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Scoping Review and Evaluation of SMS/text Messaging Platforms for mHealth Projects or Clinical Interventions

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Abstract

Objectives—Mobile technology supporting text messaging interventions (TMIs) continues to evolve, presenting challenges for researchers and healthcare professionals who need to choose software solutions to best meet their program needs. The objective of this review was to systematically identify and compare text messaging platforms and to summarize their advantages and disadvantages as described in peer-reviewed literature.

Methods—A scoping review was conducted using four steps: 1) identify currently available platforms through online searches and in mHealth repositories; 2) expand evaluation criteria of an mHealth mobile messaging toolkit and prior user experiences as researchers; 3) evaluate each platform's functions and features based on the expanded criteria and a vendor survey; and 4) assess the documentation of platform use in the peer-review literature. Platforms meeting inclusion

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Authors' Contributions

SI, WB, RG, NS, PS, and AC contributed to the study design, interpretation of data, drafting of the report, and approval of the final report. SI, WB, and RG collected the data. SI, WB, RG, PS, RS and AC analyzed and interpreted the data. All authors gave input to the final version.

Conflict of interest:

Authors declare no conflict of interest

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criteria were assessed independently by three reviewers and discussed until consensus was reached. The PRISMA guidelines were followed to report findings.

Results—Of the 1041 potentially relevant search results, 27 platforms met inclusion criteria. Most were excluded because they were not platforms (e.g., guides, toolkits, reports, or SMS gateways). Of the 27 platforms, only 12 were identified in existing mHealth repositories, 10 from Google searches, while five were found in both. The expanded evaluation criteria included 22 items. Results indicate no uniform presentation of platform features and functions, often making these difficult to discern. Fourteen of the platforms were reported as open source, 10 focused on health care and 16 were tailored to meet needs of low resource settings (not mutually exclusive). Fifteen platforms had do-it-yourself setup (programming not required) while the remainder required coding/programming skills or setups could be built to specification by the vendor. Frequently described features included data security and access to the platform via cloud-based systems. Pay structures and reported targeted end-users varied. Peer-reviewed publications listed only 6 of the 27 platforms across 21 publications. The majority of these articles reported the name of the platform used but did not describe advantages or disadvantages.

Conclusions—Searching for and comparing mHealth platforms for TMIs remains a challenge. The results of this review can serve as a resource for researchers and healthcare professionals wanting to integrate TMIs into health interventions. Steps to identify, compare and assess advantages and disadvantages are outlined for consideration. Expanded evaluation criteria can be used by future researchers. Continued and more comprehensive platform tools should be integrated into mHealth repositories. Detailed descriptions of platform advantages and disadvantages are needed when mHealth researchers publish findings to expand the body of research on texting-based tools for healthcare. Standardized descriptions and features are recommended for vendor sites.

Keywords

text messaging; mobile health; mHealth; short message service; SMS; review

INTRODUCTION

Scientific background

Seven billion people, or 95% of the global population, live in an area covered by a mobile-cellular network [1–3]. Due to ubiquitous mobile phone availability and the capacity for interactive and real-time communication, rapid expansion of mobile health (mHealth) interventions occurred over the past decade to help address disparities in healthcare service access and improve health outcomes [4]. Text messaging or short messages service (SMS), an alphanumeric message of 160 or fewer characters, is among the most frequently used tool for mHealth interventions. Text-messaging interventions (TMIs) are popular because they can be sent, stored, answered and retrieved at the user's convenience; they are relatively inexpensive; and they are available for any type of phone [5–8]. In the US alone, an average of 169.3 billion text messages per month were sent in 2015, an increase from 110.4 billion in 2008 [3]. While the rate of smartphone ownership is rapidly growing, only about a third of the world's population (about 2.6 billion) will own one by 2017 compared to over 7 billion

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mobile phone subscribers. Therefore, simple text messaging will remain an important tool to reach any mobile phone user for some time to come [9].

TMI's can be used in various types of mHealth interventions. These have been categorized in multiple ways including, for example, behavior change communication (e.g., appointment and medication reminders, health promotion such as smoking cessation, community mobilization); data or information collection (e.g., collection and reporting of health information and service provision, vital event tracking, such as outbreaks); and logistics or supply chain management (e.g., ensuring basic supplies and medications are in stock throughout disparate health facilities) [5–8, 10–13]. Evidence from systematic reviews and meta-analyses indicate that TMI significantly improved antiretroviral medication adherence, attendance at medical appointments and behavior change outcomes [5, 7], adherence in chronic disease [8] including diabetes self-management, weight loss, increase in physical activity, and smoking cessation [6]. However, authors of these reviews highlighted the need for further research to determine long-term intervention effects, identify features of TMI's that improve success, and evaluate outcome measures other than self-reported adherence [5–8, 14]. TMI is a promising avenue of research. Thus, many researchers and healthcare professionals are interested in TMI and their technical platforms as a means to improve global health.

The mobile technology marketplace supporting TMIs is dynamic and diverse; therefore, deciding which TMI platform to use can be a challenge. A mobile messaging platform is defined as a combination of one or more executable programs with SMS capability that can perform several text messaging and basic computational tasks [15]. It can typically facilitate two-way SMS communication, send messages or reminders at pre-defined times or days, and respond to established keywords to trigger surveys or questionnaires. The software on these platforms can be open source (free-of-charge with modifiable source code) or purchased software-as-a-service with capabilities for customization for a specific project by a vendor. The platforms can also be web-based or downloadable. Program attributes usually depend on the complexity of features needed and the number or types of messages planned for a project. Figure 1 shows how a text message platform interacts with service providers and wireless networks to facilitate tasks and communication between the interventionist and the participant. As depicted in the figure, a platform is often hosted on a computer and uses various communication protocols (e.g., Internet, modem) to communicate with one or more messaging services through multiple channels, antennas, and networks to deliver text messages to an end user (e.g., participants, patients, or field workers).

Rationale for the study

The driver for this review was the authors' first-hand experiences using TMI platforms for data collection and participant interactions in the US and in low-resource countries [16–18]. The authors wanted to determine what mHealth platform other researchers used, explore what options were available to mitigate some of the challenges they experienced and determine platform advantages and disadvantages.

One step in selecting a tool is deciding which functions are necessary for one's intervention and soliciting detailed services from the product vendor, as well as, understanding existing

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systems, standards and policies [19]. Selecting a text messaging platform solution is just one component of project planning. Like any intervention, a mHealth project is complex and there are many considerations for planning and implementing. Currently, a number of guides and toolkits are available for steps and key considerations to plan an mHealth intervention [15, 19–21]. These guides help outline the larger mHealth framework of, for example, developing and defining the concepts and outcomes, forming a team, planning for implementation, and estimating implementation costs. The mHealth mobile messaging toolkit provides a list of 19 questions to consider when selecting a vendor, such as “Does the vendor need to have prior experience with the project?,” “Do you need to send messages in multiple languages?,” “Does your project intend to use short code?”[15]. This toolkit provides a list of ten vendor platforms for low-resource countries and each of their hosting options, platform offerings, and geographic locations of implementation. However, no peer-reviewed evaluation was available outlining the platform selection process, identifying the larger set of platforms currently available and applying principles to evaluate platforms and summarize advantages and challenges. To date, researchers and health professionals all conducted separate, time-consuming evaluations to find suitable platforms for their projects. A more refined selection and evaluation process is needed for researchers and healthcare professionals to better meet research and clinical needs more efficiently. Without such a resource, a search for an optimal platform can be costly and time consuming particularly if the selection results in a sub-optimal match for the project. mHealth is a field that will continue to grow and evolve. This review adds to literature by creating a current list of available SMS platforms, providing a set of expanded evaluation criteria and applying them to current mHealth platforms beyond only those available for low-resource settings.

The purpose of this scoping review was to systematically identify and compare text messaging platforms and to summarize advantages and disadvantages of identified platforms as described in peer-reviewed literature. The results constitute a practical resource for identifying and evaluating mobile messaging platforms for TMIs.

METHODS

This scoping review consisted of four steps to: 1) identify currently available platforms in mHealth repositories and online searches; 2) expand evaluation criteria from an mHealth mobile messaging toolkit and integrate prior research/user experiences[16–18]; 3) evaluate each platform’s functionalities and features based on the established criteria and a short vendor survey; and 4) assess documentation of platform use in the peer-review literature [22]. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used for reporting findings of searches [23].

Research team

The research team consisted of three professors (PP, NS, AC), three assistant professors (RS, SI, WB), and a master’s-prepared researcher (RG). Five team members had first-hand experience using one or more SMS platforms in research (SI, RS, WB, RG, AC). Other team members had expertise in informatics, mHealth, user experience and/or program evaluation (NS, RS, PP).

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Platform Searches and Selection Process

The searches were done independently by two authors (SI, RG) in four phases and were limited to the English language. The first search identified available mHealth information repositories in Google searches, and a second search within these repositories resulted in specific mHealth platforms. The third search was a general search in Google to identify any additional SMS platforms and vendors, and the fourth identified peer-reviewed research articles using SMS interventions. Traditional databases were not searched for vendor information because needed technical data are not available there; instead, mHealth repositories and Google searches were conducted.

The initial searches identified four separate repositories: 1) NetHope solution center (solutionscenter.nethope.org/), 2) the Johns Hopkins Global mHealth Platform Compendium (jhumhealth.org/content/mhealth-platform-compendium), 3) mHealthKnowledge: Applications and Platforms (mhealthknowledge.org/), and 4) Humanitarian Operations Mobile Aquisition of Data (NOMAD) (http://humanitarian-nomad.org/online-selection-tool/). Within NetHope and mHealth Compendium repositories, the following key terms were used: “SMS platform,” “platform,” and “mobile platform.” All items in the mHealthKnowlege: Application and Platform repository were analyzed. NOMAD is an online tool for data collection solutions; its selection assistant tool uses survey questions to provide recommendations for program needs. The response “yes” was selected for the NOMAD question, “Is a SMS based system required?” Last, Google searches were conducted using the same search terms listed earlier. The searches were conducted up to October 9, 2016.

Inclusion and Exclusion Criteria

No list of validated inclusion criteria was identified. Therefore, the inclusion and exclusion criteria were based on those listed in the mHealth mobile messaging toolkit [15] and from the authors’ prior research experience using SMS platforms.

Inclusion criteria were comprised of mobile solutions that:

- Supported interactive two-way communication for any phone type with the capability to be used for health-related TMIs research or projects. For example, platforms must have a function to provide and manage two-way SMS communication with patients or features to support disease surveillance without exclusions to certain countries such as only low- or middle-income countries.

Exclusion criteria were:

- Basic SMS gateways, (e.g., mobile network operator software that supports communication across different mobile carriers but has limited functionalities)
- Supported only one-way messaging (e.g., not interactive, only able to set up and send reminders)
- For mobile application (app) development/management
- For mobile money transactions

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- Focused on data collection via voice/pre-recorded messages (no SMS communication such as survey building and deployment
- For the purpose of converting paper, PDFs, mapping, polling, quizzes, games or faxes into static documents.

An initial list of unique platforms was drafted from the search results. Three of the authors (SI, WB, RG) then independently evaluated each platform against the established inclusion/exclusion criteria. The separate evaluations were discussed, and a decision to retain a platform was based on team consensus.

Platform Evaluation Criteria Development

The "mHealth Mobile Messaging Toolkit" was used as the starting point and initial framework to develop the evaluation matrix of platform features and functionality [15]. The Principles for Digital Development [20], the authors' prior experience using SMS platforms [16–18], and study questions were used to expand the evaluation criteria. First, the toolkit was searched for relevant information and assessment criteria were extracted. Criteria irrelevant to 2-way SMS communication-based interventions were removed (e.g., interactive voice response (IVR) or "flashing," where someone places a call and quickly hangs up to avoid a charge and the recipient receives the number to call back, was not included. This is a technique often used in low-resource settings). The research team, described above, worked together to develop additional evaluation criteria. Additional items assessing the platforms degree of programming skills needed, functions used by authors, and interoperability with other systems were added. Corrections were made until an agreement between all members was reached.

Testing Evaluation of Platform Features and Functionality Criteria on Identified Platforms

First online descriptions were reviewed on available affiliated websites, product demonstration videos were viewed where available, and downloaded platform trials were reviewed where possible. The inclusion/exclusion criteria were reapplied. Second, a brief survey based on the guidelines and evaluation matrix was developed. The survey consisted of 15 questions directly corresponding to our evaluation criteria (e.g., is the software open source? What are options for sending and receiving text messages? Can data be synced when offline? What functions are included with SMS service? Can it generate reports and data visualization of results? Does it support multiple projects from one account or one project among multiple accounts? The complete survey is in Appendix 1). Each platform website was reviewed to identify contact information, and the survey was sent via email to vendors for whom contact information was available. Some sites without contact information had an online form to complete with questions, limited to 150 words. Therefore, a brief version of the survey was developed and sent to them (the brief survey is also found in Appendix 1). Data from the respondents (n = 17 of 27, 63%) were added into the evaluation matrix and compared to findings from our assessment. Discrepancies were resolved through consensus.

Peer-reviewed literature search

The literature searches for SMS intervention articles used the name of each identified platform and vendor as a search term (e.g., FrontlineSMS, CommCare, Dimagi). Studies that

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included an identified platform were reviewed (full text) to identify descriptions of challenges and advantages of the platform. Descriptive thematic analysis was used to summarize the descriptions of challenges and advantages of the platform during field use in peer-reviewed articles [24].

RESULTS

Platform Identification

The multiple searches yielded 1041 potential SMS platforms. The majority of these (n = 914) platforms were excluded after a review of their titles and affiliated website descriptions because they did not provide SMS services. Instead, they were guidelines, toolkits, basic gateways or duplicates of the same platform found using multiple search terms in multiple repositories (n = 67). Further evaluation was conducted on the 60 remaining platforms to include an evaluation of vendor responses to the survey questions listed above. Thirty more platforms were excluded because they were for business purposes, marketing, apps, focused on data collection only, or were no longer available. During data extraction two more were excluded because the vendor was a consulting service and SMS interventions would be managed by the company rather than the researcher. Figure 2 provides the review of the SMS platforms flow diagram. Twenty-six platforms met the inclusion criteria. Of the 27 platforms, 13 were found only in mHealth repositories, 10 only through Google Searches, and 5 in both.

Platform Evaluation Criteria Development

Final feature/functionality criteria were based on toolkit elements [15]: year established, headquarters location(s), has a website, was developed to meet needs of low resource settings, has basic function capabilities (e.g., can forward/send/receive messages, multimedia messaging service, use of keywords for auto-responses), ability to schedule messages/reminders, has alerts (e.g., warnings and event notifications to system users), interoperability with other systems, fee structure, and identified likely end-user of the product. The following criteria were added based on researchers' prior experience and the Principles for Digital Development [20]: is open source (e.g., the source code/program code is made freely available and may be redistributed and modified), is healthcare focused, has a do-it-yourself setup option (e.g., without the need of a programmer), has privacy and data security protections (e.g., reports its data security strategies), capable of online/offline syncing of data, has participant grouping features, has support for multiple users (e.g., unique user login and role/user designation) in same account, can support multiple projects in one account, has interface language option(s) other than English, and has built-in report generator and data visualization. Other criteria were considered: to list the version or iteration, collaborators in sites outside of the US, programming language, and cost per 100 users. However, program type can vary substantially and vendors indicated they could not provide a set cost without program specification needs, so these criteria were not included in the final evaluation list.

Each platform is briefly described in Table 1. Descriptions highlight the various types of services offered (e.g., coordination of data collection activities, supports every sort of mobile

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engagement), geographic coverage (e.g., enable SMS anywhere, across 200+ countries), functionalities (e.g., medication reminders, video, SMS), target end-user (e.g., last mile healthcare, deliver critical services to vulnerable populations), interoperability with other systems (e.g., integrated with OpenMRS and other common medical records), and platform hosting options (e.g., Web-based, desktop). Five sites did not provide information about the countries where they were based; of those that did, 10 were based in the US.

Table 2 summarizes the findings of the platform evaluation. Fifteen were open source, 11 focused specifically on health care, and 17 were developed for low resource settings. Fifteen reported do-it-yourself setup without need of further programming while the remainder required some coding/programming skills or could be built to specification by the vendor.

Visualization and Interface Language Options—Data visualization or report functions (to be built/customized), unique user login and role assignment for the majority of platforms were identified. Baseline data visualization varied from viewing message logs, service usage, responses to multiple choice and numeric questions, and basic tables to more advanced statistics, graphs, maps, pre-configured report generators, and data quality reviews. Eleven of the 27 indicated interface language options other than English.

Interoperability—Descriptions of interoperability with other software systems or electronic medical records were available for only 15 of the 27 platforms; others indicated where interoperability could be built or did not report these data. For example, DataWinners, Dimagi, InSEED reported interoperablility with open-source programs such as OpenMRS (open-source medical record system platform), iHRIS (open-source human resources information solution), or DHIS2 (District Health Information Software, an open-source software platform for reporting, analyzing and disseminating health program data). Others indicate that they are “generally able to share data,” can integrate with other systems (such as EHRs, research back-ends, or various communication services), e.g. Sana, Sense Health or integrate with external platforms and databases through API and webhook (e.g., Textit.in). One reported exploring integration into DHIS2 and other health systems (e.g., Voto Mobile).

Data Security—Seventeen vendors outlined a variety of data security plans. For example, security plans were described as: compliance with the Security Rule issued by US DHHS under HIPAA via secure voice and messaging (e.g., Sense Health, Celltrust); storing data solely on US-based servers protected by firewalls, permitting access only through encrypted FIPS-140–2 compliant channels, password protection/account login, hosting data on IOS accredited data centers, and limiting access to user info (e.g., Textit.in, Mobilecommons, MXT SMS Global, Magpi, Mango); two-factor authentication, login IP address whitelisting, login session management, and activity logs (Telerivet); encryption to protect communications platform and web application, specification of an HTTPS url, and cryptographic signature on requests (Twilio); or using HTTPS to protect the security of API keys (Voto Mobile). Measures to prevent unauthorized access to or disclosure of protected health information (PHI) included physical, electronic and administrative procedures to safeguard and secure PHI via encryption of medical data (Vumi) and built-in special authenticating software (industrial strength Drupal-based authentication with secure data

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transfer such as WebFirst), as well as sending alerts before transmitting potential confidential information to safeguard patient security (e.g., Sense Health).

Fee Structure—A range in the descriptions of fee structures and additional costs was evident. Fee structures ranged from free to monthly or annual subscription-based. Vendors reporting free software (e.g., MoTECT) reported that costs will be incurred for SMS messages or fees for hosting and also for support to configure software, train internal teams, and help deploy products (e.g., MedicMobile). Some offered free basic options with limited features (e.g., outgoing SMS to enumerators) or limited number of messages/users per month, as well as, monthly or annual "Pro" or "Pro/SMS" subscriptions based on the usage and number of messages sent that included additional support or services (e.g., DataWinners). A number of the platforms offer free trials to test their platforms and then varying monthly or annual subscriptions depending on the number of messages transmitted per day and the number of contacts (e.g., Push Mobile Media, EngageSpark, Telerivet).

End users—The majority of the platform websites (n = 19) did not describe targeted end-users, while nine specified health care professionals (e.g., frontline health workers, clinicians, staff, community-based workers, providers) as the primary end user (e.g., Sense Health, Celltrust). Another target audience was government ministries of health or large projects funded by international donors (e.g., NGOs) (MoTECH). Still others reported use in broad applications in various settings, including: health, agriculture, financial inclusion, education, democracy and governance, and water & sanitation (e.g., Voto Mobile, Push Mobile Media).

Platform Functionalities—Most platforms included descriptions of functions for participant grouping, keyword autoresponse, reminders and alerts (18, 19, 22, and 20 out of 27, respectively). Fewer reported functions for text-to-email (7, 25%), forwarding/sending/receiving SMS text messages (8, 28.6%), and multimedia messaging service (MMS) allowing picture or video messages) (12, 44.4%). Some indicated any functions were customizable or programmable (e.g., Mango, Twilio). Customizable platforms add only the functions needed for the project and all functions are offered.

Summary of advantages and challenges of platforms reported in the peer-review literature—The flowchart in Figure 3 illustrates the initial literature searches using each platform and/or vendor as a search term that yielded 174 articles. One hundred and twenty were excluded because they did not refer to a SMS platform and an additional 32 were not mHealth related. The 21 remaining articles were subjected to full-text review. From these authors 6 of the 27 platforms identified above were reported as being used in the studies. CommCare was used in 9 studies [25–33], FrontlineSMS in five [16, 18, 34–36], Sana in three [37–39], Rapid SMS in two [40, 41], and one each for MoTech [42] and Magpi/DataDyne [43]. Few of the articles contained information about the advantages and disadvantages of the platform; most merely mentioned the platform and how it was used in the study. Table 3 provides a summary of the extracted advantages and disadvantages.

CommCare was commonly used for programs requiring simultaneous electronic data capture by community health workers in the field and data management by program

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managers based at a hospital or clinic [28, 29, 33]. Therefore, its cloud database was a key advantage because it synchronizes in real-time [33]. One set of authors noted that it could be app-based on an Android smartphone/tablet or used on a low-end Nokia feature phone [30]. A disadvantage was in settings with limited connectivity where a CommCare project could be developed offline but needed a cellular or Internet connection to be downloaded to a smartphone [29] and to upload data to the cloud-based database [27].

For FrontlineSMS, one article reported a number of advantages and disadvantages that are outline in table 3 [16], while the other three articles listing FrontlineSMS as the platform used did not report platform-specific advantages or disadvantages [18, 34, 35]. However, one set of authors described the rationale for selecting FrontlineSMS as the following: it was an open source computer-based application where researchers could log in and manage sending and receiving messages, contact information, user preferences, and passcodes; included a message database and a module to set message reminder frequency; and it supported a global system for mobile communications (GSM) modem to send and receive text messages [18]. As noted in Table 1, there are new versions of FrontlineSMS and some of the disadvantages have likely been remedied due to the web-based platform. However, some of the features in version 1, such as language options and reminders, are no longer available in the updated version and would need to be customized. The fee structure has also changed since the publication of the prior manuscript.

Regarding Sana, both articles noted that data could be collected via a mobile device and synchronized automatically with the OpenMRS (Open Medical Health Record) application for clinical review [37–39]. However, during the review of this platform in preparation for this article, none of the links to the user guides worked which may indicate that this platform is no longer supported.

Advanced programing knowledge was required to use the MoTech platform [42]. Applications were developed to integrate mobile data collection, electronic medical records, and interactive voice response features [42]. RapidSMS provided effective and real-time two-way communication and a database for keeping clinical records [40]. However, the disadvantages listed in the paper were general disadvantages to SMS technology, such as telephone maintenance and replacement and limited access to electricity for charging the phones, rather than issues with the platform [40]. Magpi was used for daily reporting of Ebola cases to central ministry of health leadership. Authors report benefit of intervention and advantages of text messaging but no further challenges of platform use [43].

DISCUSSION

Texting continues to be a popular tool for all phone types; therefore, it remains highly relevant for health research activities. Yet, identifying and selecting appropriate SMS platforms is an enduring challenge to researchers and health professionals. This review can help mitigate that challenge by providing an expanded and updated list of current mHealth platforms with an evaluation of potential two-way SMS platforms for TMIs. Also, a solid method is outlined to search for, select, evaluate and identify platform advantages and disadvantages. The expanded platform evaluation criteria are available for other researchers

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to use. Initial evaluation criteria were informed by mHealth guides [15, 19] and expanded by the research team. Twenty-seven platforms were identified and assessed for their features and functionalities using this set of criteria. An empirical approach was used by mixing survey and experiential accounts to objectively compare SMS platforms [19].

Findings from this review highlight the variation in mHealth platform features and functions, contributing to the challenges in searching for and comparing functionalities. Baseline characteristics and functionalities were not consistently reported and no standard format or criteria are available to guide platform descriptions. Many websites were visually appealing with icons, images, vignettes and videos of usages in the field, but this made identifying functions challenging. Terms and formats describing functions varied (e.g., functions embedded in picture form, text or described in videos). More vexing, some sites indicated that additional functions were available through customization by the service provider. In this review, additional mHealth platforms were identified beyond those currently available in the NOMAD tool. This difference is likely reflective of the dynamic nature of these systems and/or the filtering system specified for SMS in Nomad. This review focused on interactive SMS functions; however, the newer functions for interactive voice response systems for low literacy populations or multimedia messaging services to add pictures and videos may be desirable features for future researchers depending upon the literacy needs in health behavior interventions [44].

Similarities and variations in platforms

Authors of mHealth principles recommended the use of open source programming because it contributes to shared coding databases [20]. However, each type of software, whether open source or fee-for-service, has advantages and challenges [15]. Modular components that allow users to build a platform to program specification with minimal to no programming are more readily available. For example, about half of the platforms had a “do-it-yourself” setup (e.g., setup wizards) without the need for further programming and many were web-based to provide easy access from anywhere. The remainder of platforms required some coding/programming skills or indicated they could be tailored by the vendor to needed specifications. Setup wizards or modular components can help users with little to no programming knowledge easily select platform features needed for a project. In contrast, open source software requires programming knowledge and skills. Using programming skills, open source platform features can be tailored; however, maintenance and upgrades can be more challenging. Further adaptations may be necessary at additional cost. On the other hand, commercial off-the-shelf software may be more expensive upfront, but maintenance is performed by the vendor, potentially offsetting the initial costs.

Functions, such as real-time data assessment and centralized project management, can improve program management and evaluation and support researchers’ understanding of mHealth interventions. The ability to assess data in real-time is one advantage of technology-based data systems compared to paper-based. Although many platforms provided baseline data visualization, the type of visualization varied from basic responses (e.g., viewing message log, service usage) to use of multiple choice and numeric questions and from basic tables to more advanced infographics (e.g., graphs, maps, data quality

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reviews). Ultimately, most of the platforms could be customized to the researchers' desired data visualization or report type.

Another essential requirement is allowing multiple users to access a project with full or limited roles. The majority (n = 23) of the platforms offered access control that allows multiple users to access the same project using unique logins and allows for project leads to monitor the type of access (e.g., full or partial data access). Moreover, controlling access is complimentary to data security. Multiple user access is needed to review responses regularly to ensure the system is functioning as programmed. When multiple distinct projects are in progress, platforms must support multiple projects from the same account to allow for centralized management of all SMS-based research interventions. Researchers will want to evaluate this particular criterion carefully to assure success in their own projects.

Understanding program costs is another important issue in platform selection. However, determining program costs for this review was difficult due to the varying fee structures and varying requirements of a mhealth intervention. For instance, each TMI will vary in program scale, location, and tools/features needed; therefore, using one of the mHealth toolkits, such as mHealth Assessment and Planning for Scale (MAPS) toolkit,[19] financial planning guide is recommended. The MAPS toolkit provides some estimates of pricing variability and a list of considerations when planning a SMS project budget.

Last, findings from this review suggest that use of TMI for health-oriented organizations is becoming more wide-spread. Some platforms focused specifically on the healthcare sector or on resource-limited areas. As a result, these systems may play a critical role in the future development of a learning healthcare system, particularly for underserved areas or hard-to-reach populations. Platforms built for low-resource settings most often had a function to synchronize (sync or upload) data or message where/when Internet access was not available. This could be an important feature for some researchers and settings. Few platforms described using in-country programmers. Identifying a tool with an in-country office could possibly mitigate challenges related to local mobile network providers.

Addressing issues of interoperability and data security

Interoperability and data security are complex issues in the health informatics domain and they are crucial to consider in mHealth evaluations [20]. Several platforms reported interoperablility using open-source programs such as OpenMRS, iHRIS, or DHIS2 or that their platforms could be built to integrate into electronic health records. Most of the platforms included descriptions of baseline measures to ensure data security, including compliance with the Security Rule issued by US DHHS under HIPAA. Various industry standard methods were also supported. However, it is possible that some vendors may not appreciate the level of sensitivity of the data being collected or transmitted across their systems. Also, interoperability and assuring HIPAA data security are costly, and vendors have to subsume a considerable amount of liability for data privacy and security. These may be reasons why not all platform descriptions included statements about data security or interoperability with other systems.

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Platform advantages and disadvantages

Twenty-three of the 27 platforms identified in this review were not reported in the peer-reviewed literature. This may suggest that few existing platforms have been trialed, that they were not specifically named in publications or that the publication cycle has not allowed naming newer platforms researchers have used. Further, few authors listed any platform advantages and drawbacks during field testing. Of the six platforms named in publications, CommCare was had the highest number of listed advantages and fewest drawbacks.

Future work

Future work is needed to develop a standardized platform rating scale and measures for trialing, classifying, and evaluating the quality of platforms. Researchers are encouraged to describe platform strengths and weaknesses to help inform future researchers' decision making and also to encourage vendors to make needed changes. Standard selection criteria need to be validated and used in platform selection. Future researchers could study platforms based on primary function other than 2-way SMS, focus on criteria for smartphone users, and re-review the published literature to better understand benefits and challenges for other mobile solutions.

Limitations

This review has several limitations. First, innate limitations exist to conducting online searches. Unlike PubMed or other medical databases, online searches cannot be easily refined. Searches in mHealth repositories, such as NetHope, produced irrelevant material such as blogs, webinars, links to events, etc. This made it more challenging to identify SMS platforms. It is possible that mobile messaging platforms were missed if the vendors' descriptions did not use words matching the search terms. To minimize this limitation, multiple searches were conducted independently by two researchers using several combinations of the search terms. Additionally, mHealth is a dynamic market and new vendors. mHealth tool repositories that are updated continuously were identified; future researchers will want to search repositories themselves for new additions. Third, surveying all vendors was attempted; however, in cases for which the vendor did not respond to the survey online vendor information and video demonstrations were used to evaluate. Finally, the information presented was not reviewed by the vendors prior to publication.

Conclusions

Searching for and selecting mHealth platforms for TMIs remains a significant challenge. The results of our review can serve as a resource for researchers and healthcare professionals wanting to integrate TMIs into health interventions. This evaluation outlines features as well as current platform advantages and disadvantages. Steps are provided to help researchers identify, select and evaluate platforms. Criteria of particular interest to researchers are emphasized, such as interoperability, data security and do-it-yourself program setup. Further recommendations include: continued and comprehensive integration of platform tools into mHealth repositories, development of standard platform evaluation criteria and publishing more detailed descriptions of advantages and challenges encountered by mHealth

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researchers. These efforts are recommended to expand the body of research of texting-based tools for the healthcare outcomes.

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Appendix 1: Survey of mHealth Platform Vendors (Full and Brief Versions)

Full Vendor Survey

Hello,

We are researchers from Columbia University who are writing an article for a widely-circulated publication in which we aim to summarize the features and capabilities of mobile SMS platforms. The article will encourage the use of SMS for data collection and behavioral interventions in large national and international studies and mHealth campaigns.

We have identified your platform as highly relevant for inclusion in our article. We have reviewed your website's description of your SMS platform. The following questions are for clarification so that we have consistent descriptions of the included platforms. Thank you very much for taking the time to respond:

1. Is your SMS platform open access?
2. What are the options for sending and receiving text messages? For example, online GSM Gateway, USB dongle with SIM card, app based on a smartphone, etc.
3. Does your system allow for offline use in areas where the Internet connection is not consistent with online syncing at a later time?
4. What functions are included with your SMS service? For example, text-to-email, forwarding, MMS, keywords, grouping recipients, reminders, alerts, etc
5. Does your system allow for reports and data visualization?
6. What type of format can data download be exported to (for example, .csv, .spss, etc)?
7. Does it support sharing one project among multiple accounts (unique login users for one project)?

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8. Does it support multiple projects from the same account?
9. Is the platform interface available in multiple languages? If so, which ones?
10. What is the fee structure (free, subscription, use-based)?
11. What would the cost be for your basic service with 200 recipients sending/receiving up to 5 messages per day?
12. Is the platform interoperable/compatible with other systems such as electronic health records, external apps, etc?
13. Is technical support provided to users? At what level (free for all, for subscribers, etc)?
14. Is there a specific target end user (for example, frontline health workers, etc)?
15. Is there a way to view a demonstration of how your platform works (via downloading a trial, etc)?

Please feel free to contact us with any questions.

Sincerely,

Brief Vendor Survey

For sites that did not provide contact information but did have a form to complete to send questions which had a maximum of 150 words allowed:

150 Word Version

We are researchers writing an article to summarize features of mobile SMS platforms. This will encourage use of SMS for data collection and interventions in large studies. We would like to include your platform, and we have some questions for clarification. We appreciate your time:

1. Is your SMS platform open access?
2. Options for sending/receiving texts? (online GSM, USB dongle, etc)
3. Offline use available with online syncing later?
4. Functions included with SMS service? (keywords, reminders, etc)
5. Reports and data visualization available?
6. Format of data download? (.csv, .spss, etc)
7. Sharing one project among multiple accounts supported?
8. Support multiple projects from one account?
9. Platform interface available in multiple languages? which?
10. Fee structure? (free, subscription, use-based)
11. Cost for basic service with 200 recipients and 5 messages per day?

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12. Platform compatible with ehealth records, external apps, etc?
13. Tech support provided to users? At what level (free, subscription, etc)
14. Target end user?
15. Can we view a demo? (download trial, etc)

Please contact us with questions!

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Summary points

What is know

- Short Messaging Service (SMS), or text messaging, is among the most frequently used mobile communication tools
- Mobile messaging platforms can support text-messaging based interventions for mHealth projects or clinical intervention research
- Identifying, evaluating, and comparing functionalities of software/platforms to support text-messaging interventions is challenging for those choosing software solutions to best meet their program needs

What this study adds

- Selection process and evaluation criteria based on guidelines and author's prior research experience using text messaging platforms
- Resource for researchers or health care professionals seeking to integrate text-messaging based interventions into health interventions and/or research
- Discussion on platform advantages and disadvantages as noted in peer-reviewed literature to consider when selecting a solution

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Figure 1.
Illustration of SMS/text messaging

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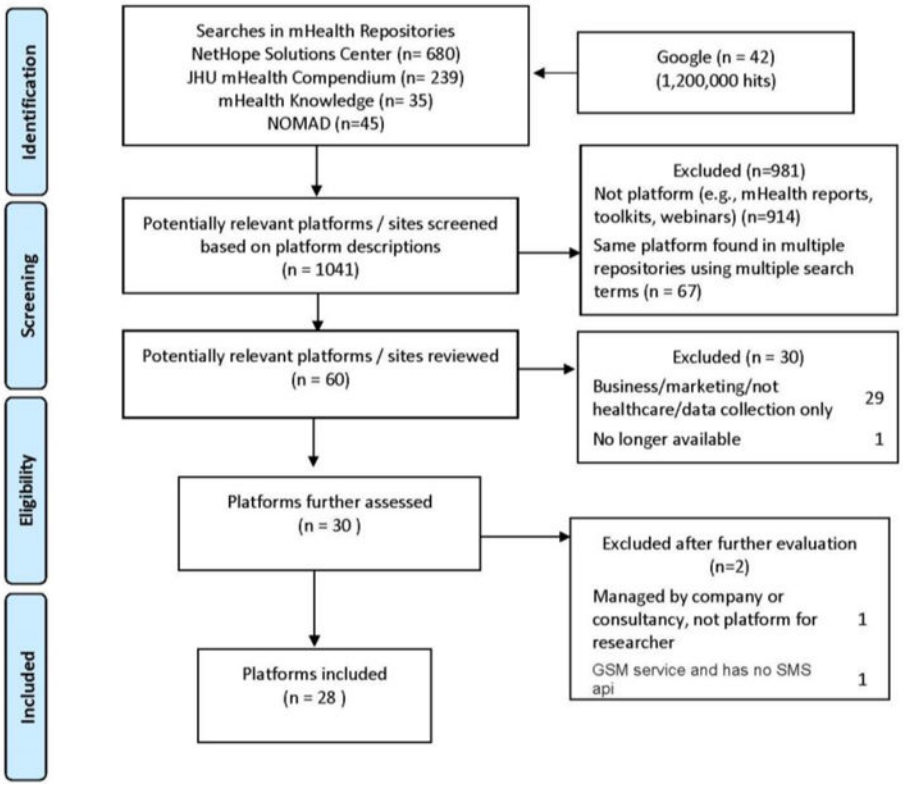

Figure 2.
Review of SMS platform flow diagram

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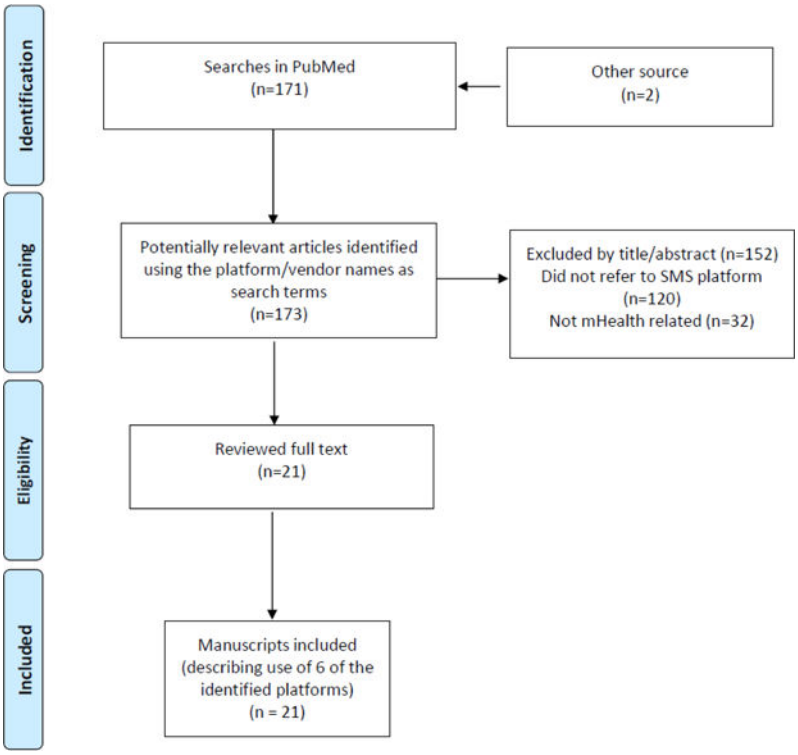

Figure 3.
Flowchart of peer-review literature searches

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Table 1

Included platforms, year founded, summary of vendor product description, website

Platform (Tools)	Year Founded	Description	Headquarter location(s)	Website
Celltrust (Secure Line for healthcare)	2006	Traceable, secure mobile communication for industries and mobile aggregation across 200+ countries with over 800 carriers and mobile operators	Scottsdale, AZ	celltrust.com
DataWinners	NR	Integrated, mobile data collection via SMS anywhere, with any phone. Bulk pre-paid SMS to eliminate negotiations with phone carriers/SMS Gateways	NR - many partners	datawinners.com
Dimagi (CommCare)	NR	Can create, edit, and deploy applications without a software developer and track e.g., clients, facilities, transactions, over time	US, India, South Africa, Guatemala, Senegal	dimagi.com/
EngageSPARK	NR	Build the platform components needed for project, no tech skills or training needed, >200+ countries	Philippines, US, Hong Kong	engagespark.com
Freedom Fone	2008	User-friendly, low-cost to empower marginalized communities and bridge the digital divide. Voice menus, SMS polls	Zimbabwe	freedomfone.org
FrontlineCloud	NR “decade”	Send, receive, and manage SMS messages and data from anywhere	NR	frontlinesms.com
FrontlineSMS	NR “decade”	Desktop software, enables instantaneous two-way	NR	frontlinesms.com

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Platform (Tools)	Year Founded	Description	Headquarter location(s)	Website
		communication to any mobile handset		
InSTEDD (Remindem, Verboice, mBuilder)	2007	Open source tools to improve collaboration, information flow & knowledge sharing to deliver services to vulnerable populations. Focus on emergencies, diseases, disasters.	US, Cambodia, Argentina	instedd.org
Magpi (formerly DataDyne)	2003	Coordinate data collection activities, send notifications, educate, or remind patients to take medications or attend appointments	Washington, Nairobi, London	home.magpi.com/
Mango (Greenmash)	NR	Complete mHealth surveillance, monitoring, and evaluation solution – currently used in dozens of global and national healthcare programs	London, Washington D.C., Auckland, Nairobi	greenmash.com
MedicMobile	NR “years”	Platform built for healthcare. Free, open-source, adaptable platforms.	California	medicmobile.org
Mobilecommons	NR	Easy-to-use platform, wide range of features to help achieve better healthcare outcomes, build solution that fit needs	Brooklyn, NY	mobilecommons.com
MoTECH (Mobile Technology for Community Health)	NR	Enables mHealth solutions to develop, manage, and monitor solutions more quickly and cost-effectively with fewer technical resources	NR	motechsuite.org

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Platform (Tools)	Year Founded	Description	Headquarter location(s)	Website
MXT SMS Global (Message Xtreme)	2007	Create and manage SMS communication, user friendly, works in any browser, fully responsive interface, includes healthcare specific solutions	Australia	smsglobal.com/web-messaging-platform
Push Mobile Media (mobile message toolkit, mobiFeed)	NR	Create and distribute interactive SMS and rich media to any mobile device, gather and analyze feedback	NR	pushmobilemedia.com/
RapidPro (evolved from TextIt and RapidSMS)	2007	Easily design, pilot, and scale services that connect directly with a mobile phone user without a software developer. For “difficult operating environments”	Rwanda	rapidpro.io
RapidSMS (Open MRS; Child Count+) (UNICEF)	2007	Free, open source framework designed to send and receive data using basic mobile phones, manage complex workflows, automate analysis and present data in real-time.	multiple contributors	rapidsms.org/
Salamanca (TERA)	2013	Fast, secure and cost effective SMS based communication platform between NGOs and the Community. Developed in cooperation with the Red Cross	Ireland, Bolivia	salamancasolutions.com/
Sana Technology Platform (MIT)	NR	Set of healthcare tools for the collection, transmission, storage and analysis of medical data. Supports audio, images,	MIT, US	sana.mit.edu/platform/

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Platform (Tools)	Year Founded	Description	Headquarter location(s)	Website
		location-based data, text, and in the future, video		
Sense Health	2013	Messaging plans that provide support based on health condition, acute health event, medication reminders, consent	NY	sensehealth.com/
Telerivet	NR	full-featured mobile messaging platform ready to use in any country	San Fransisco, CA, Tanzania	telerivet.com/
Text to Change (Vusion)	2007	Optimize services that offer unique reach, cost efficiency and direct access to target consumers (SMS, Interactive Voice Response and mobile internet)	Amsterdam, the Netherlands	texttochange.org
Textit.in	NR	Build interactive SMS applications anywhere in the world and deploy it without expensive setup costs or technical expertise	Africa (Rwanda)	textit.in
Twilio	NR	Build intelligent SMS logic and apps in web applications over local, toll-free, and short-code numbers globally.	San Francisco (10 other offices)	twilio.com/sms
VOTO Mobile	2012	Supports every form of mobile engagement, through voice and SMS in local languages	Ghana	votomobile.org/
Vumi (UNICEF)	2007	Web application to design and manage mobile messaging campaigns. Can include surveys, registration	South Africa, NY, London	vumi.org/

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Platform (Tools)	Year Founded	Description	Headquarter location(s)	Website
		drives, and bulk SMS sends.		
WebFirst (PhiCollect)	NR	SMS-based data collection mechanisms whereby users with standard mobile phones can collect data for a variety of applications	Rockville, MD	webfirst.com/phicollect

Note: SMS=short messaging system, US=United States, NR= Not reported

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Table 2

Mobile Messaging Platform Evaluation matrix

Platform	Open source	Healthcare specific	Low resource setting	DIY/setup without programming	Syncing	Text-to-Email	Forward, Send, Receive	MMS	Keywords	Participant Grouping	Reminders	Alerts	Reports/data visualization	Unique user login and user roles	Supports multiple projects from same account	Interface languages (other than English)	Interoperable with other programs	Data security strategy	Fee structure	Targeted to health care personnel (ex: clinicians, frontline health workers)
Celltrust[a]		✓			**			✓	✓	✓	✓	✓	✓	**	**	**	**	✓	**	✓
DataWinners	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	FR, MA, PR	✓	✓	Free, SUB	
Dimagi - CommCare	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	FR	✓	**	SUB	✓
EngageSPARK		✓	✓	✓					✓	✓	✓	✓	✓	✓	✓			**	UB	
Freedom Fone	✓		✓	✓					✓	✓	✓	✓		✓					Free	
FrontlineSMS Cloud			✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	FR, SP	✓	✓	SUB	
FrontlineSMS v2	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			FR, PR, SP, SW		**	Free	✓
InSTEDD*	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	**	**	✓	**	Free	
Magpi (formerly DataDyne)[a]					✓	✓		✓					✓	✓	✓	**	**	✓	Free, SUB	
Mango (Greenmash)[b]	✓	✓	✓	✓	✓						✓	✓	✓	✓	✓	FR, MA, SO, SW	✓	✓	SUB, UB	
MedicMobile	✓	✓	✓	✓	✓						✓	✓	✓	✓	**	FR, HI, NE, SP, SW	✓	**	Free, SUB	✓
Mobilecommons								✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	SUB	
MoTECH[b]	✓	✓	✓		✓	✓	✓				✓	✓		✓		FR, IT, PL, SW	✓		Free	
MXT SMS Global[a]						✓	✓	✓	✓	✓	✓	✓	✓		✓	**	**	✓	UB, SUB	✓
Push Mobile Media[a]				✓								✓	✓	✓	✓	**		✓	SUB	
RapidPro (UNICEF)[a]	✓		✓	✓	✓				✓	✓	✓		✓	✓	✓	FR, PR, SP	✓		**	
RapidSMS (UNICEF)[a,b]	✓		✓		✓				✓		✓	✓							Free	
Salamanca[a]							✓		✓	✓		✓			✓		✓	**	Free, UB	
Sana Technology Platform (MIT)	✓	✓	✓		✓								✓	✓		CH, HC, SP	✓		Free	✓
Sense Health		✓		✓	✓			✓	✓	✓	✓	✓		✓	✓	SP	✓	✓	SUB	
Telerivet						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	SW	✓	✓	SUB	
Text to Change/Vusion[a]	✓		✓		**			✓	✓		✓	✓	b	✓	✓		**	✓	UB	✓
Textit.in				✓	✓	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓	UB	
Twilio[b]				✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	UB	
Voto Mobile			✓	✓	✓				✓	✓	✓	✓	✓	✓	✓		✓	✓	UB, SUB	
Vumi (UNICEF)[a]	✓		✓		✓		✓		✓	✓	✓		✓	✓			**	✓	UB, SUB	
WebFirst/PhiCollect[a]	✓				✓						✓		✓	✓	✓	**	**	✓	**	✓
TOTAL	14	10	16	15	17	7	8	12	19	18	22	20	21	22	18	11	15	16		8

[a]Notes: Did not receive response to brief survey,

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[b] Customizable by project/Programming required to build features,

** Information not reported.

Abbreviations: MMS=multimedia messaging service, CH=Chinese, FR=French, HC=Haitian, Creole, HI=Hindi, IT=Italian, MA=Malagasy, NE=Nepali, PL=Polish, PR=Portuguese, SO=Somali, SP=Spanish, SW=Swahili, UB=Usage-based, SUB=Subscription-based

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Table 3

Advantages and Disadvantages of Identified Platforms as Reported in Peer-reviewed Literature

Platform (citations)	Advantages	Disadvantages
CommCare	• Synchronizes in real-time on mobile devices and computers (cloud database) [33] • Training course available to learn the program [33] • SMS reminders [33] • Integrated GPS [29] • "User-friendly web interface" [27, 29] • Can link data from the same respondent collected at different time points [29] • Can be used on smartphone, tablet or low-end feature phones [30] • Data related to the data collection process is automatically captured [33] • Multiple language capability [27, 29] • Rapid generation of de-identified reports [27, 29, 33] • Remote access capability [28, 29, 33] • Open-source, free resource for small projects with free technical support [27] • Can incorporate multimedia such as videos, photos or audio [27–30]	• Requires the Internet to build the application and download it to a device [29] • Not good for limited connectivity settings [27]
FrontlineSMS	• Free / low cost [16] • Reminder capability • Multiple language options [16]	• Powering off laptop caused automated messages to not be sent (version 1) • Only 100 reminders could be programmed simultaneously • Accent marks in messages caused character count and data download errors • Incorrect time stamping of messages in some cases • Messages registered as sent even when there was insufficient credit to send • Loss of data associated with spotty network coverage [16]
MoTech	• Allowed for integration of mobile data collection, electronic medical records, and interactive voice response to facilitate communication between nurses, clients, and managers [42]	• Applications were not interoperable and programmers needed advanced software programming skills to piece the programs together [42]
RapidSMS	• Automated reminders [40] • Emergency alert-system [40] • Continuous technical monitoring with an error log for inconsistencies and an automated reply with suggestions on correcting message format [40]	General disadvantages of mHealth technology • Challenges with telephone maintenance and replacement [40] • Limited access to electricity for charging phones [40]
Sana	• Interoperability with OpenMRS, "simplifies the integration process" [37–39]	• None listed

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Platform (citations)	Advantages	Disadvantages
	• opensource mobile platform that allows health workers to collect different types of information about patients [39]	
Magpi	• Works on simple phones, smartphones, tablets, and computers [43] • A subscription ($500 per month) allowing up to 500 monthly texts [43] • The data points were stored and visualised in the Magpi cloud using a line listing format containing the originating cell phone number, the SMS time/ date stamp, and the CUI result [43]	• None listed