction could be achieved through the adoption of a system, product and even a service (39). Among 15 mHealth tools, there were 5 usability attributes evaluated, including effectiveness, efficiency and satisfaction described in ISO 9241-11 (39), operability and appropriateness recognizability, learnability elaborated in ISO/IEC 25010 (40). Overall, there were 12 mHealth tools evaluated in terms of satisfaction (4,3,7,8,9,10,11,14,15,17,18,19); effectiveness was measured by 4 studies, as well as efficiency and operability. 3 studies focused on learnability (19,4,5) and only 2 studies measuring appropriateness recognizability

(14,16). However, the studies had less concerns on the attributes including user error protection and accessibility provided in ISO/IEC 25010 (40).

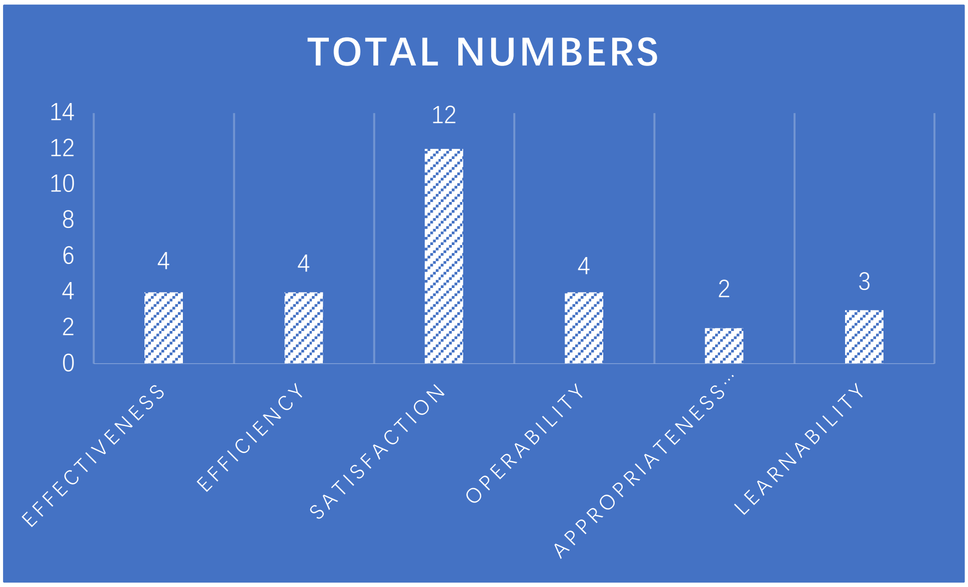

Figure 2. The overview of targeted usability attributes evaluated among studies

3.5.1 The approaches of usability evaluation

The methods to conduct usability evaluation among the reviewed literatures include questionnaire, interview, controlled experiment, observation, focus group discussion and beta testing and alpha texting. Obviously, questionnaires were the most popular approach to measure a mHealth tool related to usability. Moreover, one-third mHealth tools was measured by a single approach and two-third mHealth tools was evaluated by double approaches, mostly including questionnaire in combination with interview(5,18,19), controlled experiments in combination with observation(10,17), questionnaire in combination with controlled experiments(8), beta testing (4), alpha testing (11). The studies proposed a mHealth tool about surveillance system for health workers considered controlled experiment as an approach, this because they have high concerns on the quality of data collected including completion time, data turnaround time, accuracy, integrity, compared to paper-based approach.

Moreover, the evaluation periods among the selected studies are different from few minutes (16) to minimum of 12 months (8). The mHealth tools with monitoring and follow up functions were common assessed within several months (5,7,8,9,10,19). And all of the mHealth tools were assessed by envisaged users, which was considered as an empirical method (41). As for how to criteria usability evaluation methods, only 2 studies using System Usability Scale (SUS) validate the usability findings through alpha texting (11) and interview (19) respectively.

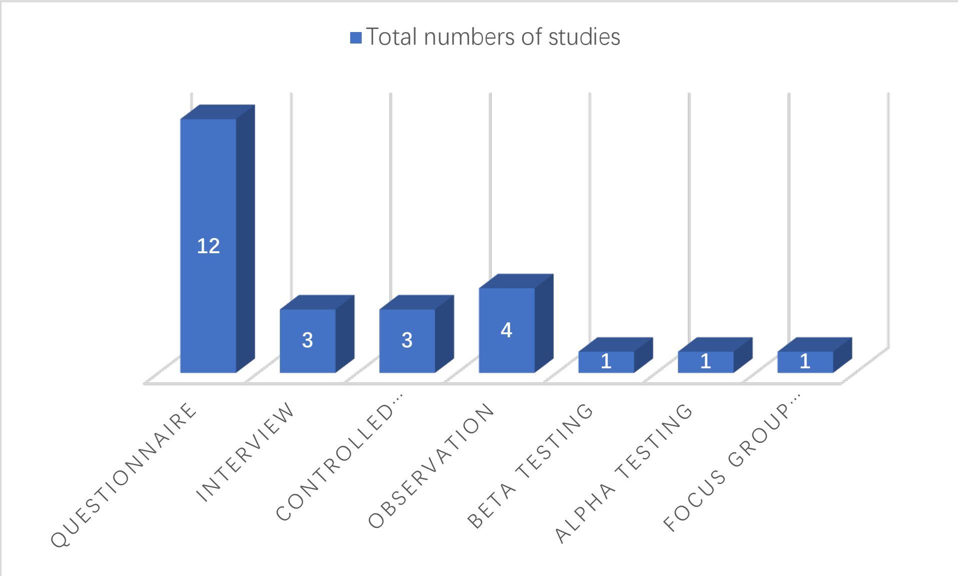

Figure 2. The overview of usability evaluation approaches among studies

3.5.2 The usability issues

The identified usability issues and suggestions recommended by reviewed studies were summarized in a below table. There is a high concern on attractive interaction with users such as tailor messaging, and the static education and information sharing have a negative influence on appealing people. Although it is common that low digital literacy and literacy among community members and even some health workers in low source areas, with mobile phone and internet technologies becoming potential and necessary solutions for delivering health care, it is necessary to design solutions accessible and easy to use to local people (19,7,14). Although some advanced technologies including machine learning, image processing have adopted by mHealth tools to facilitate health care in the case of hard-to-reach areas and lack of health workers, low wiliness to use (18) and unavoidable panic (5) were constraints on delivering a well health care.

The proposed solutions were suggested. In particular, simplicity is a key requirement for designing user interface for people with less experience on mobile phone. Collaborating with end users when designing mHealth tools could help developers to design a user interface as familiar and simple as possible for local people. And such user-center design approach also could gain an in-depth understanding about the attitude on the adoption of advanced technologies. Moreover, text to speech and graphical elements also help people with low literacy to use applications easily.

Usability Issues	Instances	Suggestions

Less attraction	• Static information components (4) • Reluctant to rely on a machine/sensitive field of healthcare (19) • Educational materials are lack of interactive (5) • A generic lack of susceptibility to dengue (4)	• Redesign with more graphical elements and an animation video using an entertainment-education (4) • Considering motivational factors into design, such a superhero, as well as updating in wording and some development of the user interface to make more appealing in order to increase the likelihood (5)
Difficulty in using and learning to use applications	• Not easy to learn about using technology and interaction with such technology was difficult without any helps (19) • Potential users are lack of technological skills (4) • Low initial uptake of Mo-Buzz, due to innate fear and distrust of technology (5) • Navigation errors, unfamiliarity with the app and touchscreen phones (14) • Problem in interface menu and screen that were laid out in a logical fashion (8)	• Organizing community sessions, workshops or health education sessions (4) • easier and reduce the number of steps for each task. Technically proficient health workers training others (5) • Collaboration with users before the development process (8)
Not ease to use	• Information provided by system were outdated (19) • Complex login process, leading to frequent typing errors and eventually caused the devices to be blocked (7) • Low literacy rate (14)	• Large screens (7) • Using text to speech and animation to guide and explain for further operation (17)
Negative influence on user behaviors	• Trigger outbreaks of panic by using predictive surveillance system (5) • The possibility of causing embarrassment to the patient due to the use of photographs of facial lesions (18)	• Dynamic disease mapping component can be only used by general public (5)

Low efficiency	• Required more time to enter ovitrap data and cups data into the system (12) • A need for collecting enough details (19)	• Automatic retrieval of current address could consume less time (12).

Table7. The list of usability issues and proposed suggestions

4. Discussion

4.1 Interpretations and Implications

The reviewed studies demonstrate that surveillance in low resource environments is commonly associated with a time-consuming and fiddly task, such as recording confirmed patient data with a lengthy or complex form, inaccurate geographical information recorded in the paper-based system and lack of space to store paper-based report. To facilitate the data collection in local communities, mobile phone-based data collection and reporting systems have been rolled out in many regions and developing countries by three approaches, namely: mobile application, text messaging and voice call. No matter which approach facilities the data quality in terms of timeless aspect, compared to paper-based approach. Commonly, online form within a mobile-based application or web-based application allows health workers and community members to real-time reporting data, which is becoming a potential and necessary solution for early detection in developing countries. However, inevitably, low resource environments are commonly associated with poor internet performance, e.g. weak transfer rates and intermittent mobile connectivity. This unreliable network has occurred in all the reviewed studies. For rural or mountain area lacking internet access or people with low literacy, text messaging and interactive voice response were considered as more suitable possible solutions. Therefore, it is necessary for developers to conduct context analysis to gain in-depth understanding before starting to design a solution.

We uncovered that regardless of which approach used has an influence on data quality. Most of recent studies involving mobile application have focused on typically internet technology, web technology and database, which facilities the legibility of data. This can be explained that the functionalities of automatically check for missing field and data errors used could avoid unreadable handwritten, and to reduce the possibility of missing necessary data, compared to paper-based and text message approaches. However, although the time of data collection have been successfully reduced and variety of data have been improved, the low level of accuracy and validity has not been significantly improved as poor IT literacy of users.

Transferring raw data into information through graphical-based data visualization has been used to interaction with end users. Information visualization allow Health workers to have a clear understanding on the location of current hotspots. However, such alert and predictive functions could trigger outbreaks of panic for community members. Similarly, using image processing and machine learning technologies to screen patients also trigger patents' embarrassment. This could have a negative impact on their acceptance and behaviors for adopting such advanced technologies. Besides photo-based screening, other mHealth tools for self-screening make a decision depending on symptom patients. The lack of support by qualified professional of the results also has becoming a key aspect for the adoption of such tools (18).

Usability evaluation also revealed possible approaches, existing issues and potential solutions which could have the implications not only for the mHealth tools described in the review but also for the development of mHealth systems for use in low resource settings. These issues revealed the highly demand on simplity, improving motivation and collaboration with end users.

4.2 Limitations

The generalizability of the results is limited by the different databased used between two reviewers. Because of the research questions related to technical perspective, the reviewer also used IEEE Explore as a database besides PubMed and Web of Science. Due to the lack of available data, the results cannot confirm the current trend of technologies. Because of the time limitation, the reviewer only chose the most relevant and important database for the review. Some literatures searched by database from medical perspective had less concerns on providing detail about design and development, because many mHealth tools used in the studies were developed by IT companies or technical experts. Similarly, most of publications searched by database from technical perspective are lack of usability evaluation and user feedbacks. To gain a comprehensive and in-depth understanding and answering research questions, we searched the name of mHealth tools or systems to related papers. The title and abstract-based screening were conducted by dividing the work for two reviewers. This could cause a bias related to the agreement on inclusion and exclusion criteria. Moreover, there were more inclusion criteria included in this review due to the constraints of sub research questions.

4.3 Further research

Further research is needed to establish a more representative insight, they could only focus on low income countries or middle-income countries, because there are different contexts and needs. Moreover, the types of infection diseases could be extended, in the review only focusing on vector borne diseases, which enable to give a more general understanding on the role of and interests in mHealth tools. Furthermore, future studies should take into account both technical perspective and user perspective, since the topic is highly relevant to local context and end users. This could give an implication for developer from outside of context or with different cultures to have a general knowledge.

5. Conclusion

By analyzing mHealth-based early detection tools for infectious disease in low- and middle-income countries in the past five year, this review will provide an insight for application developers as well as infectious disease researchers into the design and usability evaluation approaches. This literature has shown that predominant functionalities on mHealth systems focused on digital traditional surveillance including data collection and reporting, data analysis and interpretation and case management, and self-screening. The predominant technologies were used for mHealth-based early detection, including internet technology, computing technology, web technology, machine learning, information visualization and advanced algorithms. Moreover, predominant usability evaluation approach were questionnaires, interviews and observations and all of the mHealth tools were assessed by envisaged users. The attribute of usability including effectiveness, efficiency, satisfaction, operability and appropriateness recognizability.

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Appendix

Appendix A

Searching Query： https://drive.google.com/file/d/1qoE1wVI27L_-y-NcS1vCbgymfWWBp6ba/view?usp=sharing

Appendix B

Full text screening:
https://drive.google.com/file/d/1yU4tImQOZO7DpGjXbspC6AGHjKlep_Xb/view?usp=sharing

Appendix C

Data Extraction: https://drive.google.com/file/d/1JTFP4jBvrOswvxMqPeWmQjlcPsm5OY-o/view?usp=sharing