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Original Paper

The Development of the Recovery Assessments by Phone Points (RAPP): A Mobile Phone App for Postoperative Recovery Monitoring and Assessment

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Abstract

Background: In Sweden, day surgery is performed in almost 2 million patients per year. Patient satisfaction is closely related to potential adverse events during the recovery process. A way to empower patients and give them the opportunity to affect care delivery is to let them evaluate their recovery process. The most common evaluation method is a follow-up telephone call by a nurse one or two days after surgery. In recent years, mHealth apps have been used to evaluate the nurse-patient relationship for self-management in chronic diseases or to evaluate pain after surgery. To the best of our knowledge, no previous research has explored the recovery process after day surgery via mobile phone in a Swedish cohort.

Objective: The objective of the study is to describe the process of developing a mobile phone app using a Swedish Web-based Quality of Recovery (SwQoR) questionnaire to evaluate postoperative recovery after day surgery.

Methods: The development process included five steps: (1) setting up an interdisciplinary task force, (2) evaluating the potential needs of app users, (3) developing the Swedish Web version of a QoR questionnaire, (4) constructing a mobile phone app, and (5) evaluating the interface and design by staff working in a day-surgery department and patients undergoing day surgery. A task force including specialists in information and communication technology, eHealth, and nursing care worked closely together to develop a Web-based app. Modifications to the QoR questionnaire were inspired by instruments used in the field of recovery for both children and adults. The Web-based app, Recovery Assessment by Phone Points (RAPP) consists of two parts: (1) a mobile app installed on the patient's private mobile phone, and (2) an administrator interface for the researchers.

Results: The final version of the SwQoR questionnaire, which includes 31 items, was successfully installed in RAPP. The interface and the design were evaluated by asking for user opinions about the design and usefulness of the app with 10 day surgery patients. Some minor adjustments were made concerning text size and screen color.

Conclusions: Taking advantage of joint expertise, a useable Web-based app adaptable to different technical platforms was constructed. In addition, the SwQoR was successfully transferred into digital format for use on mobile phones.

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KEYWORDS

cellular phone; postoperative recovery; day care

Introduction

Day Surgery

In Sweden, almost 2 million day surgeries are performed in adults each year [1,2]. The literature has different definitions of day surgery, varying from the patient going through surgery and staying in a patient hotel overnight, to same-day admission and discharge [3,4]. There are few patient-related contraindications to day surgery, but social and medical factors are both assessed in order to select suitable patients [3]. The advantages for patients undergoing day surgery include a lower risk of hospital infections, earlier mobilization, and the convenience of recovering at home. For health care providers, day surgery is cost-effective and spares beds for other surgical cases [3]. From the perspective of safe and effective day surgery, anesthesia must minimize the postoperative discomfort of patients. Working with the goal of rapid recovery, the induction agents must have rapid and smooth onset [3], the airway needs to be carefully managed [5], and the risk for postoperative nausea and vomiting (PONV) and postoperative pain needs to be addressed before and after surgery [3,6]. A study reported that 82% of patients are discharged <270 minutes after surgery. Delayed discharge was mainly due to adverse events, such as PONV and pain [6]. According to a large survey involving more than 12,000 patients, the most common complaints after surgery with general anesthesia are PONV, sore throat, and hoarseness [7]. Other reported adverse events are dental damage, headache, urine retention, and confusion [8]. Women also seem to be more likely to experience adverse events than men [8]. Though objective symptoms have traditionally been monitored as an integrated part of care and treatment [1], patients' subjective descriptions (patient-reported outcomes measures) have come to be considered a fundamental element of measure and follow-up [9,10]. During the first two weeks of recovery, many patients experience symptoms requiring unplanned health care contacts, phone calls, or outpatient clinic visits [4] and, in North America alone, these unexpected visits and readmissions to hospitals cost billions of dollars annually [11].

Follow-Up Assessment Studies

Studies show that patient satisfaction is directly related to their experience with adverse events related to anesthesia and surgery [7,12]. However, according to a previous survey conducted in Sweden, not all units performing day surgery have implemented routines for follow-up assessment [4]. Also, several studies have reported that the most common method of follow-up is a phone call from a nurse 1-2 days after surgery [1,4]. This procedure can be seen as time consuming for personnel and not cost effective. A face-to-face meeting with a nurse anesthetist or an anesthesiologist would be desirable for follow-up, but as this is difficult to achieve, an alternative is to use technological solutions [11]. As a subcategory of eHealth, the new concept of mHealth refers to using mobile phones in health care [13]. Patient use of the Internet via mobile phones, such as self-management by means of text messaging persons with diabetes or asthma [14,15], providing prevention information

for breast cancer [16], and soliciting experiences with pain after surgery [17], has been reported in different chronic diseases to improve the nurse-patient relationship. However, limited knowledge is available about how information and communication technology is perceived in the peri-operative context [11]. To the best of our knowledge, a Swedish cohort of day-surgery patients has not yet been explored. The present study describes the process of developing a mobile phone app using a Swedish Web-based Quality of Recovery (SwQoR) questionnaire for evaluating postoperative recovery after day surgery.

Methods

Development Process

The development process included the following steps: (1) setting up an interdisciplinary team, (2) evaluating the potential needs of app users, (3) developing the Swedish Web version of a QoR questionnaire, (4) constructing a mobile app, and (5) evaluation of the interface and design of the app by staff working at a day-surgery department and patients undergoing day surgery.

The Interdisciplinary Research Team

Interdisciplinary research involves the translation of scientific knowledge between members of the research team [18]. In this specific project, it was important to include researchers with broad expertise and perspectives that would enrich the research team. This includes the project leader who is a professor and head of the "Perioperative nursing" research environment, with broad experience in intra and postoperative care, both as a nurse anesthetist and as a researcher; an associate professor in pediatric nursing, with research focus on measuring health conditions in children and adolescents; a professor in informatics, who is experienced in implementing information systems in organizations and evaluating their effects on processes and users, with a special focus on public sector organizations in Sweden and internationally; and a professor in information systems development, and informatics, with specialization in information security and privacy. The team also includes an associate professor and anesthetist, with a broad experience in anesthesia and postoperative care, both as a clinician and a researcher, and who has knowledge on postoperative cognitive dysfunction; a professor and psychologist, with broad experience and knowledge in cognitive impairment and cognitive aspects; and a senior lecturer with a PhD in nursing and knowledge in nursing informatics. Finally, the team includes a health economist (PhD), a postdoctoral researcher (in nursing) who is also a nurse anesthetist, and a doctoral student (in nursing), with experience in day surgery and postoperative care.

Prior to the first meeting, all members in the group read the same articles describing mHealth [19]. To facilitate cooperation in the team, the researchers started by discussing a joint framework with clear goals. The next step was to define the focus of the app (Table 1).

Table 1. Focus of the app from the perspectives of the health care organization and the patient.

Health care organization	Patient
To get reports back from the patients	Provide personalized feedback to the health care about the recovery process
To support the management of the individual patient in follow-up contacts by a health professional	A feeling of being cared for A sense of empowerment
To reduce serious recovery problems associated with suffering and costs	
To learn more about postoperative reactions and recovery and to improve surgical and anesthetic procedures in the long-term	
Being easy to understand for nurses and medical doctors in the health care system	Being easy to understand for patients in the health care system
Reduce unplanned or unnecessary health care contacts	Reduce unplanned or unnecessary health care contacts

Evaluating the Potential Needs of App Users

In order to determine the potential needs of users of the app, the researchers reviewed the literature and brainstormed during a workshop. The members shared their own personal experiences in postoperative recovery as both patients and researchers in the field of anesthesia and postoperative care. In order to make the app user friendly, the research team established that it would be important to use the patients' own mobile phone [17], rather than a specified mobile phone for the research project [11]. A review of the literature showed that mobile phone technology needs to be user friendly, easy to navigate, and not show a large amount of text on the screen [20]. Also, the use of a push function can encourage individuals to leave a response at a given time [17]. Finally, it was hypothesized that users being able to compare their recovery to a sample of other patients would give them a sense of empowerment.

Swedish Web Version of a Quality of Recovery Questionnaire

Myles et al [12] developed the instrument QoR-40, which has been adapted to a Swedish day surgery context for adults as the QoR-24 [21]. A meta-analysis including 18 studies (3459

patients) concluded that the QoR-40 has excellent validity, reliability, responsiveness, and clinical utility for a broad range of patient populations [2]. The Swedish version of QoR-24 [21], together with inspiration from the newly developed questionnaire Postoperative Recovery in Children (PRiC; personal communication with Ulrica Nilsson, April 27, 2015), the Postoperative Recovery Profile [22], the Post-discharge Surgical Recovery scale [23], and Nilsson and Idvall's study [24], contributed to the final version of the SwQoR, which includes 31 items (Table 2). The items applied from QoR-40 [11] and QoR-24 [21] were originally scored on a 5-point scale (for positive items, 1=none of the time to 5=all of the time; for negative items the scoring was reversed). In line with Stark et al [25], the scaling properties and options of obtaining verbal numerical responses would be easy to understand for the patients. We changed the format of the pain rating scale used in clinics to a horizontal visual analog scale from 0 ("none of the time") to 10 ("all of the time"). At the end of the questionnaire, the patients are asked if they want to be contacted by a nurse (response alternative YES or NO). If the answer is YES, a nurse at the day-surgery department contacts the patient and offers further information and assistance.

Table 2. The revision and rationale for items in the SwQoR.

QoR-24	Revision/rationale	SwQoR
Able to breathe easy	-	Able to breathe easy
Sleeping well	-	Sleeping well
Being able to enjoy food	-	Being able to enjoy food
Feeling rested	-	Feeling rested
Having a general feeling of well-being	-	Having a general feeling of well-being
Feeling in control	-	Feeling in control
Pain in the surgical wound	-	Pain in the surgical wound
Feeling relaxed	-	Feeling relaxed
Speaking normally	-	Speaking normally
Able to brush teeth	Merged into one item and linguistic revision	Able to look after personal hygiene
Able to look after own appetite		
Able to write	Linguistic revision	Able to write as usual
Able to return to work	Linguistic revision	Able to return to work or usual duties about the home
Nausea	Merged into one item	Nausea and vomiting
Vomiting		Nausea or vomiting
Feeling restless	-	Feeling restless
Shivering or twitching	-	Shivering or twitching
Feeling too cold	-	Feeling too cold
Dizziness	-	Dizziness
Nightmares	-	Nightmares
Anxiety	-	Anxiety
Depressed	-	Depressed
Feeling lonely	-	Feeling lonely
Difficulties getting to sleep	-	Difficulties getting to sleep
	[24]	Headache
	[24]	Muscle pain
	[24]	Back pain
	[24]	Sore throat
	[22]	Difficulties concentrating
	[22] ^a	Trouble urinating
	[22,23] ^a and divided into two items	Feeling constipated
Difficulties defecating		Diarrhea

^aFrom PRiC, personal communication with Ulrica Nilsson, 20150427

Constructing a Mobile App

Our goals were that the app should be easy to use, be safe and secure, and allow aggregation of data to a study database. A wishing list of app functions, interface, and design were established and presented to the commissioned software company, which developed the Web-based app Recovery Assessed by Phone Points (RAPP) in close collaboration with the interdisciplinary team.

The technical solution consisted of two parts, a mobile app for patients and a Web-based administrator interface for the

researchers. A patient interacts with the mobile app to report his or her postoperative recovery. In the development and testing phases, the app was designed in HTML5 (the most recent version of the markup language used for structuring and presenting content for the World Wide Web) and JavaScript to largely mimic a native mobile app. The Web-based technical solution was a mobile app platform that made it easier to implement the solution regardless of the end user's technical equipment. Thus, it is possible to use RAPP regardless of the type of mobile phone being used.

In the development phase, none of the data imputed by patients were collected. Study-specific log-in codes were set up and used in connection with the installation of RAPP on the participants' mobile phone.

Evaluating Interface and Design

A difference between answering a questionnaire on the small screen on a mobile phone and answering on a paper is that one item at a time is shown on the screen versus multiple items on a paper page [26]. The app's interface and design were evaluated asking for user opinions about the design and usefulness of the app. There were ten day-surgery patients that were recruited from two day-surgery departments in Sweden. Patients who were included brought their own mobile phone to the day-surgery department at one of two specific days when the testing took place. No one who was asked about participating in the testing declined. The app was installed on the patient's own mobile phone by the researcher. Instructions about the SwQoR and how to navigate the app were given. The questions asked to the patients were: (1) "What is your opinion about the layout?", (2) "Can you describe any obstacles when using the app?", (3) "What is your overall opinion about the app?", and (4) "Do you think that this would be a useful method to use after ambulatory surgery?"

A member of the research team wrote down all responses as field notes. Staff working at one of the day-surgery departments also had the opportunity to provide feedback on the device's interface. The included staff members were nurses (n=10), surgeons (n=5), and anesthesiologists (n=2), all with experience from working in a day-care setting. This testing was carried out in connection with a lecture about postoperative recovery, in which also the app (RAPP) was demonstrated. The staff was invited to give their opinion about the layout of the interface. There was one researcher that took field notes.

Ethical Considerations

As the study did not collect or handle any sensitive personal data, ethical approval was not required according to the Swedish Act concerning the Ethical Review of Research Involving Humans (SFS 2003: 460) [27]. Nevertheless, the study followed standard research ethical principles, and the project did not collect or handle any sensitive personal data. The participants were given written or verbal information (depending on the clinical guidelines when contacting the patient before surgery) about the study, including the purpose and procedures and that participation was voluntary by the staff working at the day-care department. The participants were also asked to bring their mobile phones to the day-surgery department at the day of surgery. When arriving to the day-surgery department, members

of the research team gave oral information about the testing. The patients were guaranteed that no personal data would be collected. After asking for user opinions about the design and usefulness of the app, the Web-based app was uninstalled from the patient's mobile phone. No data from the SwQoR were collected for further analysis.

Results

There were four patients that reported that the background color was an issue and three patients had comments about the text size. Regarding obstacles to use, five patients thought the scale to be confusing. There were two that found it impractical that they could not move back and forth between questions. When discussing the overall opinion of the app, three patients suggested that it would be easier if the dot on the visual analog scale (Figure 1 shows this) could be moved also by touching the line to choose score, instead of drawing the dot with the index finger. Overall, all ten patients expressed a positive attitude toward the method of evaluating postoperative recovery using an app.

The staff working in the day-care settings gave similar feedback. They commented about the text size, the background color, and several of the staff found the scale confusing. Overall, all staff were positive to RAPP. They found the questions in the SwQoR relevant, and they also confirmed the need for systematic follow-up in the recovery process.

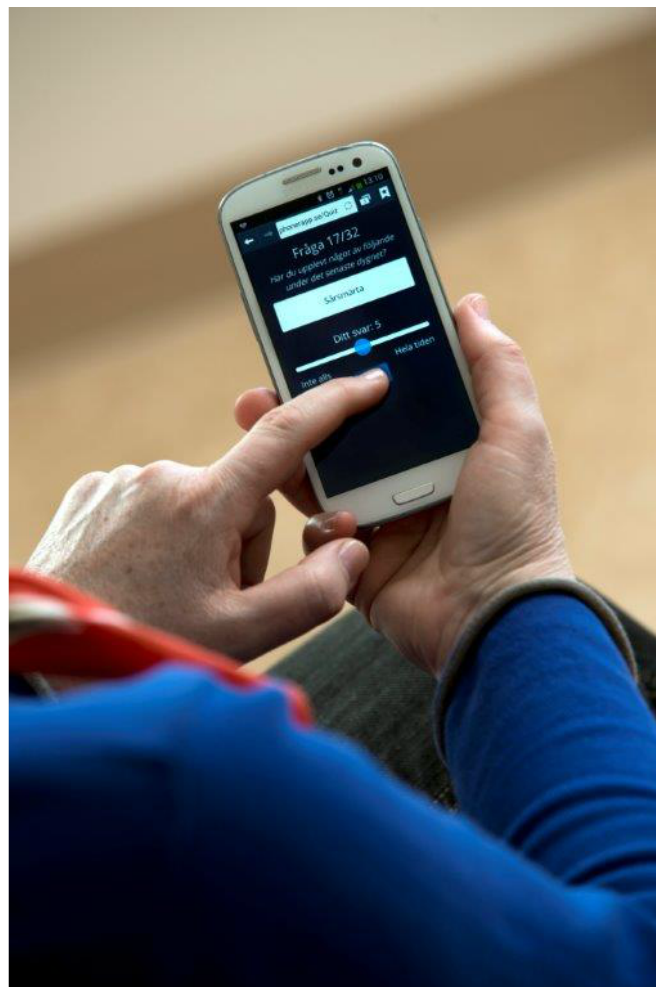
Patient and staff feedback led to several changes in the app. The text background was changed to a darker color (Figure 1). The size of the text was also increased and the scale was clarified. At first, the visual analog scale was rated 0 "all of the time" and 10 "none of the time" for positive items and the opposite for negative items, which confused both patients and staff. Therefore, the scale was changed to 0 "none of the time" and 10 "all of the time" for all items whether the item was negative or positive. Regarding the dot along the visual analog scale, the opportunity to choose score by touching the line was added (Figure 2 shows this). The dot on the visual analog scale line was also programmed to go back to neutral, 5, each time a new question was shown on the screen to make it clearer that a new question was to be answered.

During the testing, it became clear that not all of the text was visible on the screen of some older mobile phone models with small screens. Thus, the app was reprogrammed so that it would also fit smaller screens. Overall, the app was considered easy to use, to understand, and to navigate by both patients and personnel.

Figure 1. An example of the Recovery Assessed by Phone Points (RAPP) after the patients' feedback, the background has a darker background and the text has been increased. (During the last 24 hours I have: Slept well, None of the time-All the time).

The screenshot shows a mobile app interface with a dark blue background. At the top, it says "Fråga #2/30" in white. Below that, in smaller white text, it says "Under det senaste dygnet har jag:". A white rectangular button with rounded corners contains the text "Sovit gott" in dark grey. Below the button, it says "Ditt svar: 7" in white. Underneath is a horizontal white line with a blue circular slider dot positioned at the 7th mark. Below the line, the text "Instämmer helt" is on the left and "Instämmer inte alls" is on the right, both in white. At the bottom center, there is a blue button with white text that says "Svara".

Figure 2. The patient can move the dot simply by touching the line. (During the last 24 hours Have you had any of the following: pain, None of the time-All the time) © Ulla-Carin Ekblom.



Discussion

Principal Findings

This project is unique in its intention to develop a mobile phone app that will be used with the patients' own mobile phones in the peri-operative context. To our knowledge, there are no published papers with focus on the development process of an app for evaluating postoperative recovery. However, in other areas, there are some newly published articles [28,29]. Therefore, this paper demonstrates the process of establishing an interdisciplinary research team, which together developed a useable app in regard to interface, design, and utility, for which testing was done with both patients and personnel. To the best of our knowledge, no systematic assessments of patients' postoperative recovery, paper-based, Web-based, or mobile phone-based, are yet available. The majority of previously published national and international studies have developed mobile apps for use on devices provided by the research projects. For example, to study the use of a mobile app to monitor postoperative recovery, Semple et al [11] gave the patients either a mobile phone or a tablet with the app installed on the device prior to discharge. This uniqueness of the present study is a strength with regard to implementation, as it would be difficult to convince the health care system to adopt the costs for providing all patients with devices for self-reporting.

A new patient safety law (The Swedish Code of Statutes, SFS 2014:821) was implemented in January 2015. This law gives patients even more power to affect their care. Notably, patient participation is a core element in patient-centered care [30], and it is crucial to involve patients and evaluate the care provided, in this case anesthesia and postoperative care. A benefit of using the RAPP could be increased patient satisfaction, as well as improving peri- and postoperative care in specific groups.

The provision of health care can be evaluated using different methods, each with advantages and disadvantages. A paper questionnaire is easy to use, has low implementation cost, and needs little support to the patients, but disadvantages include costly delivery of the questionnaire and potential negative attitude of respondents toward answering a lot of questions [26]. The advantages of technical tools, such as mobile phones and tablets, include a reduction in missing data by requiring completion of the item and only allowing one item at a time on the screen so as to improve the response rate. Furthermore, a mobile phone is easy to carry around and frequently used by most people in everyday life [31]. The downside of a technical solution is that some individuals do not have private mobile phones, though this group is decreasing more and more. Moreover, the attitude and ability of the individual, for example, lack of interest or limited knowledge of mobile phone use, could be an obstacle [16].

A number of studies have compared electronic evaluation of patient-reported outcomes (ePRO) and paper and pencil administration and shown an advantage for ePRO [32,33]. However, there seems to be a lack of knowledge concerning the use of a mobile phone app instead of pen and paper to collect patient-reported outcomes in a peri-operative context. For further development of RAPP and of the SwQoR, there is an ongoing

study with the aim of exploring the difference between the two methods' ability to assess patient-reported outcomes as suggested by Coons et al [32]. This study will show if there is equivalence between the two questionnaire delivery modes (paper vs app). In the mentioned pilot study, patients undergoing day-care surgery evaluated the acceptability and feasibility of the app. In the near future, a multicenter randomized controlled study (n=1000) with a primary outcome of cost effectiveness and secondary outcomes of postoperative recovery, QoL, overall health, and health literacy will be performed by our research team. Future studies include also qualitative research evaluating the patients' experience of the intervention and the staffs' experience of the implementation.

According to literature, mobile features used in other studies are, for example, text messages, pedometers for physical activity, or video, voice, or multimedia messages [14]. The RAPP is designed to solve some problems, not all. The problems we set out to solve are well defined, and hence, so can the solution be. Some functionality, such as personalized feedback, is extremely difficult to design (as there are many possible situations and multiple factors involved) and do more harm than good if not accurate enough. Therefore, this project aims at making improvements to some problems to which there are credible and robust solutions. Solving them is a big step forward. In the future, further functionality may be added. Patient requirements for other functionalities as well as opportunities to actually implement such will be further analyzed in our upcoming studies. Our research team is planning on developing RAPP in an ongoing process, and, thereby including the patients by continuing to evaluate the patients' need for support in the postoperative process.

Our projects overall aims are to integrate society's need for quality auditing and assurance in health care with the patients' need for safe and reliable information and communication regarding their postoperative recovery. We believe that the project will increase patients' self-care. Using systematic follow-up remote symptom monitoring during postoperative recovery enables evaluations and comparisons of the usefulness and cost-effectiveness of different technical approaches to care, drug treatment, care activities, and competence development. It is also hoped that the use of systematic follow-up will help guide improvements in areas of anesthesia and postoperative care among patients who currently have low-quality postoperative recovery.

Limitations

Having members from different disciplines work together is a way of avoiding fragmented research [18]; this is one of the strengths of this research team. The development and implementation of a Web-based app can overcome some barriers, which were discussed by the members of the team. A barrier includes the type of device, as some people may prefer their tablet or computer to a mobile phone. Another barrier may be the small screen size, which could be difficult to read or handle. A slow Internet connection or slow app loading time could be a problem for users at home, the app will need to be usable on both mobile phones and tablets, and both the app and

the data it transfers should be small in size to minimize network load and memory usage.

The respondents are also asked to give responses about their recovery after anesthesia and surgery. The patients may be affected by the residuals of anesthesia and miss responding within a specific time frame [17]. In order to improve the response rate in the pilot study, a reminder in the form of a text message will be sent to the respondent each day.

Another factor that could affect the use of health care information technology is staff attitudes toward technology and perhaps the fear of dehumanizing care [34]. To counteract this risk, the members of the research team included both a nurse

anesthetist, a nurse with experience in the post anesthesia care unit, and an anesthesiologist. All team members were involved in the app development process together with the software company. This approach may improve attitudes toward and the usability for nurses and physicians in the peri-operative context [34].

Conclusions

With joint expertise, a useable Web-based app, RAPP, adaptable to different technical platforms was developed and tested for understandability and user-friendliness. The SwQoR has also successfully been transferred into digital format for use on mobile phones.

Acknowledgments

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Authors' Contributions

KD, ME, and UN made substantial contributions to the conception and design. Acquisition of data, or analysis, and interpretation of data were made by KD and MJ. KD, ME, MJ, UN, and ÅG drafted the article or revised it critically for important intellectual content. Final approval of the version to be published was made by KD, ME, MJ, UN, and ÅG.

Conflicts of Interest

Author UN and Örebro University Enterprise AB hold shares in RAPP-AB.

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Abbreviations

ePRO: evaluation of patient-reported outcomes

PONV: postoperative nausea and vomiting

PRiC: Postoperative Recovery in Children

RAPP: Recovery Assessed by Phone Points

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Original Paper

Effectiveness of Using Mobile Phone Image Capture for Collecting Secondary Data: A Case Study on Immunization History Data Among Children in Remote Areas of Thailand

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Abstract

Background: Entering data onto paper-based forms, then digitizing them, is a traditional data-management method that might result in poor data quality, especially when the secondary data are incomplete, illegible, or missing. Transcription errors from source documents to case report forms (CRFs) are common, and subsequently the errors pass from the CRFs to the electronic database.

Objective: This study aimed to demonstrate the usefulness and to evaluate the effectiveness of mobile phone camera applications in capturing health-related data, aiming for data quality and completeness as compared to current routine practices exercised by government officials.

Methods: In this study, the concept of “data entry via phone image capture” (DEPIC) was introduced and developed to capture data directly from source documents. This case study was based on immunization history data recorded in a mother and child health (MCH) logbook. The MCH logbooks (kept by parents) were updated whenever parents brought their children to health care facilities for immunization. Traditionally, health providers are supposed to key in duplicate information of the immunization history of each child; both on the MCH logbook, which is returned to the parents, and on the individual immunization history card, which is kept at the health care unit to be subsequently entered into the electronic health care information system (HCIS). In this study, DEPIC utilized the photographic functionality of mobile phones to capture images of all immunization-history records on logbook pages and to transcribe these records directly into the database using a data-entry screen corresponding to logbook data records. DEPIC data were then compared with HCIS data-points for quality, completeness, and consistency.

Results: As a proof-of-concept, DEPIC captured immunization history records of 363 ethnic children living in remote areas from their MCH logbooks. Comparison of the 2 databases, DEPIC versus HCIS, revealed differences in the percentage of completeness and consistency of immunization history records. Comparing the records of each logbook in the DEPIC and HCIS databases, 17.3% (63/363) of children had complete immunization history records in the DEPIC database, but no complete records were reported in the HCIS database. Regarding the individual's actual vaccination dates, comparison of records taken from MCH logbook and those in the HCIS found that 24.2% (88/363) of the children's records were absolutely inconsistent. In addition, statistics derived from the DEPIC records showed a higher immunization coverage and much more compliance to immunization schedule by age group when compared to records derived from the HCIS database.

Conclusions: DEPIC, or the concept of collecting data via image capture directly from their primary sources, has proven to be a useful data collection method in terms of completeness and consistency. In this study, DEPIC was implemented in data collection of a single survey. The DEPIC concept, however, can be easily applied in other types of survey research, for example, collecting data on changes or trends based on image evidence over time. With its image evidence and audit trail features, DEPIC has the potential for being used even in clinical studies since it could generate improved data integrity and more reliable statistics for use in both health care and research settings.

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KEYWORDS

health care information system; DEPIC; mobile technology; maternal and child health; mHealth; vaccine record; electronic data capture

Introduction

Paper-based case report forms (CRFs) have long been used as the standard method to collect data in research studies and health care services [1]. Both primary and secondary data are collected in many public health surveys using paper-based CRFs. Once data are collected, they should be accurately entered, coded into an electronic form, and subsequently converted into many forms for further analysis [2]. However, this approach presents many problems due to frequent errors and high storage costs when performing data collection and double data entry [3]. Moreover, there are many problems that can arise after data collection—especially when collecting secondary data—including lost forms, incompletely filled forms, and poor handwriting of data collectors. There are multiple potential sources of error that can occur when performing manual data collection, particularly if data collection involves multiple data collectors across multiple health care units, or even if data collection is done within 1 unit [4-5]. Mobile phones offer an attractive possibility to address these problems in terms of their accessibility, effectiveness, and quality of data that includes data completeness and validation.

It is suggested in literature that several mobile phones features have created opportunities for data collection, and that these features could also improve data quality [3,6-9]. Mobile phone cameras have been used as an alternative method for health care data collection in recent years, although mobile phone cameras are still mostly used in capturing clinically relevant images for rapid diagnosis [10]. For example, the use of mobile phones by medical doctors to view medical image data such as neurosurgery and dermatology for rapid and convenient diagnosis has been reported [9,11,12]. Other examples include the use of mobile phone imaging in microscopic diagnosis of soil-transmitted helminthic infections and diagnosis of sputum slides for TB. [10,13-15]. Although mobile phone cameras are useful in health care data collection, usage should be carefully planned due to a higher equipment cost, lack of ability to verify miscoded data against paper records once data is entered, and the varying quality of images taken with different mobile phones [10,16].

In Thailand, mobile phones have been used as data collection tools in the health care system. A project supported by Google Thailand developed and employed mobile applications for health data collection in the Northern provinces. The data collected via mobile phones were compared to paper CRFs flowing

directly to the hospital electronic database and the health care providers, and policy makers could see all details of individual health data of the entire district [17]. Another study conducted in northern Thailand showed that the customized-language voice surveys for textual data, together with capturing image data on mobile phones, could be successfully used to collect data among ethnic populations who speak different languages [8]. Moreover, 1 project in Thailand supported by Microsoft Research showed the effectiveness of using mobile technology in routine health care services that focused on reminding an individual of scheduled visits for antenatal care and Expanded Programme on Immunization (EPI) services [18]. Similarly, another project in Thailand focused on malaria case management by implementing a module on mobile phones to monitor and follow malaria cases, including patient treatment [19]. Various studies revealed that mobile technology is the fastest growing sector in the communications industry, especially in low-income countries [20]. Thus far in the context of poor resource settings for large-scale public health surveys, the availability and affordability of mobile phones and wireless networks create a possible alternative mechanism for data collection that might replace traditional paper-based methods.

The routine work on immunization services at a primary health care unit consists of 4 steps as presented in [Figure 1](#). As an enforced routine practice of the Thailand Ministry of Public Health, a MCH logbook is given and owned by 1 mother/caretaker and every health care unit that provides the service asks for the MCH logbook and records the child's immunization history into the logbook every time the mother/caretaker brings a child for immunization. As shown in [Figure 1](#) as step 1, on a vaccination day, the mother/caretaker presents the logbook to the health care provider at the primary health care unit. In step 2, the health care provider gives the immunization(s) as per schedule then separately records the vaccine(s) administered, actual date of immunization, and the date for the next appointment on 2 documents, the MCH logbook and the individual immunization history card. In step 3, the MCH logbook is returned to the mother/caretaker while the individual immunization history card is kept at the primary health care unit. In step 4, the record on the immunization history card is entered into the national health care information system (HCIS) by health care providers, which is when data problems usually occur. There is a time gap between when data are entered on the immunization history card to when data are entered into the HCIS; data entry cannot be done in real time due to the workload of health care providers on the vaccination

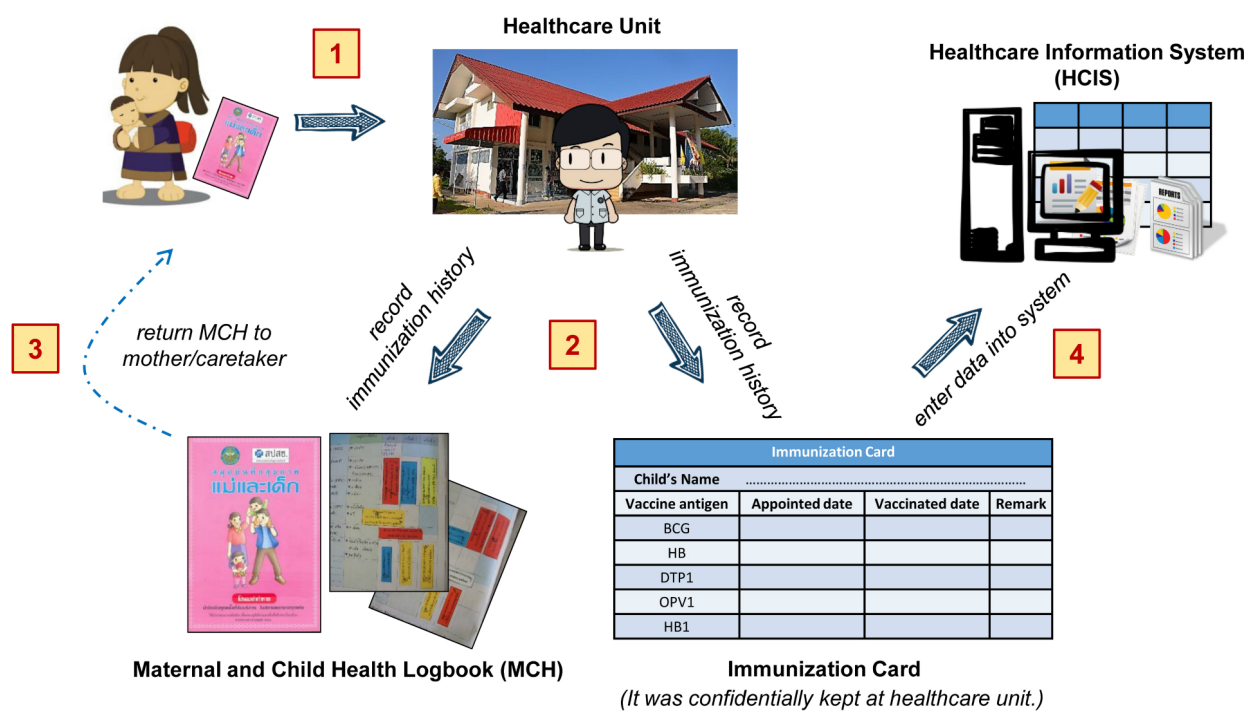
day. And since it has been generally recognized that data in the HCIS are incomplete or missing, any reports/statistics about immunization generated from the HCIS database will be unreliable.

It would be a great challenge to change the 4-step routine practice by having health care providers enter the data into the HCIS at the same time they provide the services and discard the use of MCH logbooks and individual immunization history cards. In Thailand, the problems of the health sector at district level are limited human resources and inadequate infrastructure. It is difficult to carry out data entry while providing services to a large number of patients. The MCH logbooks usually have an almost-complete immunization history of each child, and the mother/caretaker who owns it often use it as an immunization schedule reminder. The mother/caretaker is required to bring the MCH logbook to every scheduled

immunization, and health care providers usually rely on the information in the logbook more than that in the HCIS. Collecting secondary data for further analysis using source documents or logbooks can be another challenge due to difficulties in reading, extracting, and transcribing such information, especially if the data are collected by those who are not familiar with all information content and context.

This study aimed to demonstrate the use and evaluate the effectiveness of the camera function on mobile phones combined with online connectivity as a tool for health data collection. The effectiveness of data image capture feature was assessed through data quality in terms of completeness and consistency of the records by comparing the captured images with the data on the national HCIS database. In addition, the impact of data quality was confirmed through comparisons of some statistics generated from the 2 data sources.

Figure 1. Routine immunization service at health care unit.



Methods

Study Sites and Study Participants

This cross-sectional study was conducted in 8 villages in the Wawee Subdistrict of the Mae Suai District, which is in the Chiang Rai Province of northern Thailand, during May through August 2013. The majority of people in these areas are from ethnic groups, including Karen, Lahu, Lisu, Hmong, Mien, Yunnan Chinese, and Akha; some of which have no writing system. Village health volunteers (VHVs) in these villages were recruited as data collectors. They were trained to collect data

from MCH logbooks using a mobile phone camera application equipped and were assigned to make home visits. Images of immunization history records were then captured from the MCH logbook of each hill tribe child. Data to be used for an analysis are those recorded on MCH logbooks from the child's first immunization until the end of April 2013. Since there were 790 children under 6 years of age in these 8 villages, the 363 mothers possessing the children's immunization logbooks were randomly selected using simple random sampling technique. Figure 2 shows some of the study sites where these minority groups are located in the highlands.

Figure 2. Study sites were located on the highlands of northern Thailand.



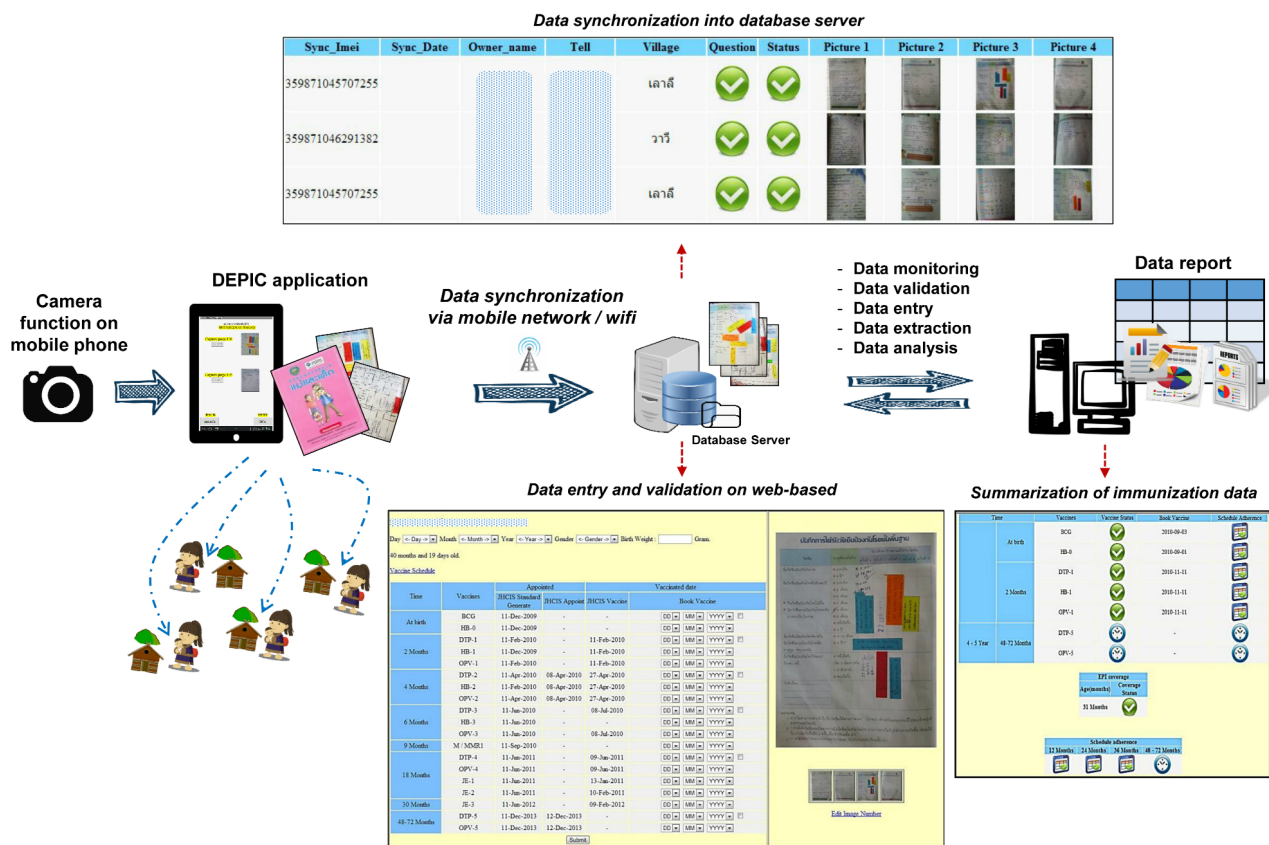
Implementation of DEPIC

DEPIC stands for “data entry via phone image capture.” DEPIC was developed as part of the smartphone survey project initiated by the Center of Excellence for Biomedical and Public Health Informatics (BIOPHICS) at the Faculty of Tropical Medicine, Mahidol University, Thailand. The smartphone survey application ran on Android SDK, and was built using Eclipse open-source software. DEPIC was an enhancement of the survey tool performing 1 of the 3 main features of the smartphone survey application. The details of the other 2 features of the smartphone survey, including drop-down menu choice and voiced-questioning in selectable ethnic languages, are discussed elsewhere [8]. This smartphone survey tool application was successfully developed and tested in the previous study in northern Thailand among different ethnic minority groups. The previous study was conducted to assess data quality in terms of data completeness and time consumed in collecting the information in comparison with traditional data collection methods (eg, paper-based questionnaire). Besides data quality, the participants’ satisfaction with the smartphone customized-language voice-based questionnaire in terms of perceived ease of use and perceived usefulness was assessed [8]. The particular purpose of the DEPIC application was to reduce the workload and form-filling mistakes by data collectors in the field. The data image capture functionality on mobile phone was employed to make it faster and easier to collect secondary data, with no need to extract data from the source document, enter the data onto CRFs, and reenter the data again

into the electronic database. DEPIC can be used either online and automatically synchronized with a central database or offline and synchronized with a central database when telephone signals or wireless networks are available.

In this study, DEPIC was used to collect immunization history records (eg, prescheduled date and actual vaccination date) from mother and child health (MCH) logbooks. A conceptual framework of the DEPIC feature is shown in Figure 3. The image-taking was designed to decrease the workloads of VHVs while interviewing hill tribe mothers/caretakers so that the health workers did not need to manually extract data from the logbook and transcribe the data onto paper CRFs. While working in the field, VHVs who performed routine monthly home visits simply asked for the MCH logbook from the mothers, captured the data image of the immunization history pages via the DEPIC application, and saved the image automatically in the mobile phone. Each picture was then synchronized to the central database, where an electronic Web-based form was created according to the transmitted picture. If the picture was not clear, the VHVs repeated the picture-capturing process until a suitable image was captured. DEPIC mapped picture images with a data entry screen for each child’s logbook. Data were then manually entered by the data management team and submitted to the study investigator. At this phase of DEPIC development, there are no features of automatic character (ie, text) recognition and no double data entry from the image; these are in the planning phase. The purpose of this study is to capture presumably complete data from logbooks to compare against the data in the health care unit’s HCIS database.

Figure 3. DEPIC conceptual framework.



Data Linkage for Comparison

To demonstrate the use of mobile technologies in data capturing, the immunization history data from 2 databases were compared. Data collected via DEPIC were compared with data points in the standard HCIS database. Data in the DEPIC database represent complete immunization history data that were actually recorded in a MCH logbook during the immunization process by the health care providers on the scheduled immunization dates. The data extracted from HCIS database represent data entered ad hoc by health care providers from duplicate information of the logbook data on individual immunization history cards after the immunization process. Data between the 2 databases, DEPIC and HCIS, were linked by each child’s hospital number to extract both the appointment date and the actual vaccination date of each child. The matching of the data was done using Excel and then transported to a statistical package for further analysis. The data fields in the MCH logbooks are always more complete than those in the HCIS; there were no data fields that were found in the HCIS but not in the logbooks.

Data Definitions and Analysis

For the purposes of this study, completeness was defined as all records being entered into the database, with no missing or incomplete data. Consistency was defined as the absence of typographical and transcription errors which may lead to differences in the immunization history data between the 2 databases. The comparisons of completeness and consistency of the data in the 2 databases were performed on immunization

history records in 2 aspects: percentage of completeness of the number of immunization history records and consistency of the actual vaccination date(s) reported in each record. The completeness of the number of records for each MCH logbook was determined by the number of immunization records that were not entered into the HCIS but were captured and presented in DEPIC. The consistency of the individual actual vaccination date was determined by the number of records in each MCH logbook that such dates were matched between the 2 databases, DEPIC and HCIS.

In order to assess the impact of completeness and consistency of the data in the 2 databases, derived statistics on immunization coverage and compliance to immunization schedule status were calculated and compared. Immunization coverage status was displayed in individual summary statistic, as well as the immunization schedule compliance status of the district. The status of immunization coverage was categorized into 2 groups: “complete immunization” and “incomplete immunization.” The complete immunization status was applied if a child had fully received the correct number of doses of all vaccines following the immunization schedule by child’s age, while the incomplete immunization status was applied if a child had missed at least 1 dose of all vaccines. Regarding the compliance to the immunization schedule, the term “compliance” in this study referred to when the child completely received the correct number of doses of each vaccine according to time (ie, the child’s age) and sequence of vaccines, as stated in the Thailand immunization schedule guideline [21,22]. The compliance to immunization schedule status was classified into 3 levels: “on

time,” “out of schedule,” and “pending schedule.” The on time status applied when the child had fully received a number of doses of all vaccines according to the time sequence in the guideline. The out of schedule status applied when a child had fully received a number of doses of all vaccines, but at least 1 vaccine did not follow the time sequence according to the guideline. The pending schedule status meant that the child was not required to be immunized with the particular vaccines at the analysis time.

Ethical Considerations

This study was a part of the project “Assessment of Immunization Status of Hill Tribe Children Using Multilingual Audio Visual Mobile Technology.” The project was reviewed and approved by the Ethics Committee of the Faculty of Tropical Medicine, Mahidol University. This study involved vulnerable research participants belonging to ethnic groups in the Chiang Rai Province of Thailand. All participants were informed about all details regarding the study and asked to sign an informed consent form before participating. The document was translated by VHVs into the participants’ dialect or language.

There was no identification of first or family name of the respondents on the CRFs. The individual information was kept completely confidential during data collection and analysis. The respondents were able to stop participating at any time and did not need to give a reason for the withdrawal of their consent.

Data Security and Storage

All captured pictures of immunization history records were kept confidentially on mobile phones designated to each VHV, who was responsible for his/her own catchment villages. In this study, all of these pictures were synchronized and transferred for analysis at the central database at BIOPHICS with a secured system to ensure limited accessibility and scheduled backups. Data entry and analysis was done by the investigators on a designated computer that was locked using a secured password.

Results

Use of DEPIC for Data Capture in the Field

The DEPIC tool was developed for use in the field with minor effort, as camera functionality is normally available on most cell phones, mobile phones, and tablets. Android platforms also enable the development of customized camera applications. The application was found to be easy to use and required few hours of training for the VHVs, who comprised were ethnic people living in the remote areas and acted as the data collectors in the

project. The VHVs reported that they felt capable of using the application in collecting the secondary data of the MCH logbook. The VHVs agreed that they could take pictures and submit them to the data center with minimum effort. Of 726 page-pictures from 363 records, only 64 pages of data images (8.82%) had to be re-submitted. Based on the observations at the study sites, the health care personnel who worked with the HCIS database suggested that an application like DEPIC could increase data quality within the national database system, as well as the efficiency of survey data collection. With the current version of DEPIC, the submitted images were automatically transferred to the central data center whenever the telephone signal was available; however, they were not automatically read. The data entry people had to key in the data from the image into a pop-up data screen that matched the images received. The clear images facilitated the data entry process. The data entry people were satisfied with the task assigned to them. The information in the MCH logbook was comprised mostly of check-boxes and data fields with immunization information filled in using preprinted stickers prepared by the health care unit. In the case that the immunization was not performed at the participant’s primary health care unit, such information was handwritten.

Differences of Immunization History Records Between HCIS and DEPIC

During the study period, 363 hill-tribe mothers/caretakers from 8 villages were randomly selected for participation in the project; they were requested to submit the MCH logbooks to VHVs for capturing the immunization history records using DEPIC. DEPIC and HCIS records were matched for all 363 mothers’ and children’s identifications. Considering the images taken from MCH logbooks via DEPIC as complete, completeness and consistency of immunization history records were assessed by comparing the 2 databases, DEPIC and HCIS, as presented in [Table 1](#). In terms of completeness of immunization history records, 17.3% children (63/363) had totally different immunization history records when looking into DEPIC and HCIS; complete immunization history records were found in DEPIC, but none in HCIS. Regarding the consistency of actual vaccination dates, the information taken from MCH logbooks was compared to data in HCIS and it was found that 31.1% (113/363) of the records’ dates in HCIS matched dates in DEPIC 51%-70% of the time, 28.4% (103/363) of records matched 50% or less, and for 24.2% (88/363) no dates matched. It should be noted that no records matched 100%.

Table 1. Difference of immunization history records between DEPIC and HCIS.

Variables	Number (N=363)	Percentage (%)
Completeness of immunization history records (DEPIC vs HCIS)^a		
≤ 50% difference	238	65.6
51%-80% difference	49	13.5
81%-99% difference	13	3.6
100% difference	63	17.3
Consistency of actual vaccination dates (DEPIC vs HCIS)^b		
100% unmatched	88	24.2
≤ 50% matched	103	28.4
51%-70% matched	113	31.1
> 70% matched	59	16.3

^aThe percentage of completeness was determined as number of records that were not entered in HCIS but presented in DEPIC for each MCH logbook.

^bThe percentage of individual actual vaccination date consistency was determined as number of records that were matched between DEPIC and HCIS for each MCH logbook.

Differences of Immunization Coverage Status Between DEPIC and HCIS

One of the purposes of collecting the immunization records was to assess immunization coverage among the targeted populations. In this study, the focus was on immunization coverage within the first year of age. Individual records from both DEPIC and HCIS were calculated in 2 dimensions: immunization coverage status (both overall and by each vaccine antigen) and compliance to immunization schedule status. Differences of calculated immunization outcomes from the 2 databases are presented in [Table 2](#). The number of individuals who had complete immunization according to DEPIC records was higher than that derived from HCIS records (ie, 79.1% (287/363) vs 0.3% (1/363)). For immunization coverage status by each vaccine antigen, records stored in DEPIC revealed that

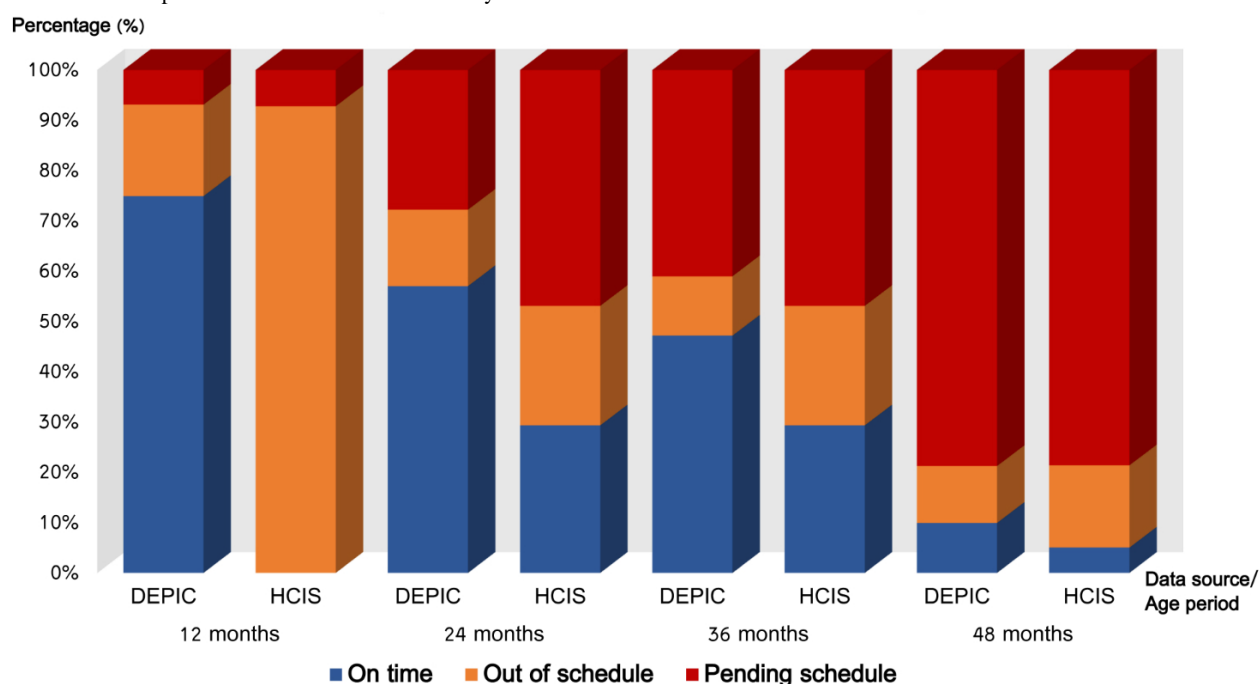
all children in the study received the BCG vaccine, and the immunization rates of the other vaccines were more than 90%. In contrast, the records in HCIS indicated that immunization rates of different vaccines varied from 1% to 74%. That is, status of complete immunization in each vaccine antigen was shown to be much higher with DEPIC than HCIS.

Status of compliance to immunization schedule by age group revealed different outcomes, as shown in [Figure 4](#). When the calculation was based on the records in DEPIC, more children were immunized according to the scheduled time sequence. According to the DEPIC records, 74.9% (272/363) of children received vaccines on time during their first year of age (ie, 12 months), while HCIS records showed the result of 0% (ie, no children received the vaccines on time). The same patterns were found for subsequent age groups.

Table 2. Data analysis of immunization outcomes between DEPIC and HCIS.

Immunization Coverage Status	DEPIC		HCIS	
	Number (N=363)	Percentage ^a (%)	Number (N=363)	Percentage ^a (%)
Overall status				
Complete immunization	287	79.1	1	0.3
Incomplete immunization	76	20.9	362	99.7
Status by vaccine antigen				
BCG	363	100.0	73	20.1
DTP1	362	99.7	201	55.4
HB1	362	99.7	212	58.4
OPV1	362	99.7	268	73.8
DTP2	359	98.9	254	70.0
HB2	359	98.9	253	69.7
OPV2	359	98.9	249	68.6
DTP3	354	97.5	231	63.6
HB3	354	97.5	5	1.4
OPV3	354	97.5	226	62.3
M/MMR1	338	93.1	23	6.3

^aThe percentage was calculated from number of children with an immunization schedule.

Figure 4. Status of compliance to immunization schedule by data source.

Discussion

Principal Results

Differences in the completeness of immunization history records and consistency of individual actual vaccination dates for each record in the MCH logbooks between 2 databases, DEPIC and HCIS, reflect the problematic situation of data entry of

immunization records into the national database system in Thailand. This study finds that should the data recorded in MCH logbooks be simultaneously entered directly into the electronic database—rather than being recorded on the individual immunization history cards before being entered into the electronic database—there will be more complete and accurate data in the national HCIS database. The simple explanation for incomplete and missing information in the HCIS database is

that data entry into HCIS is usually delayed due to case-management workloads on prescheduled immunization days. Moreover, the individual immunization history cards used as source documents for HCIS data entry are often incomplete. It doubles the work for health care providers to collect data during the vaccination day on both data sources: the MCH logbook, which is kept by the mother/caretaker, and the individual immunization history card, which is kept by the health care unit for ad hoc entry into HCIS. Health care providers also might be more likely to miss recording the data on the card but complete the MCH logbook since the logbook record is fully enforced by the Thailand Ministry of Public Health and is used by the mother/caretaker as a reminder for the next scheduled immunization. It is thus assured that the child's complete immunization history will be recorded and can be found in the MCH logbook.

The incompleteness of immunization information in the HCIS database as compared to data captured via DEPIC is also reflected in the statistics on vaccine coverage and compliance to the immunization schedule for children. Using statistics calculated from information in the HCIS alone, it appears that Thailand has lower immunization coverage and compliance according to the national guideline. But when compared with statistics calculated from the DEPIC records, it appears to be quite the opposite with study participants showing high immunization coverage and compliance rates. Therefore, comparing data quality on immunization history among children in remote areas as an example, we suggest that DEPIC could be used to collect data quite effectively.

The DEPIC was implemented in the field with minimum requirements. Data images were captured and automatically submitted to the data center when there was telephone signal. In this study in a remote area, data images were collected and submitted by local VHVs who had limited education levels. They expressed that it was not a burden to collect DEPIC data while performing their routine home visits. They collected data for health care providers easily, and not much effort was required. At the local health centers in the study locations, health care personnel indicated that DEPIC would help them cut down the workload if it was redesigned as a mobile technology tool for use by the health care personnel at the local center for data capture. This is an issue that needs further planning and collaboration in order to lessen the workloads of health care providers by using DEPIC for data image capture onto HCIS, rather than the current system of entering data twice, first into an MCH logbook and then onto an individual immunization history card for HCIS.

The development of DEPIC was based on the idea of creating a data collection tool for capturing secondary data in survey research. DEPIC has shown its potential use in collecting secondary data as a direct image when it is difficult for data collectors to collect the secondary data on paper-based CRF. This is due to the difficulties in reading, recalling, and writing such information. This method is quite effective as it can capture data directly from source documents (eg, MCH logbook) and, thus, there is no need to perform data extraction and/or source data verification (ie, cross-checking between source documents and CRFs). As also demonstrated in other studies using mobile

technology in remote areas [23,24], it simplifies the process of survey data collection in remote areas where study participants speak other languages. As found in many previous studies that used paper-based methods in collecting secondary data, such methods appear to have more transcription errors and missing data [25-32]. Transcription errors could occur at 2 stages—from source document to paper-based CRF, and then from CRF to database. The DEPIC application acts as a direct electronic CRF, thus halving the sources of error in the data-capture process. The implementation of DEPIC in this study suggests that it helped reduce the time consumed for data collection. Other studies have also reported decreased time spent in data collection using mobile technology [16,30,33].

In this study, data captured via DEPIC and entered into the HCIS database for further analysis has shown to improve the accuracy and completeness of data. One of the advantages of using DEPIC is that it provides evidence-based data via photographic images from the original source document. As shown in this study, DEPIC can capture all relevant information regarding the immunization history of children. Data stored in the DEPIC database were more complete, with supporting electronic evidence as an audit trail, and so could provide more reliable statistical analyses when needed. It should be noted, however, that errors or incomplete data could occur even with DEPIC due to unclear pictures—even if VHVs usually use mobile phones every day—and this might require retaking of the data image. It is important that the data collectors who use the device receive appropriate training for proficiency in camera use when a new data collection tool/application is introduced or if new survey content is planned.

Limitations of Current Version of DEPIC

The results of this study confirmed the potential implications of using camera applications on mobile devices in various ways to provide health care services, as is shown in previous studies [1,9-15,34]. In this study, DEPIC was developed and used for a simple descriptive survey, particularly to collect immunization history data from MCH logbooks or immunization cards. We recognize that in the comparison of data quality in this example of immunization history recording we assumed that the MCH logbooks are the complete and correct data source and, relying on these alone, we suggest that data quality captured by DEPIC is better than data in the national data source. It should be noted that we did not claim that the DEPIC provides more accurate data, but rather focused on completeness and consistency of data between the 2 data sources. There are several potential sources of inaccuracies; for examples, in either data sources, vaccines may be misrecorded, may be replaced with missing/incorrect data, or may be written as given when immunization did not actually happen. The results in this study simply demonstrate that (1) DEPIC could be used as a data collection tool to capture complete data with data images rather than the traditional paper-based data collection-and-entry method that results incomplete data; and (2) that DEPIC requires less effort and time to collect secondary data by cutting down the typical steps from extracting data from source documents to paper-based CRFs and then from CRFs to electronic databases.

In this study, the DEPIC was implemented as an example for use in data collection of a single survey. The DEPIC concept, however, can be easily applied as a data collection tool in other types of survey research; for example, collecting data on changes or trends based on image evidence over time. With its image evidence and audit trail features, DEPIC has potential applications for use even in clinical studies. With the purpose to prove the concept of using DEPIC for secondary data, the current application does not yet allow for double data entry to cross-check data validity. To comply with best data-entry practices in clinical studies, the next version of DEPIC should incorporate a double-entry function from image capture.

Conclusions

DEPIC, or the concept of collecting image data as a primary source, has proven to be a useful data collection method. It was found to be superior to paper-based methods in regard to the consistency and completeness of data. As a case study of using DEPIC to capture immunization history data among minority populations in remote areas, this study shows that the concept can be applied in a limited-resource environment. With traceable evidence-based images and better data quality, the DEPIC concept also has a potential to generate improved data integrity and more reliable statistics for use in public health and research settings.

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Authors' Contributions

KJ and JK designed and planned the study, drafted the first version of the paper, submitted the paper, and approved the final version. KJ and PW designed and programmed the survey for use on mobile phones, collected data, and monitored activities at study sites. AK, SL, and WW assisted in designing and planning the study, wrote the submitted paper, and approved the final version.

Conflicts of Interest

None declared.

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Abbreviations

BIOPHICS: Center of Excellence for Biomedical and Public Health Informatics

CRF: case report form

DEPIC: data entry via phone image capture

HCIS: health care information system

MCH: mother and child health logbook

VHVs: village health volunteers

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Original Paper

Potential Roles of Mhealth for Community Health Workers: Formative Research With End Users in Uganda and Mozambique

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Abstract

Background: Community health workers are reemerging as an essential component of health systems in low-income countries. However, there are concerns that unless they are adequately supported, their motivation and performance will be suboptimal. mHealth presents an opportunity to improve support for community health workers; however, most interventions to date have been designed through a top-down approach, rarely involve the end user, and have not focused on motivation.

Objective: To use formative research to explore the views of community health workers in Uganda and Mozambique on the potential role of mHealth in their work delivering integrated community case management of children.

Methods: We conducted 24 in-depth interviews and 5 focus group discussions with community health workers in Uganda and Mozambique. Data were collected on: current phone use, preferred phone and charger characteristics, and perceptions of a range of potential mHealth interventions. Interviews were conducted in the local language, were audio recorded and converted into expanded notes. Interviews were coded for key thematic areas using both deductive and inductive codes. Deductive codes included mHealth's potential impact on motivation and performance.

Results: The most salient roles of mHealth in improving performance and motivation were reducing the need for travel, improving efficiency and planning, receiving feedback and information, and improving communication with supervisors and other community health workers. This was mostly through improved voice and short message service (SMS) text communication. Specific components of mHealth interventions that participants felt could improve motivation included increasing their visibility and credibility through branding of phones; providing an SMS response to data submission; and sending SMS messages about the importance of their work and achievements, rather than just reminders or technical messages. Participants identified feasibility issues related to the language of SMS messages, network coverage, and the need for a balance between phone function and battery life. Phones with a dual SIM cards would ameliorate network problems but would reduce battery life. The provision of a solar charger was viewed as beneficial.

Conclusions: Conducting formative research with end users is likely to improve mHealth interventions by: (1) identifying interventions that are likely to have the greatest impact and be the most acceptable, (2) developing salient SMS messages, and (3) identifying feasibility issues. mHealth interventions also could have an important impact on health worker motivation, which should be considered by intervention developers and in evaluations, especially as small modifications could have a significant

impact. Our study suggests that using phones to improve direct communication should be considered, even when planners aim to focus on the provision of a specific application.

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KEYWORDS

mobile phones; mHealth; community health workers; motivation; performance

Introduction

After years of relative neglect, community health workers (CHWs) are reemerging as an essential component of health systems in low-income countries [1-3]. They are central to programs such as the integrated community case management (iCCM) of childhood illness. iCCM aims to reduce child mortality by increasing the coverage of community treatment of diarrhea, pneumonia, and malaria, and the detection of malnutrition [4]. There are concerns, however, that unless CHWs are adequately supported, their retention, motivation, and performance will be suboptimal [5,6]. This could lead to a breakdown in programs, which indeed occurred in many countries in the 1980s and 1990s [7-9].

The advent of mHealth, which is the use of mobile technology to support medical and public health, and its potential to reach “new horizons for health” [10] presents an opportunity to improve support for CHWs. To date, mHealth for CHWs has primarily focused on software applications for data recording and submission, job aids to improve diagnosis and consultations, and sending and receiving short message service (SMS) text messages and reminders [11]. Stakeholders working with CHWs have highlighted the motivational potential of mobile technologies through communication with other CHWs (peer support) and with supervisors and the health system (functional support) [12], but few rigorous evaluations of mHealth have been conducted with CHWs. The limited evidence suggests that mHealth could be beneficial for performance and program efficiency [11,13]. No mHealth studies targeting CHW motivation have been published.

Previously, most CHW mHealth interventions were designed through a top-down approach, with the end user rarely involved [13]. However, research with end users is important for improving the effectiveness of intervention design, and the need to explore users’ perspectives when designing mHealth interventions is recognized [14]. In this paper we present formative research findings from Uganda and Mozambique on CHWs’ views on the potential role of mHealth in their work delivering iCCM. The data were collected as part of the formative research for the inSCALE project, which aims to test innovative approaches to improving the motivation, performance, and retention of CHWs to improve the quality and coverage of iCCM [15].

Methods

Data Collection

We conducted a total of 24 in-depth interviews and 5 focus group discussions with iCCM-trained CHWs on: current phone use, preferred phone and charger characteristics, and perceptions

on a range of potential mHealth interventions. The potential interventions included using mobile phones to: increase contact with other CHWs, improve supervision, receive information through SMS text messages, submit data, provide treatment guidelines, and receive personalized performance-based feedback. Information on how these interventions were selected for inclusion in the interview content is available elsewhere [15].

Data were collected in January and February 2011 in the Kiboga and Hoima districts of Uganda and in March 2012 in the Massinga District and in Inhambane City in Mozambique. CHWs are called agentes polyvalentes elementares (APEs) in Mozambique and village health team members (VHTs) in Uganda. In both sites, CHWs diagnose and treat childhood diarrhea, pneumonia, and malaria, but major contextual differences exist between the sites. In Mozambique, each district has 25 APEs who are each responsible for approximately 2000 people. In Uganda, VHTs are more numerous with 2-3 iCCM-trained volunteers per village, covering between 250-500 people each. In Mozambique, each supervisor oversees only 2-3 APEs. But in Uganda, 1 supervisor oversees 25-90 VHTs. In both settings, CHWs are actively selected by the communities based on their age, gender, and ability to read and write. From a financial perspective, APEs receive US \$40 per month for their work, whereas VHTs are voluntary workers. The APEs are trained for 4 months while VHTs receive training for 6-11 days.

In-depth interviews and focus group discussions were conducted in the local language by trained interviewers using pretested semistructured guides. Sessions lasted between 45 minutes and 2 hours, and were audio recorded, with interviewers also taking field notes. Interviewers wrote out the findings of the in-depth interviews and focus group discussions in full in English using the expanded notes method [16]; this included recording their observations and reflections. They used the audio recordings to check completeness of their expanded notes and to add verbatim quotes. Field supervisors ensured the quality of the data through reflective meetings with interviewers and a daily review of the expanded notes.

Recruitment

CHWs within the study districts were purposively selected from a list of iCCM trained CHWs to reflect variability in mobile network coverage and distance to supervising facility. They were approached by the interviewers and interviewed in a location of their own choosing; there were no refusals. Table 1 shows the sample size and the characteristics of participants in each setting. Sample size was determined a priori based on predictions as to when saturation in themes was likely to be reached (ie, when interviews and focus group discussions stop

providing new insights into the topic). Provision was made to increase the sample size if saturation was not obtained.

Table 1. Sample size and characteristics of the CHWs who were selected for in-depth interviews at each site.

Characteristics	Mozambique (N=12)	Uganda (N=12)
Age, y		
25-35	8	5
36-55	4	7
Gender		
Male	9	7
Female	3	5
Has a job in addition to being a CHW		
Yes	7	12
No	5	0
Residence		
Urban	0	3
Rural	12	9
Network availability		
All or most of the time	9	9
None or only some of the time	3	3
Distance to supervising facility		
<10 km	8	8
>10 km	4	4

Data Analysis

Data analysis started with multiple readings of the expanded notes to ensure familiarity with the data. Expanded notes were then coded for key thematic areas using both deductive and inductive methods. Inductive codes related to the potential impact of mHealth interventions on the motivation and performance of CHWs, and on the feasibility of using mobile phones. Within each inductive code, deductive coding was then conducted. Themes were then compiled into matrices to enable comparisons across participants and to identify deviant cases more easily. Data were analyzed as a team with regular reflective discussions, which included reviewing and discussing the coding frame and the emerging themes.

Ethical Considerations

Written informed consent was obtained from all participants and the trial protocol was approved by ethical review boards at Makerere University and the Uganda National Council of Science and Technology in Uganda, the Comité Nacional de Bioética para a Saúde in Mozambique, and London School of Hygiene & Tropical Medicine Ethics Committee in the United Kingdom.

Results

Data revealed 3 inductive themes related to the impact of mHealth interventions: performance, motivation, and the feasibility of mobile phone use.

Performance

The main theme relating to CHW performance was the potential for mHealth interventions to ease infrastructure problems and enhance feedback. Currently, CHWs submit numerical data, such as number of children treated, using a paper-based system. This requires traveling to the supervising facility; CHWs therefore face time, cost, and transport issues. Data submission by mobile phone was perceived as having the potential to enhance performance by improving efficiency:

[I]f...we can send the statistical data via mobile phone...we would not be worried more about the transportation, travel time to go and return from the health center and the time lost in the health center in the process of data submission.... [APE, 29-year-old male]

CHWs also felt that a mobile phone would enable improved planning and improved referral of very sick children.

At the time of the study, CHWs received little or no feedback on their performance, which they found discouraging and felt that it hindered self-improvement: "I wonder if I'm doing well or not [in] my work...because if someone let me know that I am not doing a good work I can correct my mistakes and improve my performance" [APE, 28-year-old female]. Data submission by mobile phone was seen as a potential avenue for improved feedback, as their supervisor could use the submitted data to judge their performance and could then give feedback through a text, voice call, or face-to-face visit. CHWs stressed that feedback needs to be supportive: "Feedback should not be in

form of blame but rather simple and calm advice and not given in a rude way” [VHT, 36-year-old male].

CHWs felt that receiving regular SMS text messages that provided knowledge, reminders, or advice would be beneficial for their performance. CHWs raised concerns that the content of the messages may not be relevant at the time they were received, and that message length restrictions would limit their usefulness: “The kind of information I would like to receive is anything that contributes to VHT knowledge...if they address the challenges we put across, then it would be more useful” [VHT, 52-year-old female].

CHWs felt that having treatment guidelines on their phone would benefit performance by improving their decision-making: “...when I face a difficulty in treating a patient...I can immediately check on my phone for making a better decision” [APE, 38-year-old male]. The potential availability of treatment guidelines was received less enthusiastically by CHWs than the interventions that focused on improving communication or data submission. Treatment guidelines were sometimes discussed in terms of reducing CHWs’ need to call their supervisor rather than as a new innovation: “...it would enable me to immediately check on my phone instead of calling my supervisor to ask for advice...” [APE, 28-year-old male]. There were some concerns that using guidelines would be time consuming and boring, and that unless CHWs were well trained the guidelines could be misinterpreted.

Motivation

The main theme that emerged regarding mHealth and motivation was the ability of the phone to enhance community standing and visibility, and to improve general communication and supervision. CHWs described the potential for mobile phones to generate greater levels of community standing by increasing community trust and credibility: “A phone always has an impact on the community, it changes someone’s status and people start trusting that person” [VHT, 35-year-old male]. The degree to which a phone could increase status was linked to its perceived value:

Those modern phones are beautiful and all the people know that they are expensive. It would increase our status in the community as the people will perceive that we are recognized by the government as people who are doing a useful work.... [APE, 33-year-old male]

VHTs and APEs unanimously agreed that branding phones with program logos could increase visibility, status, and phone use: “Having a VHT marked phone brings you respect from the people in your community” [VHT, 36-year-old male]. Branding would also protect the phone against theft and loss.

APEs and VHTs already used their personal phones to contact each other and their supervisors, but this contact was limited by the cost of airtime. Informants felt that the provision of CHW phones and airtime would enable them to interact and support each other more frequently, and in so doing reduce stress, increase the bond felt between CHWs, allow drugs to be borrowed if a CHW ran out, and help solve problems. Many respondents felt that interactions with their peers was beneficial:

“...we are able to work together as a team and solve some problems that cannot be solved by an individual...” [VHT, 35-year-old male], and expressed a collective identity and a common aim: “These interactions with other APEs are important because they avail learning from each other and makes us feel a part of 1 big family working toward the same goal...” [APE, 32-year-old female]. The potential for phones to motivate through increased contacts with other CHWs was considered greater in Mozambique, where APEs are more scattered. In Uganda, VHTs felt they could contact other VHTs in their community in person if needed.

Although most respondents wanted contact with their peers, some felt that contact with the facility was more important, especially as current contact with supervisors was often infrequent and irregular: “I like the contacts that I have with my supervisor as it allows me to improve my skills. But I need more contacts...in order to gain more experience and improve permanently my performance” [APE, 28-year-old male]. Being “on air” was perceived as allowing access to supervisors at short notice for problem-sharing, gaining information, facilitating community mobilization, and to inform supervisors about referrals of sick children: “As I live far from the health facility, being provided with a phone and to call for free would be a benefit as it would enable me to frequently be in contact with my supervisor and indeed receive support when needed” [APE, 42-year-old female]. Possible problems with voice calls or SMS included that supervisors may not be available when the CHWs called, may not call back, or may not act on reported problems, all of which were felt to be demotivating.

Other concerns were that some supervision needed to be done face-to-face, since supervisors may not get an accurate picture of what was happening over the phone and may not be able to give adequate guidance: “It is more important for the supervisor to be there physically and explain specific tasks or challenges...this cannot easily be explained on the phone” [VHT, focus group participant]. Linked to the need for face-to-face visits was a fear that phone supervision would lead to a reduction in supervisor visits, which would reduce the visibility and status of the CHWs:

I like to be visited by the health workers because it not only allows me to exchange experiences and improve my performance, but also because the community recognizes that I’m a son of the ministry of health; so I’m wondering whether the phone call from the health center could reduce such visits.... [APE, 28-year-old male]

Acknowledgement and feeling valued by the system was a strong motivator, and all CHWs interviewed wanted any electronic data submission to be followed by an acknowledgement: “For me, being thanked after data submission will be motivating because I’ll know that who received it recognize that I’ve performed an important task” [APE, 33-year-old male]. Participants felt that any intervention to send regular SMS text messages should not focus only on technical issues but should also stress the importance of the CHWs’ work and their achievements by, for example, telling them the number of children they have treated: “Receiving messages stressing

the importance of my work in the community will mean appreciation, recognition, and indeed an encouragement to keep working” [APE, 38-year-old male].

Feasibility of Using Mobile Phones

In both settings, CHWs felt that the impact of mHealth interventions would be undermined by patchy network coverage and system overload, but felt that this could be overcome by using phones with dual SIM cards. CHWs also expressed concern over the maintenance of the equipment and theft or damage: “What about if I lost the supplied phone or if it was stolen from me? Are you going to arrest me or ask for replacement/payment? I’m wondering because I can’t afford it...” [APE, 33-year-old male].

Despite a lack of electricity, most CHWs kept their personal phones charged: “My mobile phone is always on and with me because it belongs to me.... I know that someone can call me at any time” [APE, 28-year-old female]. Phone charging sometimes required travel and monetary costs: “In my village there are few places where one can charge the phone and it is costly.... I normally take my phone to [a] trading center..., which is about 3 km from my home” [VHT, 35-year-old female]. In response to issues of charging the phones, CHWs wanted phones that maximized battery life, even if this meant using a simple rather than a multifunctional phone. Participants felt that a solar charger would enhance their effectiveness and allow them to use more sophisticated phones with a shorter battery life: “It will save me the burden of incurring transport and charging costs” [VHT, focus group participant].

Although most CHWs had been exposed to mobile phones, they had concerns about complex phone functions or apps, but they felt they could cope if they were given training and support: “My main concern will be our ability to use these phones because it will be the first time for most/all of us to use them for this kind of work. However, with the constant training, I think we shall be able to slowly learn how to use them” [VHT, 40-year-old male]. Feasibility issues also related to language, such as sending SMS texts in the local languages, was difficult because not all CHWs spoke fluent Portuguese or English: “The challenge is...we do not understand English at the same level...” [VHT, 30-year-old female].

Themes around feasibility were also framed within the perspectives of other village and family members wanting to use the phone: “People may come asking for help to use the VHT phone and say it is a group phone and may hate you if you refuse to give it to them” [VHT, focus group participant]. There was a preference for the use of the phone to be unrestricted in terms of making calls to family and friends:

What about if there is an emergency not related to my work as APE, may I use such a phone for calling purposes? If not, what are the real advantages of having such phones...?” [APE, 46-year-old male]

Discussion

Principal Findings

Our study found that the most salient roles of mHealth for the participants were reducing the need for travel, improving efficiency and planning, receiving feedback and information, and improving communication with supervisors and other CHWs. These reflect some of the most pressing challenges that CHWs face, and are similar to findings from a study in Senegal where phones were valued most for addressing training, stock management, reporting, and transportation challenges [17]. Despite the contextual differences between the 2 study sites, findings were surprisingly similar. For example, despite a higher supervisor-to-CHW ratio in Mozambique compared to Uganda, the desire to use mobile phones to increase and improve supervision was similar. This is likely to be related to the fact that the supervision system was not functioning optimally in either site. That despite different systems, the realities of supervision were similar.

Limitations

A limitation of the study is that respondents were talking hypothetically, and previous studies have shown that enthusiasm for an mHealth intervention does not always correspond to uptake [14]. Participants were generally enthusiastic about the potential interventions; but this may be due to social desirability affecting reporting, which may be particularly strong when a desired commodity such as a mobile phone is being discussed. CHWs may not be in the best position to evaluate problems in their technical abilities and skills, and this study would have been strengthened by an objective assessment of CHWs’ skills.

Our findings were broadly similar in 2 very different sites. Care should be taken, however, in applying the findings to other sites as CHWs elsewhere may have different characteristics, experiences, needs, and perceptions.

Comparison With Prior Work

Most CHW mHealth interventions to date have focused on applications for data submission, diagnosis, and SMS text message reminders [11], but our findings suggest that improving voice and text communication with other CHWs, supervisors, and health facilities could itself improve motivation, performance, and efficiency. A study in South Africa found that, although an application to improve CHW reporting of adverse events related to TB medication was not frequently used, improved text and voice communication with clients and supervisors was highly valued and enabled collaboration, reduced travel time, and made CHWs feel part of a team [14]. The potential for mobile phones to improve direct communication should be considered, even when studies or programs focus on the provision of a specific application. That said, improved communication must be 2-way, and CHWs in our study felt that if they called their supervisor and the call was not answered, or if they reported an issue and the issue was not solved, they would become demoralized. This reflects findings from Malawi on the importance of improving both communication and the outcome of the communication [18].

Implications

By understanding CHWs' needs, and by explicitly thinking about motivation, we were able to identify specific modifications to mHealth interventions that could improve motivation. For example, our findings suggest that intervention designers should consider how mobile phones could increase the standing, visibility, and credibility of CHWs through strategies such as clear branding of phones with the project's logo. Other modifications that could be made to existing applications to improve motivation include providing an SMS message response to CHW data submission and sending SMS text messages about the importance of CHW work and achievements, rather than just reminders or technical messages. Data from formative research allows SMS text messages to be designed in a way that is salient to the CHWs.

Studies of the impact of mHealth on CHWs' work have, to date, focused on measuring processes and uptake, and rigorous large-scale studies are needed with behavioral and health outcomes [11]. Our study suggests that mHealth interventions could also have an impact on motivation, and we propose that motivation should be considered during both the design and evaluation of mHealth interventions. This is supported by the "unexpected" finding from a study with HIV/AIDS community workers in Uganda where an mHealth intervention appeared to improve worker morale and job satisfaction [19]. Recently framed "pathways of research" for mHealth interventions in low-income countries do not include motivation as an outcome [20], which we feel is an important omission that should be rectified.

Our study illustrates the importance of including end-users in the design of mHealth interventions, which should become best practice for all those designing mHealth interventions. In this study, CHWs were able to identify key feasibility issues such as the language in which SMS text messages are sent and the balance between the relative importance of phone function versus battery life. We found that although poor network coverage was a reality in both settings, this could be ameliorated by providing CHWs in locations with poor coverage with a dual SIM phone. The impact of providing phones with a reduced battery life needs to be considered, and solar chargers may be a solution.

Conclusions

There has been a call for mHealth interventions to explicitly consider theory in their design [20], using models such as the mobile phone technology acceptance model [17]. The results of the formative research presented in this paper were reviewed in light of worker performance and motivation theory, and the findings and the theory were used to design mHealth interventions in each site [15]. The use of performance and motivation theory provided a lens through which the formative research findings could be viewed and helped the team make decisions about the design of the interventions and their potential impact. We feel that the design of mHealth interventions would be strengthened by using theories that help understand performance and motivation, rather than those that focus solely on acceptance and use of the phone.

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Conflicts of Interest

None declared.

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Abbreviations

- APE:** agente polivalentes elementares
CHW: community health worker
iCCM: integrated community case management
SMS: short message service
VHT: village health team member

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Original Paper

The Prevalence and Characteristics of Emergency Medicine Patient Use of New Media

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Abstract

Background: Little is known about “new media” use, defined as media content created or consumed on demand on an electronic device, by patients in emergency department (ED) settings. The application of this technology has the potential to enhance health care beyond the index visit.

Objective: The objectives are to determine the prevalence and characteristics of ED patients’ use of new media and to then define and identify the potential of new media to transcend health care barriers and improve the public’s health.

Methods: Face-to-face, cross-sectional surveys in Spanish and English were given to 5,994 patients who were sequentially enrolled from July 12 to August 30, 2012. Data were collected from across a Southern Connecticut health care system’s 3 high-volume EDs for 24 hours a day, 7 days a week for 6 weeks. The EDs were part of an urban academic teaching hospital, an urban community hospital, and an academic affiliate hospital.

Results: A total of 5,994 (89% response rate) ED patients reported identical ownership of cell phones (85%, $P<.001$) and smartphones (51%, $P<.001$) that were used for calling (99%, $P<.001$). The older the patient, however, the less likely it was that the patient used the phone for texting (96% vs 16%, $P<.001$). Income was positively associated with smartphone ownership ($P<.001$) and the use of health apps ($P>.05$) and personal health records ($P<.001$). Ownership of iPhones compared to Android phones were similar (44% vs 45%, $P<.05$). Race and ethnicity played a significant role in texting and smartphone ownership, with Hispanics reporting the highest rates of 79% and 56%, respectively, followed by black non-Hispanics at 77% and 54%, respectively, and white non-Hispanics at 65% and 42%, respectively ($P<.05$).

Conclusions: There is a critical mass of ED patients who use new media. Older persons are less comfortable texting and using smartphone apps. Income status has a positive relationship with smartphone ownership and use of smartphone apps. Regardless of income, however, texting and ownership of smartphones was highest for Latinos and black non-Latinos. These findings have implications for expanding health care beyond the ED visit through the use of cell phones, smartphones, texting, the Internet, and health care apps to improve the health of the public.

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KEYWORDS

medical informatics; new media; health care services; personal health management; mobile phones

Introduction

New media is part of the communication science lexicon—yet it is frequently omitted from the health care literature and often is incorrectly interchanged with cell phones. “New media” is defined as media content created or consumed on demand on an electronic device (eg, mobile phones, computers, tablets, etc) [1-8]. In contrast, simple cell phone technology does not support health apps or Web browsing for health information. While most cell phones also have other communication modes beyond a simple telephone, such as texting, there is an age cohort effect whereby the elderly population is more likely to only use the phone features because that population is less comfortable texting or using mobile phone apps [9-15]. Thus, cell phones must be thought of as a subcategory of new media and distinct from mobile phones. New media has unrealized potential to improve health outcomes compared to traditional or legacy media (eg, print materials, radio, television, etc) [16-23].

According to Jenkins, new media can be thought of “as the convergence of 3 concepts—media convergence, participatory culture, and collective intelligence” [24]. With new media, consumers “interact with” a digital device as opposed to being “exposed to” legacy media, which is passive media spectatorship [24-29]. Therefore, new media has a greater potential to improve patient care and health outcomes [13,30-34]. Mobile phones, tablets, laptops, and desktops allow the consumer to search health information repositories, or “collective intelligence,” related to their health condition [35-37]. “Media convergence” refers to how patients interact with each other or experts [38-41] (eg, chat rooms for women with breast cancer) [42-45]. And a “participatory culture” allows active engagement in treatment [46-48] (eg, messaging medication adherence or provider communication) [49-51]. Engaged patients experience better health outcomes and higher satisfaction [52-58]. The purpose of this study is to improve our understanding of the prevalence, uses, and typology of new media in the emergency department

(ED) care setting [59-65]. We theorize that if a critical mass of patients are using new media, it may drive a paradigm shift in health care delivery by enhancing care beyond the ED visit.

Methods

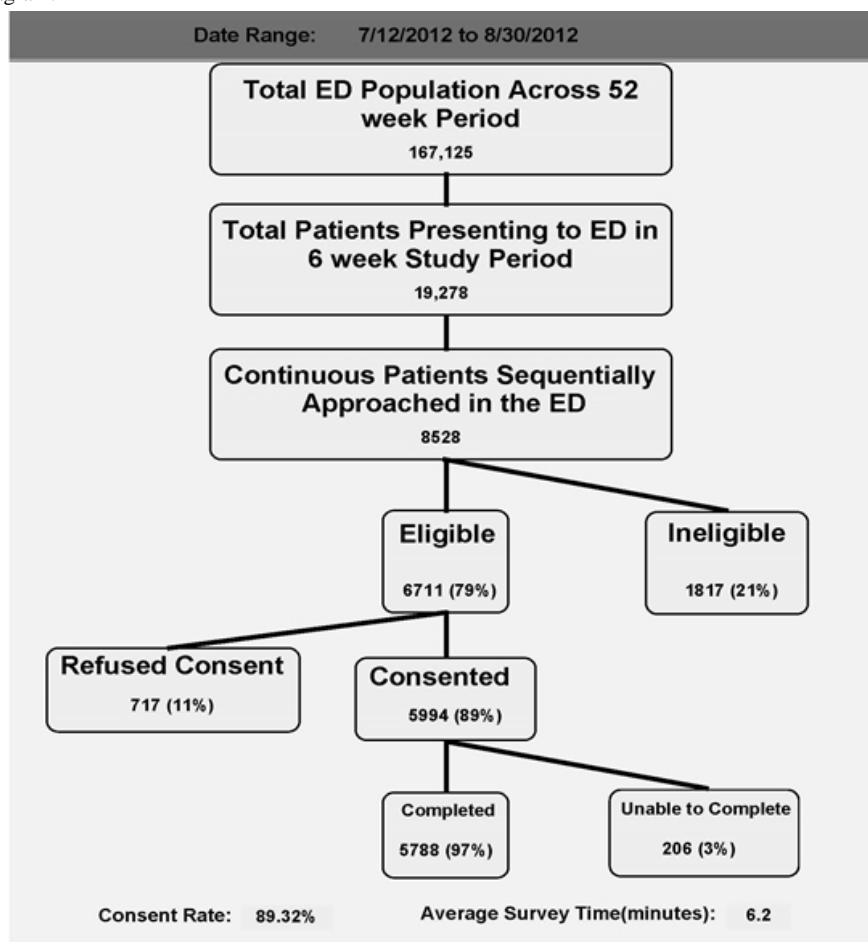
Overview

We designed and administered a cross-sectional survey of patients presenting to 3 EDs in southern Connecticut that are part of the Yale-New Haven Health System (YNHHS). Data were collected over 24 hours a day, 7 days a week for a total of 6 weeks. During the study period, the annual census for Yale-New Haven Hospital York Street Campus, an urban academic teaching hospital, was approximately 81,000 adult visits per year and serves a population that is 52% white, 28% black, and 18% Hispanic, with 40% receiving Medicaid. Bridgeport Hospital, an urban academic affiliate of YNHHS, receives approximately 45,000 adult visits per year and serves a population that is 44% white, 38% black, and 15% Hispanic, with 46% receiving Medicaid. The annual census for the Saint Raphael Campus ED, best described as an urban community ED, was approximately 45,000 visits per year and serves a population that is 36% white, 31% black, and 34% Hispanic, with 50% receiving Medicaid.

Selection of Participants

Research assistants (RAs) enrolled patients presenting to 1 of the 3 EDs. Twenty-two trained RAs enrolled patients on every ED shift, 24 hours a day, 7 days a week, during a 6-week period (July 12 to August 30, 2012). Patients were excluded if they were 17 years of age or younger; alcohol or drug impaired; had a condition that precluded interview; were in police custody; had active psychosis, suicidal, or homicidal ideation; or were unwilling to consent. RAs entered patient data into the electronic data capture system based on time of patient arrival (Figure 1). The institutional review board of each participating hospital approved all study procedures.

Figure 1. Patient flow diagram.



Data Collection and Analysis

Our research consortium reviewed and selected questions from the information technology study conducted at Brown University's ED [66], by the Department of Veterans Affairs [67], and some instruments from health communication literature [68]. Our multidisciplinary research group consisted of individuals with expertise in informatics, emergency medicine, bioinformatics, engineering, and social sciences who recommended validated questions to include on the survey instrument based on their specific areas, such as media usage [69,70], substance abuse [71,72], tobacco use [73,74], the elderly [75-81], public health records [82], veterans [83], and ethnic minorities [84-86]. The survey was derived from other validated survey or screening questionnaires and new media surveys in combination with original questions specific to the ED, health care, and patient populations. Participants were asked a series of questions representing a number of domains, such as: (1) new media technology ownership (eg, "Do you own a cell phone?"); (2) new media use (eg, "What do you use your cell phone for? Check ALL that apply."); (3) type of technology owned (eg, "Is your cell phone a mobile phone (eg, iPhone, BlackBerry, Android?"); and (4) frequency of use (eg, "How often do you use your cell phone for text messaging?"). Contingent on answers to these prior questions, participants were asked about new media behaviors such as: (1) seeking health information (eg, "Do you use your cell phone to look up health information?"); and (2) tracking or managing one's health

(eg, "Do you use a software application on your phone to help you track or manage your health?"). The survey ended with the collection of the following demographic data: age, gender, ethnicity, race, preferred language, highest level of education completed, rural/urban status, and annual household income.

The survey was pilot tested over the course of 1 month (with observers) and tested for fourth grade Flesch-Kincaid readability. Some data regarding race were missing (<1%) due to confusion between "race" and "ethnicity." Thus, participants who reported Latino/Hispanic as a racial category were corrected using hot deck imputation [87-98].

We compared ED patients' new media use between 3 urban EDs in southern Connecticut. The survey was conducted in English and Spanish. We derived point estimates with 95% confidence intervals (CI) using the normal-theory method for a binomial parameter. Variables of interest include *P*-values based on the test for a binomial proportion. Analyses were performed using SPSS version 20 (IBM Corp, Armonk, NY).

Results

A total of 5,994 (89% response rate) ED patients consented to participate in the study from southern Connecticut (Figure 1). The average time for survey completion was 6.2 minutes. The 3 EDs within the health care system are presented disaggregated and then were combined for purposes of analysis (Table 1). A total of 58.43% (3,382/5,788) of ED users were female; the mean

age was 46 years old; whites comprised 42.14% (2410/5719), blacks 34.11% (1951/5719), and Latinos 23.75% (1358/5719) of the patient population; 2.95% (171/5788) of the participants elected to complete the survey in Spanish; 14.60% (845/5788) of the respondents had none to some schooling; and 39.38% (1775/4507) of the ED patients earned less than \$15,000 per year. There was little if any variation among the 3 EDs, with the exception of income. A total of 47.10% (674/1431) of Saint Raphael's patients earned less than \$15,000 per year while only 34.97% (583/1667) of Yale-New Haven York Street Campus patients reported an income in this bracket (Table 1). ED patients reported high ownership of cell phones (4934/5788, 85.25%, $P < .001$) and mobile phones (2500/4934, 50.67%, $P < .001$) that were used for calling (4892/4934, 99.15%, $P < .001$). The older the patient, the less likely it was that the patient used their cell phone for texting (96% of 18-29 year olds vs 16% of those age 65 or older, $P < .00$). Ownership of iPhones (1093/2500, 43.72%) compared to Androids (1117/2500, 45.88%) were similar ($P < .05$). Of those patients with a contract, 49.57% (2446/4934) reported having unlimited minutes and 49.57% (2446/4934) reported having limited minutes. Furthermore, 20.25% (999/4934) of patients reported having a pay-as-you go plan, which may or may not have included a contract. Finally, 4.32% (213/4934) of patients reported owning a Medicaid phone (aka, "Obama phone") (Table 2). Income was positively associated with mobile phone ownership ($P < .001$), use of health apps ($P > .05$), and use of personal health records ($P < .001$) (Table 3). Race played a significant role in texting and mobile phone ownership, with Hispanics reporting the highest rates (79% and 56%, respectively), followed by black non-Hispanics (77% and 54%, respectively) and white non-Hispanics (65% and 42%, respectively) ($P < .05$). ED users also demonstrated higher rates of African American and Latino patients (34% and 24%, respectively). In summary, ED patients had high rates of minorities, no to little education, and low income (Table 3).

While not directly comparable, as these 2 surveys are from 2 different sampling frames, the Pew Foundation and the California HealthCare Foundation (CHCF) conducted a similar media health care study during the same time period [99]. Coincidentally, ED patients in our study had identical ownership of cell phones benchmarked against the Pew-CHCF study (4934/5788, 85.25%, $P < .001$). Income impacted the type of mobile phone and the nature of the contract, however, functionality remains identical. Basic functions such as calling (4892/4934, 99.15%, $P > .05$) and texting (3595/4935, 72.86%, CI 95% 72-74) were high (Table 2). Internet connections for browsing (2283/4934, 46.27%, 95% CI 45-48), e-mailing (2081/4934, 42.18%, 95% CI 41-44), and social networking (1903/4934, 38.57%, 95% CI 37-40) were less prevalent. Among all cell phone owners, 50.67% (2500/4934, 95% CI 49-52) reported that their device was a mobile phone. The Pew-CHCF study had a rate of 53%, meaning that ED users have 1% fewer mobile phones when benchmarked against the general population. iPhones were more pervasive among higher income ED patients than lower income patients; however, the functionality of Android phones is identical in terms of apps, texting, and Web browsing capability.

Table 3 demonstrates the health care utility for new media beyond calling capabilities according to selected demographic characteristics. The youngest age cohort of 18-29 years old reported the highest rates of texting (96%) compared to the older patients, significantly higher rates of mobile phones (79%, $P < .001$), high rates of using new media to seek health information (65%, $P < .001$). Among the eldest ED patients, those 65 years old or older, the highest rates were for using health apps (16%, $P < .05$) and seeking health information (33%, $P < .001$). African Americans (54%, $P < .001$) and Latinos (56%, $P < .001$) in the ED reported significantly higher rates of mobile phone ownership than whites (44%, $P < .05$). There was a similar pattern for seeking health information.

Table 1. Demographic breakdown of 3 emergency departments, July 12 to August 30, 2012.

Demographic	ED #1 Yale-New Haven Hospital York Street Campus	ED #2 Yale-New Haven Hospital Saint Raphael Campus	ED #3 Bridgeport Hospital	Total All EDs, combined (N=5788)
Female	1081/1922 (56.24%)	1177/1966 (59.87%)	1124/1900 (59.16%)	3382/5788 (58.43%)
Mean age, year (SD)	45 (18)	48 (21)	44 (19)	46 (20)
White, Non-Hispanic	891/1888 (47.19%)	889/1954 (45.50%)	630/1877 (33.56%)	2410/5719 (42.14%)
Black, Non-Hispanic	567/1888 (30.03%)	774/1954 (39.61%)	610/1877 (32.50%)	1951/5719 (34.11%)
Hispanic	430/1888 (22.78%)	291/1954 (14.89%)	637/1877 (33.94%)	1358/5719 (23.75%)
Spanish language survey	68/1922 (3.54%)	51/1966 (2.59%)	52/1900 (2.74%)	171/5788 (2.95%)
None to some schooling	253/1922 (13.16%)	304/1966 (15.46%)	288/1900 (15.16%)	845/5788 (14.60%)
Income <\$15,000	583/1667 (34.97%)	674/1431 (47.10%)	518/1409 (36.76%)	1775/4507 (39.38%)

Table 2. New media use prevalence and taxonomies, July 12 to August 30, 2012.

New media profile		ED #1	ED #2	ED #3	Total
		Yale-New Haven Hospital York Street Campus	Yale-New Haven Hospital Saint Raphael Campus	Bridgeport Hospital	All EDs combined (N=5788)
Cell phone ownership		1677/1922 (87.25%)	1591/1966 (80.93%)	1666/1900 (88.68%)	4934/5788 (85.25%, 95% CI 84-86)
Cell phone use	Calling	1666/1677 (99.34%)	1572/1591 (98.81%)	1654/1666 (99.28%)	4892/4934 (99.15%, 95% CI 98.9-99.4)
	Texting	1235/1677 (73.64%)	1141/1592 (71.72%)	1219/1666 (73.17%)	3595/4935 (72.86%, 95% CI 72-74)
	E-mailing	654/1677 (39.00%)	624/1591 (39.22%)	803/1666 (48.20%)	2081/4934 (42.18%, 95% CI 41-44)
	Surfing Internet	762/1677 (45.44%)	652/1591 (40.98%)	869/1666 (52.16%)	2283/4934 (46.27%, 95% CI 45-48)
	Social networking	664/1677 (39.59%)	545/1591 (34.26%)	694/1666 (41.66%)	1903/4934 (38.57%, 95% CI 37-40)
	Playing games	422/1677 (25.16%)	430/1591 (27.03%)	564/1666 (33.85%)	1416/4934 (28.70%, 95% CI 27-30)
Mobile phone ownership		837/1677 (49.91%)	716/1591 (45.00%)	947/1666 (56.84%)	2500/4934 (50.67%, 95% CI 49-52)
Mobile phone operating system	iPhone	404/837 (48.27%)	278/716 (38.83%)	411/947 (43.40%)	1093/2500 (43.72%, 95% CI 42-46)
	Android	333/837 (39.78%)	333/716 (46.51%)	451/947 (47.62%)	1117/2500 (44.68%, 95% CI 43-47)
Mobile phone contract type	Contract, Limited Min	909/1677 (54.20%)	687/1591 (43.18%)	850/1666 (51.02%)	2446/4934 (49.57%, 95% CI 48-51)
	Contract, Unlimited Min	909/1677 (54.20%)	687/1591 (43.18%)	850/1666 (51.02%)	2446/4934 (49.57%, 95% CI 48-51)
	Medicaid phone (aka Obama phone)	66/1677 (3.94%)	84/1591 (5.28%)	63/1666 (3.78%)	213/4934 (4.32%, 95% CI 4-5)
	Pay-as-you-go	255/1677 (15.21%)	391/1591 (25.58%)	353/1666 (21.19%)	999/4934 (20.25%, 95% CI 19-21)

Table 3. New media device ownership and use by ED survey participants versus Pew-CHCF study data, July 12 to August 30, 2012.

Demographic (N=5788)		Text Messaging, 73% (CI 95% 72-74)			Mobile Phone Ownership, 51% (CI 95% 49-52)			Use of Health Apps, 19% (CI 95% 17-21)			Health Info Seeking, 60% (CI 95% 58-62)			Personal Health Records, 6% (CI 95% 6-8)
		EDs	Pew-CHCF	P	EDs	Pew-CHCF	P	EDs	Pew-CHCF	P	EDs	Pew-CHCF	P	EDs
Gender	Men	68 (66-71)	81	<.001	47 (45-49)	46	>.05	17 (15-20)	16	>.05	53 (49-56)	29	<.001	7 (6-8)
	Women	76 (74-77)	80	<.001	53 (52-55)	45	<.001	20 (18-22)	23	.007	64 (62-67)	33	<.001	6 (5-7)
Age	18-29	96 (95-97)	97	.04	79 (77-81)	66	<.001	18 (16-21)	24	<.001	65 (62-68)	42	<.001	7 (5-8)
	30-49	84 (82-85)	92	<.001	54 (52-57)	59	<.001	20 (18-23)	19	>.05	57 (53-60)	39	<.001	8 (7-9)
	50-64	55 (52-58)	72	<.001	30 (27-33)	34	.004	17 (11-22)	16	>.05	53 (47-60)	19	<.001	7 (5-8)
	65+	16 (13-19)	34	<.001	10 (7-12)	11	>.05	16 (4-27)	10	>.05	33 (19-47)	9	<.001	2 (1-2)
Race/Ethnicity	White, Non-Hispanic	65 (63-67)	79	<.001	44 (42-46)	42	>.05	21 (18-24)	19	>.05	61 (58-65)	27	<.001	8 (6-9)
	Black, Non-Hispanic	77 (75-79)	80	.008	54 (51-56)	47	<.001	17 (15-20)	21	.01	57 (54-61)	35	<.001	5 (4-5)
	Hispanic	79 (77-82)	85	<.001	56 (53-59)	49	<.001	18 (15-21)	15	.03	61 (57-65)	38	<.001	6 (5-7)
Annual Household Income	<\$30,000	71 (69-73)	78	<.001	45 (43-47)	35	<.001	16 (14-18)	14	>.05	63 (60-66)	28	<.001	3 (3-4)
	\$30,000-\$59,999	76 (73-79)	78	>.05	56 (53-60)	42	<.001	21 (17-25)	21	>.05	59 (54-64)	30	<.001	8 (6-10)
	\$60,000-\$89,999	78 (74-82)	89	<.001	60 (56-65)	56	>.05	23 (17-28)	21	>.05	61 (54-67)	37	<.001	11 (8-14)
	≥\$90,000	80 (76-85)	90	<.001	70 (65-74)	68	>.05	26 (20-32)	23	>.05	67 (60-73)	37	<.001	22 (18-26)
Education Level	No HS Diploma	55 (51-59)	65	<.001	33 (29-37)	21	<.001	-----	Not reported		54 (47-62)	17	<.001	2 (1-3)
	High School Graduate	69 (67-71)	75	<.001	42 (39-44)	36	<.001	14 (11-16)	11	.04	55 (51-58)	26	<.001	3 (3-4)
	Some College	83 (80-85)	85	.01	62 (60-65)	50	<.001	20 (17-24)	24	.02	62 (59-66)	33	<.001	9 (7-11)
	College+	78 (76-81)	86	<.001	63 (61-66)	61	>.05	24 (21-28)	22	>.05	65 (61-69)	38	<.001	15 (13-18)

Discussion

Principal Findings

While the conventional main focus of hospital EDs has been to provide immediate treatment to patients with acute conditions,

the use of new media could extend the reach of the ED visit. These clinical encounters provide unique and important opportunities to the clinicians and system of health care to positively influence individual health behavior beyond the emergency department setting.

We sought to define and differentiate new media from cell phone ownership to bring health care operationalization of electronic devices consistent with the communication literature. Furthermore, because information technology is already playing an increasing role in improving health care, delivering interventions, navigating the health care system, and improving the public's health at large, we wanted to determine (beyond the anecdotal) that sufficient numbers of ED patients own and use new media. Survey participants' ownership of cell phones (4934/5788, 85.25%) and device usage for calling (4892/4934, 99.15%) and texting (3595/4935, 72.86%) were high. Among all cell phone owners, mobile phone ownership was moderate (2500/4934, 50.67%) with minorities reporting the highest rate of ownership. Benchmarked against the Pew-CHCF study [99], we observed similar prevalence figures for cell phone ownership and use for texting as well as mobile phone ownership (Table 3).

EDs are concerned with enhancing continuity of care throughout an entire health system and optimizing cost containment. As a result, they have generally heightened and expanded their attention to pre-hospital and post-discharge care implications of acute care. Finding new forms of effective communication facilitates expanding the scope of prevention, health promotion, health maintenance, and disease management services [100-102].

ED patients are segmented in this study to those most likely to own and use new media technology. Hence, we determined the characteristics of ED patients that own and use new media to tailor intervention strategies. Text messaging can be used to provide health information to most cell phone users (depending on their phone plan). We examined the relationship between ED patients' use of text messaging and individual patient characteristics. A higher prevalence of text messaging was reported by ED patients who were female, younger, nonwhite, and more educated (Table 2). Text messaging was less common among ED patients regardless of gender, age group, race/ethnicity, or socioeconomic status.

While mobile phone ownership is not as ubiquitous as overall cell phone ownership, mobile phone technology is important for behavioral interventions (eg, mobile phone health apps). Thus, we examined the relationship between ED patients' mobile phone ownership and individual patient characteristics. Participants who were female, younger, nonwhite, and had higher income reported greater ownership of mobile phone technology (Table 3). Notably, ED participants with lower household income, less formal education, and either urban or rural residency (data not shown) reported the highest ownership.

Female and younger ED patients who owned mobile phones, as well as those with greater educational attainment, reported higher online searching for health or medical information. Consistently, ED participants reported greater health information seeking than the general population as measured by Pew-CHCF.

We found similar patterns of usage of cell and mobile phones in both the ED patient population and the general population with the exception that ED patients are more likely to use desktop and laptop computers to seek health information than a mobile phone and the general population is more likely to rely on e-mail to communicate through a laptop or desktop computer.

Limitations

We compared the prevalence of health information seeking by ED patients with that of the general population. ED participants invariably reported greater health information seeking than participants in the Pew-CHCF survey. Individuals presenting to the emergency department likely have health conditions that trigger new media use to manage disease and seek information on treatment and care.

Racial/ethnic minorities and persons of lower socioeconomic status were overrepresented in the EDs as compared to the general US catchment area. Compared to the benchmark Pew-CHCF survey, our ED sample was similar in terms of gender but (predictably) was made up of more nonwhite participants who were poorer and had less schooling.

Conclusions

Our study formally defines new media and disambiguates cell phones from mobile phones. We established a scientifically derived baseline of new media use for ED patients and determined that a critical mass of patients use new media and would perhaps benefit from new media technology to manage their health and seek information. Most importantly, we found that more marginalized populations—such as the poor, homeless [48], and minority patients—do not differ significantly in ownership or usage rates from the general population and that sufficient ownership exists to reach a significant portion of the population using new media. New media may be a health care equalizer to address health care disparities by reaching minorities and low income patients better. This research also suggests that potentially assisting ED patients without information technology is an option to extend services such as the Lifeline Program for Low-Income Consumers [103]. This study increases confidence in the utility of new media for health care services, interventions, and follow up [61,104105].

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Conflicts of Interest

None declared.

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Abbreviations

- ED:** emergency department
- CHCF:** California HealthCare Foundation
- CI:** confidence interval
- RA:** research assistant
- YNHHS:** Yale-New Haven Health System

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Original Paper

Use of Mobile Clinical Decision Support Software by Junior Doctors at a UK Teaching Hospital: Identification and Evaluation of Barriers to Engagement

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Abstract

Background: Clinical decision support (CDS) tools improve clinical diagnostic decision making and patient safety. The availability of CDS to health care professionals has grown in line with the increased prevalence of apps and smart mobile devices. Despite these benefits, patients may have safety concerns about the use of mobile devices around medical equipment.

Objective: This research explored the engagement of junior doctors (JDs) with CDS and the perceptions of patients about their use. There were three objectives for this research: (1) to measure the actual usage of CDS tools on mobile devices (mCDS) by JDs, (2) to explore the perceptions of JDs about the drivers and barriers to using mCDS, and (3) to explore the perceptions of patients about the use of mCDS.

Methods: This study used a mixed-methods approach to study the engagement of JDs with CDS accessed through mobile devices. Usage data were collected on the number of interactions by JDs with mCDS. The perceived drivers and barriers for JDs to using CDS were then explored by interviews. Finally, these findings were contrasted with the perception of patients about the use of mCDS by JDs.

Results: Nine of the 16 JDs made a total of 142 recorded interactions with the mCDS over a 4-month period. Only 27 of the 114 interactions (24%) that could be categorized as on-shift or off-shift occurred on-shift. Eight individual, institutional, and cultural barriers to engagement emerged from interviews with the user group. In contrast to reported cautions and concerns about the impact of clinicians' use of mobile phone on patient health and safety, patients had positive perceptions about the use of mCDS.

Conclusions: Patients reported positive perceptions toward mCDS. The usage of mCDS to support clinical decision making was considered to be positive as part of everyday clinical practice. The degree of engagement was found to be limited due to a number of individual, institutional, and cultural barriers. The majority of mCDS engagement occurred outside of the workplace. Further research is required to verify these findings and assess their implications for future policy and practice.

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KEYWORDS

clinical decision support systems; health care technology; human-centered computing; medical education; patient safety; ubiquitous and mobile computing

Introduction

Background

Although the influence of evidence-based medicine (EBM) on health care is gaining in importance, there can be challenges for health care professionals to practice EBM at the point of care [1]. Clinical decision support (CDS) systems, defined as “information systems designed to improve clinical decision making” [2], enable health care professionals to leverage the benefits of technology and access the latest evidence to guide their clinical practice [3]. Traditional forms of CDS range from electronic patient record database systems in which clinicians can access patient details and retrieve relevant drug information, through to standalone software applications that are effectively a repository or textbook of guidelines on a given clinical topic [2]. Despite the affordances brought by these CDS systems, a number of individual, organizational, and technological barriers affected the engagement of clinicians with the technologies [4].

Smartphones enable users to perform tasks such as replying to email and accessing Internet-based resources [5]. They can increase the productivity of people in the workplace, but can also provide an additional burden and distraction. They are increasingly prevalent with over 82% of doctors reported to be using a smartphone in the workplace to facilitate their care for patients [6].

The prevalence of smartphones among those entering the workforce is high, with 92% of junior doctors (JDs) owning such a personal device [6,7]. In the United Kingdom, JDs include foundation year (FY) doctors (those in their first 2 years of training following graduation) and core trainee (CT) doctors

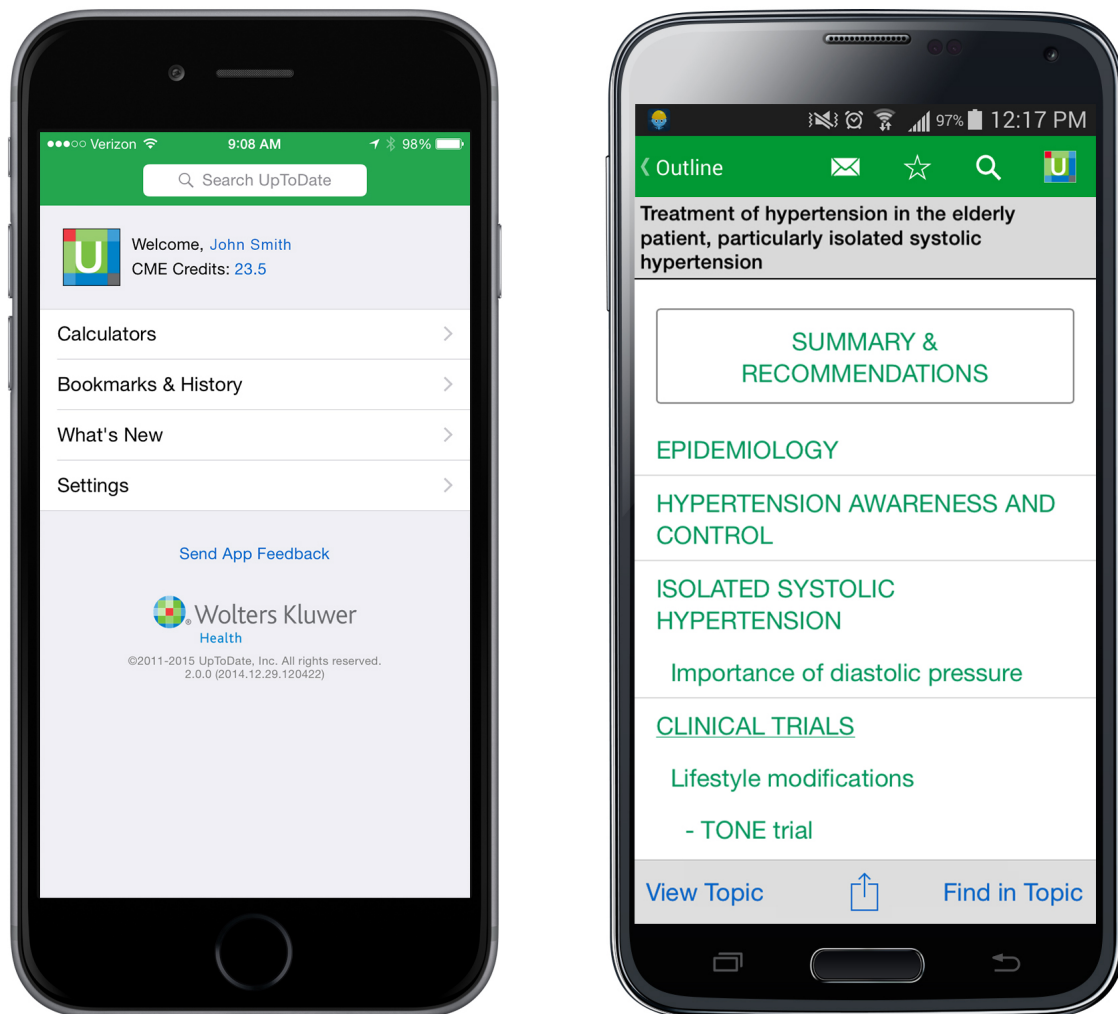
(in years 3-5 following graduation). This prevalence is increasing and parallels other trends such as the growth in health care-related apps, with over 10,000 now available [8]. This suggests that ownership and usage of mobile software applications among this group is already ubiquitous. Nevertheless, there is little understanding about the use of CDS on mobile phone (mCDS) devices by JDs for improving clinical care.

There are a wide range of papers describing the use of mCDS [9], yet few focus on the factors affecting engagement with mCDS by JDs. Previous studies explored the use of CDS on technology such as personal digital assistants [10] yet barriers to the use of these devices such as usability and functionalities likely relate to the outdated hardware, rather than the CDS tools per se. Although this evidence remains useful for understanding the challenges with technology acceptance among medical staff, more research about engagement with CDS following the development of smartphone devices is necessary. JDs are poor at answering their clinical questions and likewise they require significant support for finding answers on traditional CDS tools [11]. Therefore, better understanding about the usefulness of smartphones to meet their needs is required.

Study Objective

We aimed to explore the factors influencing JD engagement with mCDS (Figure 1) for answering clinical questions in the workplace. The objectives of this study were to quantify the usage of mCDS by JDs; to compare the perceived drivers and barriers held by individual JDs with their usage of the technology; and to triangulate these findings with patient perceptions about JDs using mCDS in the workplace.

Figure 1. An example of a clinical decision support system on mobile phones (UpToDate) on a smartphone displaying the home page and an Android device displaying an example topic.



Methods

Methodology

A mixed-methods approach was used for researching engagement with technology among JDs in this health care setting [12,13]. Mixed-methods approaches give researchers flexibility for exploring complex phenomena such as technology engagement, and enable data derived from multiple sources to be triangulated so that such complex phenomena can be more accurately explained.

Context

The study was completed as part of the University Hospitals of Leicester NHS Trust's wider clinical effectiveness (study reference number 6608E) and quality improvement program (Health Education East Midlands study reference number LEI0085), based in the East Midlands, United Kingdom. Therefore, all issues related to perceptions of surveillance and temporary behavior changes were minimized. The study was

undertaken across 4 in-patient wards in a tertiary center renal unit with a total of 59 beds. All patients are admitted under specialist renal care. Consent was obtained from all JDs and patients who participated in the study and both were reminded of their right to withdraw consent at any point during the period of data collection and analysis, before dissemination of the findings. All data were anonymized to remove personally sensitive or identifiable information. At the time of the study, all medical notes at the Trust were handwritten and there were no electronic patient records. There was no electronic prescribing system; however, hospital guidelines and British National Formulary were available on the hospital intranet, accessible from any desktop computer located on all wards [14]. As this study was conducted as part of the clinical effectiveness program, JDs were not asked to stop using other CDS that they were familiar with as this could have impacted patient care.

Sample

Sixteen JDs (FY1, FY2, and CT levels) were invited to participate in this study. These doctors were based on the renal unit as part of their individual training rotations across a 4-month period between August and November 2013. The doctors were provided with personal access to CDS technology (UpToDate) [15] on their mobile phone or equivalent device at the start of the rotation.

Data Collection

Overview

Data were collected from the following 3 main sources:

1. JDs usage with mCDS
2. JDs perceptions toward mCDS
3. Patients' perceptions toward mCDS.

Usage of mCDS

The usage statistics from JDs accessing the technology were collected to measure the quantity of mCDS use. An interaction was classified as a text search conducted by an individual for a specific query (eg, tacrolimus, transplant rejection, or heparin infusion). Other data were logged by the system, but they do not provide any insight into participant system usage. This includes, for example, system synchronization to receive software updates, Internet protocol address changes, and error logs.

Any interactions made by JDs while online, in this case text searches, were transmitted to a central server in real time. Usage data from offline mode were transferred when individuals next used the software online. All data were organized according to the time of the interaction to investigate periods of high and low engagement. The usage data were triangulated with the on-shift commitments of JDs to further contextualize the nature of usage with mCDS.

JD Perceptions Toward mCDS

To investigate the perceptions of JDs toward mCDS technology, semistructured interviews were conducted with JDs on 2

occasions during the rotation. The first interviews exploring factors affecting mCDS use were conducted after 2 months so JDs had enough time to settle into the workplace and develop ways of integrating the technology into their daily work. The second interviews were conducted after a further 2 months at the end of the job, to evaluate the main factors that promoted or prevented use of mCDS during the rotation. Prompts during the interviews included JDs' perceived usage, their perceived usefulness and usability of the mCDS, and perceptions about acceptability of use in the workplace in front of patients.

Patient Perceptions Toward Engagement With mCDS

Feedback from patients about their perceptions of JDs using mCDS in the workplace was collected using semistructured interviews. Only patients who had observed first-hand JDs using mCDS on the ward were invited to share their reflections. Only members of the local area Kidney Patient Association could be approached. Patients were asked to describe their recollections of a doctor's mCDS usage at the bedside, on the ward, or in other instances when they observed interactions with the technology.

Data Analysis

Overview

Quantitative and qualitative analyses were conducted on the data collected using 3 methods. All interviews were transcribed verbatim.

Usage of mCDS

Interactions with mCDS were divided into on-shift and out-of-hours interactions by cross-referencing the time of interaction with available on-shift data. On-shift data were not available for 2 JDs.

JD Perceptions Toward mCDS

A framework analysis of emergent themes based on the integrative model of technology acceptance among professionals [16] was completed on the qualitative data collected from JDs. The themes are outlined in [Table 1](#).

Table 1. Outline of the themes included in the integrative model of technology acceptance among professionals [16], which were used in the framework analyses of the interviews.

Framework themes	Definition
Personal innovativeness in information technology	The willingness of an individual to try out any new information technology.
Result demonstrability	The extent to which the tangible results of using an innovation can be observable and communicable.
Image	The extent to which use of an innovation is perceived as enhancing one's own image or status.
Subjective norm	The perception that other people considered important by the person think that he or she should perform the behavior.
Perceived behavioral control	The perception of internal and external resource constraints on performing the behavior.
Perceived ease of use	The extent to which a person believes that using the system will be free of effort.
Perceived usefulness	The extent to which a person believes that using the system will improve his or her job performance.
Behavioral intention	A person's subjective probability to perform a specified behavior.

The raw data were explored so that codes were applied to phrases which aligned to components of the model. Any code or theme that did not align with a component in the model was identified as an emergent theme and organized into a new component. All codes within components and existing or new themes were triangulated with findings from the other analysis to explain mCDS engagement among JDs.

Patient Perceptions Toward Engagement With mCDS

A thematic analysis was completed on the qualitative data collected from patients. This approach was chosen because there was no expectation that the process of coding would fit the data into a pre-existing model or frame. This inductive or data-driven approach ensured all themes were rooted in the raw data where the focus of inquiry was patients' perceptions, feelings, and experience of JDs' mCDS usage. In particular, the relationship between patients' subjective experience of mCDS usage by JDs and their confidence with the problem-solving or decision-making skills of the individual in question was explored. Furthermore, themes that identified a relationship between JD mCDS usage at the point of care and patients' subjective experience about safe or effective care on the ward were also explored. Finally, the themes identified by patients and JDs about mCDS were compared and contrasted.

Results

Usage of mCDS

A total of 142 mCDS interactions across 16 JDs were recorded during the 4-month study period (Table 2).

Five JDs made 14 or more recorded interactions. This equates to 90.1% of all observed interactions (n=128). Seven JDs did not use the mCDS software. The JD who interacted the most made 43 interactions, equating to 11 interactions/month. The mean number of interactions across the JDs who used mCDS (excluding those who did not interact at all) was 4 interactions/month. The 2 JDs who had the most interactions (43 and 36) were both FY1. These 2 JDs had nearly twice as many interactions as the JD with the next highest number of interactions (20). While this is potentially interesting, no further statistical analysis has been performed due to the small sample across the 3 occupational-grade groups.

Data from 14 of the 16 JDs were available to establish whether mCDS usage was conducted while on-shift or not. Of the 113 accountable interactions, 27 interactions were recorded while JDs were on-shift, and 86 interactions were recorded when JDs were off-shift. This suggests that a greater proportion of interactions are conducted off-shift. Unfortunately, the interactions for JD 4 and JD 5 could not be categorized as either on-shift or off-shift.

Table 2. Recorded interactions with clinical decision support on mobile phones among junior doctors.

Junior doctor (JD)	JD grade	Total interactions (n)	On-shift interactions (n)	Out-of-hours interactions (n)	Interview conducted? (Yes/No)
1	FY1	43	18	25	No
2	FY1	36	5	31	No
3	CT	20	1	19	Yes
4	CT	15	N/A	N/A	Yes
5	FY2	14	N/A	N/A	Yes
6	FY2	6	1	5	Yes
7	CT	4	0	4	Yes
8	FY1	2	2	0	Yes
9	FY2	2	0	2	Yes
10	FY1	0	0	0	Yes
11	FY2	0	0	0	Yes
12	FY1	0	0	0	Yes
13	FY1	0	0	0	Yes
14	FY1	0	0	0	No
15	FY2	0	0	0	No
16	FY1	0	0	0	Yes
Total	16	142	27	86	Yes = 12

JD Perceptions Toward mCDS

Overview

Twelve JDs completed a semistructured interview exploring their perceptions about using mCDS (Table 2). Four JDs were not available for interview due to their availability. The main themes that explain the engagement of JDs with mCDS based on the framework analyses of the integrated model of technology

acceptance among professionals [16] (Table 3) relate to personal innovativeness, and the impression given by the JDs when using mCDS to others around them (image and subjective norm), perceived ease of use, and perceived usefulness. Eight barriers or reasons for nonengagement with the mCDS emerged from these themes. They are categorized as being individual, institutional, or cultural (Table 4).

Table 3. Summary of the framework analysis of junior doctor perceptions of clinical decision support on mobile phones (themes that did not emerge have been removed).^a

Positive or negative perception	Framework theme	Personal innovativeness in information technology	Image	Perceived ease of use	Perceived usefulness	Subjective norm
Positive perceptions toward clinical decision support on mobile phones (mCDS) software	Number of times theme emerged	0	0	2	3	0
	Example comment	—	—	<i>It is fantastic to have it available...on your phone as well, that's brilliant.</i>	<i>I had downloaded it on my phone and I found it really helpful.</i>	—
Negative perceptions towards mCDS software	Number of times theme emerged	1	1	1	0	1
	Example comment	<i>I need to sign up for an Athens account and I haven't really done that either, purely because we've been updated with so many passwords and user-names. I thought this is one too many, I can't cope.</i>	<i>My major issue with it in terms of using it at work is still the acceptability of using mobile phones in a ward environment where everyone assumes that you are doing a million and one other things but certainly not looking up educational materials. I'm sure the patient still thinks that you are calling and arranging your social life.</i>	<i>If we are talking about BNF [British National Formulary app] I only use my phone, I don't use anything else because it's faster, it's easy access. But, this [mobile CDS software] is so much worse, it is killing me.</i>	—	See image comment

^aThis is based on the integrative model of technology acceptance among professionals [16]. Themes that emerged to explain the behavior of junior doctors (JDs) with clinical decision support on mobile phones (mCDS) related to perceptions around the ease of using mCDS and the perceived usefulness of mCDS for working as a JD, personal initiative, and capability for using technology in general, as well as the impression given by the JDs when using mCDS to others around them and the subjective norm. Eight individual, institutional, and cultural barriers were identified from these themes.

Table 4. Individual, institutional, and cultural perceptions to explain the engagement with clinical decision support on mobile phones. The 3 categories emerged from 8 subthemes.

Perceptions	Theme	Example
Individual	Usability: Small screen hard to read	<i>I don't particularly use it on my phone. I sometimes do, but it tends to be not necessarily at the bedside or on the ward because it's quite hard to look at on the phone. [JD 7, 4 interactions]</i> <i>I use it on the computer a lot of the time...rather than using it on my phone, just because we have quite a few computers on the ward and it is just easier, bigger screen. [JD 13, no interactions]</i> <i>I prefer the computer you know...the mobile is small. I try to use it from the computer, it's much more comfortable. [JD 3, 20 interactions]</i>
	Fit-for-purpose: clinical decision support on mobile phones (mCDS) preferred as out-of-hours learning resource	<i>I use it more for MRCP [Membership of the Royal College of Physicians diploma] revision I think rather than actually looking things up for work. I've only used it maybe once or twice at work for work reasons. [JD 6, 6 interactions]</i>
	Perceived lack of time	<i>[A barrier is] physically having time allocated to be able to look through these different resources. [JD 10, no interactions]</i>
	Existing resources equally effective	<i>I generally ask someone...because there's generally a lot of people around, or use the hospital guidelines, they are really quite good. [JD 11, no interactions]</i> <i>[I use] mostly BNF online, BNF paper copy. I've used up-to-date a few times. [Interviewer: On your own phone?] No. On the computer. And also asking the pharmacist questions, and asking the seniors questions and the...actual Internet of the hospital. [JD 7, 4 interactions]</i>
Institutional	Information conflicts with local/national guidelines	<i>[A barrier is] knowing that most of what you are researching is going to be overruled by local guidance anyway, so it doesn't actually tie in with what your local trust policy is saying. [JD 10, no interactions]</i> <i>The other thing I've found with [the mCDS] was that...it's not NICE Guidelines...and it's not, not always Trust guidelines in terms of, sort of, management and prescribing...There's a Trust policy on those sorts of things...If one deviates from the other, obviously you're going to go with the Trust policies, not [mCDS]. [JD 12, no interactions]</i> <i>The problem is though...when you are working in a big Trust really, you should be following clinical guidelines that are available. [JD 8, 2 interactions]</i>
	Lack of support	<i>I think I need to sign up for an Athens account and I haven't really done that either, purely because we've been updated with so many passwords and usernames. I thought this is one too many, I can't cope. [JD 12, no interactions]</i> <i>They said before our rotation they will send [information about the mCDS introduction] meal as well. [Interviewer: Really?] Yeah, and then they kept asking us, "Did you want the [mCDS introduction] meal?" [sic] I was like, "We did not receive any email regarding the [mCDS introduction] meal." [JD 9, 2 interactions]</i>
	Lack of supporting technological infrastructure	<i>The [Hospital] is not blessed with [Wi-Fi] signal, so that makes it very difficult to try and access things on your phone. [JD 12, no interactions]</i>
Cultural	Prevailing cultural norm surrounding technology discourages use of mobile devices at bedside	<i>I think my major issue with it in terms of using it at work is still the acceptability of using mobile phones in a ward environment where everyone assumes that you are doing a million and one other things but certainly not looking up educational materials...I'm sure the patient still thinks that you are calling and arranging your social life and so I just don't like that gap in terms of people accepting that you can be using or texting or being on Facebook or something. That has limited how much I've used it in the workplace, and I will really miss not having it soon on my mobile device. [JD 4, 15 interactions]</i>

Individual Barriers

JDs preferred using the desktop-based CDS to the mCDS where reading information on a small screen in certain clinical contexts was perceived as challenging. JDs also preferred using mCDS as a learning resource in their own time rather than as a tool exclusively to aid them at the bedside in the workplace. Furthermore, JDs suggested difficulty integrating mCDS into their pattern of work, which was conditioned through previous

jobs where mCDS was not available. As a consequence, JDs had difficulties integrating mCDS into their role in the workplace and so sought instead to use alternative and more established sources of support when presented with a clinical question. On direct probing of these alternative sources, at least seven were cited by JDs within interviews (Table 5). It is particularly surprising that colleagues were not consulted for a second opinion more often as a CDS resource, which is in contrast to previous findings [17].

Table 5. Alternative sources of clinical decision support reported by junior doctors in this study.

Resource	Number of junior doctors referring to resource
UpToDate desktop [18]	7
British National Formulary Desktop [19]	6
British National Formulary book [14]	3
British National Formulary App [20]	2
Colleagues as a “second opinion” (seniors/pharmacists)	2
Local clinical guidelines	1
Academic journals	1

Institutional Barriers

JDs confirmed that inconsistencies between recommended and expected clinical practice presented challenges to the adoption of mCDS guidance. A regular dilemma for JDs was choosing between suggestions given by mCDS and receiving instruction from alternative, traditionally “trusted” sources. This dilemma was more challenging when instruction varied across sources such as local, mCDS, and national guidance (eg, National Institute for Health and Care Excellence clinical guidelines) [21]. JDs gave up using mCDS in these situations, defaulting to resources perceived as being more accessible such as desktop computers.

The motivation for JDs to persist with using mCDS against this backdrop was challenged, especially in the face of other barriers such as reported usability and accessibility issues. Although JDs cited usability and accessibility as a factor for deterring the use of mCDS, all were provided with personal subscriptions for the software to enable access with minimal effort and all participated in an induction session where mCDS was carefully introduced to them. Irrespective of these specific accessibility issues, JDs also cited the general lack of information communications technology infrastructure as a barrier to active mCDS use.

Cultural Barriers

Some of the JDs explicitly expressed belief that the use of mCDS in direct view of patients would be perceived as being unprofessional. They, therefore, chose not to use devices in plain view. This concern was also raised in relation to senior colleagues considering JDs’ use of their mobile device in front of patients or on the ward as being unprofessional. This dissuaded JDs from using mCDS at and away from the bedside. Paradoxically, other JDs acknowledged the opportunity for using mCDS positively and so used mCDS, as they felt it appropriate and had less concern for the negative views of others.

Patient Perceptions Toward mCDS

Four kidney patients were interviewed as part of the study. Patients interviewed were all members of the local area Kidney Patient Association. At the time of the study only 4 of their members were on the ward. The study was not permitted to approach other patients due to confidentiality reasons.

All patients were in favor of using technologies such as mCDS to better inform clinical diagnostic decision making.

Furthermore, all the patients were comfortable with JDs using the mCDS at the bedside as part of the consultation process if appropriate to the delivery of care.

I don’t mind, I’m quite happy with that. There’s so many drugs and so many side effects and whatever, I want them to be as informed as possible, please.
[Patient 3]

Patients acknowledged the complexity of their medical condition, which comprised multiple long-term conditions. For the patients, deciphering the condition that contributed to their presenting problem was not obvious. Furthermore, patients believed that prescribing medication and avoiding drug interactions required JDs in the absence of clinical experience to seek support from a variety of sources such as mCDS.

Patients believed accessing mCDS was equivalent to asking senior clinicians for the answer when making a clinical decision.

When the doctor says to you, “I’ve got to go and consult a senior,” we exactly know what they’re going to do. It’s the same thing. Otherwise they say to you, “I have to go and look it up.” [Patient 1]

Patients also felt reassured that JDs sought to use mCDS in their clinical diagnostic decision making, rather than make decisions without some form of support in a setting of uncertainty. Furthermore, patients believed that the comfort with using mCDS in the clinical diagnostic decision-making process communicated something positive about the confidence and competence of the health care professionals.

...a GP [General Practitioner] that was looking after me, he was ready to say, “I want to check on one or two things,” and he would pull them up on his PC. You can’t know everything. I think it’s reassuring to know that your physician isn’t pompous enough that it stops them from genning-up [revising] on something that they’re uncertain about or totally ignorant, maybe. So I’d rather they do that...I think it’s reasonable to use the tools of the day, and [mCDS is] one of them. [Patient 4]

Patients stressed the importance of JDs explaining their intention for using mCDS prior to doing so. While patients were supportive of mCDS, all felt that a brief explanation of the rationale for using mCDS in the consultation was important to prevent any misappropriation of their behavior, such as handling

of devices that could be seen as an intention to use them for nonwork-related purposes.

If the doctor does have to use a mobile while he's with the patient, he has to just tell the patient, "Listen, I'm looking up a certain drug, I want to see what it says about it," and the patient will perfectly understand that...As long as they explain it, that's fine. [Patient 1]

If they say, "I'm just going to use this to just check on this, because it could have side effects or it could have something, so, do you mind if I just look at it now?" That's all they need to do, isn't it?" [Patient 3]

Discussion

Descriptive Findings

This research explored the factors influencing JDs engagement with mCDS for answering clinical questions when in the workplace; in addition, we compared the perceived drivers and barriers held by individual JDs with their usage of the technology and considered these findings in relation to patient perceptions about JDs using mCDS in the workplace. Surprisingly, of the 16 participants who had the opportunity to utilize the mCDS through the free, personal subscription, no interactions were recorded for 7 JDs. As many as 128 (90.1%) of the interactions were recorded by 5 of the 16 JDs, with a range from 14 to 43 interactions/JD, indicating a large individual variance. The remaining 14 interactions (10%) were recorded by the remaining 4 JDs. Of the 9 JDs who did interact with CDS, 4 interactions were recorded on average/month. An interesting finding is that the majority (n=86) of the interactions were conducted out-of-hours.

mCDS is more accessible to the end user at the bedside to make clinical decisions, compared with equivalent systems available on desktop computers. JDs who lack experience are more likely to seek information to support clinical diagnostic decision making compared with clinicians who are more likely to use experience as a driver for decision making [17,22]. The usage of mCDS was initially considered low by the research team (4 interactions/month for those who did engage). However, the engagement of JDs is more than other research which concluded that bedside use of CDS was, "feasible and useful in addressing unresolved clinical questions" [17]. For example, Phua et al [17] reported 157 searches by 27 doctors (5 consultants, 2 associate consultants, 4 registrars, 13 medical officers, and 3 house officers) between their study period from September to November [17]. Nonetheless, these figures do seem to be low given the number of clinical decisions made in practice. The barriers identified in this and previous studies provide explanations for this low engagement which should be addressed in future research.

At first glance, the attractiveness to using mCDS for JDs may appear to be when physical presence in the form of senior support is lacking; however, this study did not confirm this assumption. In the absence of previous studies exploring the use of mCDS among JDs, possible reasons for reduced mCDS

use while on-call may include the increased availability of senior advice or the perceived lack of time from volume of work. A previous study identified that JDs found lack of time as a pervasive barrier to answering their clinical questions with evidence-based support tools accessible on desktops [23].

Junior Doctors' Perceptions Toward mCDS

The main barriers to mCDS were anticipated following a review of conceptual models for explaining technology acceptance by health care professionals [16,24-27]. These models did not predict all the barriers identified in this study. Part of this is due to the model variables not including some of the specific characteristics unique to mCDS. Previous researchers have criticized the exclusive use of models to explain drivers or barriers for engagement with technology for this very reason [28,29]. Although existing models may explain an individual's intention to use a given technology such as mCDS, they lack solutions to overcome context-specific barriers to engagement. This suggests that the models need to be revisited in relation to mobile-specific technology in tertiary care.

Individual Barriers

Usability issues were a barrier to mCDS use in this study. This supports the findings from other studies in general workplace settings including health care, which have identified screen size as a particular issue for end users [30,31]. However, some studies report that doctors prefer smaller devices with better form function over a larger device that would be easier to read at work [32], suggesting that usability issues are context specific and require further research in the health care setting. Alternatives to smartphone access for improving usability issues include the provision of tablets; however, other factors such as the risk of theft in the health care setting need careful consideration [33].

The extent of mCDS usage outside the workplace rather than within it has not been extensively reported because research to explore engagement of technologies has generally taken place as during work hours [17]. This observation suggests that the attractiveness of mCDS among JDs was sufficient to encourage them into accessing the resource away from the workplace, despite suggesting perceived lack of time was also an issue. Similarly, the range of alternative sources used for accessing other CDS systems suggests that it is not the perceived usefulness of CDS in general that is of concern. Previous studies in North America have indicated that desktop versions are most widely used among doctors in training [34] as well as established nephrologists [35]. Alternative sources of information are likely to be advocated in some contexts and may form the basis of individual, institutional, and cultural habits. These practices may be a barrier for the adoption of mCDS but are not necessarily problematic for patient safety and decision making. Rather, CDS should be used to supplement these practices. Clinical guidelines should be developed locally to advise how inconsistent information across sources should be resolved.

Institutional Barriers

Although JDs cited that a conflict between local guidelines and information on commercial software prevented greater engagement with mCDS, some tools do have functionality for

clinicians to edit information within the software and achieve better concordance with local guidelines [36]. Further research is necessary to examine whether alternative choices represent deviations from clinical guidelines or whether the clinical context in which JDs were immersed in required an alternative approach.

Despite an induction to the technology at the start and a group-based review in the middle of the rotation, this study supports the finding from the wider literature that a perceived lack of support is likely to inhibit technology use. A literature review of evidence for measures to support technology implementation in health care confirms a lack of appropriate training and technical support as major barriers to engagement with technology [37]. Poor information technology infrastructure for new technologies such as Wi-Fi access is already a well-reported barrier for engagement with mCDS by JDs in other parts of the United Kingdom [38].

Cultural Barriers

The culture of the renal unit emerged in the interviews as a barrier to JD engagement with the mCDS. This relates to the use of a personal mobile device on the ward to access mCDS as being perceived by patients and senior colleagues as unprofessional or demonstrating inexperience. Conversely, some of the JDs were not concerned. Previous research has demonstrated that there can be striking differences between what individuals consider to be socially appropriate mobile phone use in particular contexts [39]. Palen et al [39] demonstrated that behavior and considerations for what is deemed to be appropriate are modified quickly following experience. Nickerson et al [40] also reported differences between what is acceptable voice and texting mobile phone use based on national culture and a user's age.

These findings suggest 2 things for future adoption of mCDS at the bedside. First, if the usage of mCDS were normal practice for all health care professionals, these barriers would be minimal. Second, national culture and age will have an impact on what is deemed to be appropriate or not. However, given the sensitive environment of health care, further research should establish whether or not Palen et al's [39] and Nickerson et al's [40] findings predict what is socially appropriate for mobile device use in health care. For example, Brady et al [41] reported that mobile communication devices can be contaminated with bacteria and as such procedures have to be followed to reduce contamination or banned in some more critical hospital areas. If there were a number of publicized episodes of such contamination, the perception toward mobile device use on wards and at the bedside would soon decline.

Patient Perceptions Toward mCDS

Despite the positive feedback from patients about the use of mCDS by participants, other research suggests that patients who observe clinicians using mCDS perceive them as being having poorer diagnostic ability and as demonstrating less professional awareness compared with clinicians who do not regularly access such technologies [42,43]. In their case [42,43], research involved simulations with undergraduate students playing the

role of patients; therefore, how well these perceptions generalize to the beliefs of patients in real practice is unclear.

Limitations

There are 4 main limitations to this study. First, the lack of data attributable to individual users who accessed CDS on desktop computers limits the true engagement of JDs with CDS to be evaluated. There is a strong case for enabling greater ease of access on desktop versions, rather than forcing individuals to login (and capture their individual user information), which risks people not using the resource in the first place. Second, no data were collected on the use of other online CDS accessed through the mobile phones. A number of online reference tools such as Medscape also provide CDS; therefore, the actual engagement with CDS in the widest sense is likely to be underreported. Third, the use of mCDS by senior colleagues was not studied despite the apparent influence of their actions on the behavior of JDs. Finally, the actions that senior colleagues expect JDs to take when they are uncertain and have unanswered clinical questions were not identified in this study, although these appear to influence the behavior of JDs. Thus, these should be the subject of future research.

Implications

The findings of this study carry a number of implications for current practice, institutional policy, and further research. The perceived lack of time cited by JDs for using mCDS raises questions about the usage and accessibility to these technologies at medical school. The need for medical students and JDs to become more digitally literate was recognized 20 years ago [44]. Twenty years later, this study's findings lend further support for this call. Health care professionals are now working in an age where the medical knowledge doubling time is rapidly reducing and predicted to be only 73 days by 2020 [45]. Rather than squeezing more new things into undergraduate or postgraduate curricula, developing traditional communication skills courses and re-examining the role of digital devices such as mCDS in the consultation process may seem more appropriate. Furthermore, over time and with more practice using mCDS as part of a forward-looking training program, productivity and quality of patient care could improve, resulting in benefits for patients, health care professionals, and organizations [46].

Organizations should carefully consider the reported individual, institutional, and cultural barriers before implementing new technologies such as mCDS, as they otherwise risk little or no technology adoption by health care professionals. Active training and technical support must be provided to all potential end users, with protected time set aside to target barriers such as misconceptions, and give health care professionals the best chance of engaging with the software. Technical infrastructure must be evaluated prior to adopting technology such as mCDS that requires frequent updates to ensure information is up to date. Without a reliable Internet connection, the sustainability of technology adoption may be affected detrimentally, as health care professionals may soon abandon technology that is not reliably available and is potentially out of date. Buy-in from management and senior clinicians is also likely to influence

uptake from JDs and the prevailing beliefs held by clinicians about new technologies accessible on mobile devices.

JDs engaged with mCDS outside the workplace, despite the primary function of the technology being a CDS tool for answering clinical questions at the bedside. Although usability and in particular screen size was reported as a barrier for mCDS use, alternatives such as tablet computers are potentially available. Clearly, more research is necessary to better understand the feasibility of providing such devices for the ward-based setting, given the associated risks such as theft. One of the main unanswered questions where there is a paucity of evidence concerns the impact of mCDS or CDS upon patient care [38]. A multisite study [47] suggested correlation between availability of a desktop-based version of CDS and a shorter length of stay with lower mortality rates for patients. However, while the effects in small and nonteaching hospitals were strong, the benefits were not as clear in larger teaching hospitals [47]. A large-scale study in the United Kingdom is necessary to confirm the benefits and assess the nature of impact before reallocating significant resources to mandate the use of any innovative CDS systems among JDs in the National Health Service.

Conclusions

This research explored the factors influencing JD engagement with mCDS for answering clinical questions in the workplace. The usage of mCDS to support clinical decision making was considered to be positive as part of everyday clinical practice. However, there are large differences between JDs' usage. This is attributed to individual, institutional, and cultural barriers

that must be overcome for mCDS to become a part of clinical working practice. Individual barriers to engagement include usability issues such as finding information hard to read due to the small device screen, preference to use the mCDS away from the workplace, feeling pressured to have sufficient time to engage with the mCDS, and feeling more comfortable in using more familiar sources of clinical support on the ward. Three institutional barriers were reported to mCDS engagement, namely, disagreement between information given by the mCDS and local or national guidelines, a lack of support provided to JDs by the implementation team, and poor Wi-Fi coverage at the hospital. One major cultural barrier existed, in relation to JDs' concern for being seen to use the mobile phone while interacting with patients. Patients, contrary to JDs' concerns, felt great enthusiasm for mCDS to inform and enhance patient safety, on the assumption that JDs would explain why a mobile phone was being used as part of doctor-patient interaction.

The study observed the implementation of mCDS into clinical use for JDs and found that engagement among the user group was low, albeit more than that of similar studies. Many of the barriers identified are relevant to the implementation of all new technologies in health care. In particular, 2 barriers (providing adequate support to JDs and changing organizational culture to encourage engagement) are of particular note as these require change at the institutional level. Two novel findings emerged from the study, namely, patients reported positive perceptions of mCDS use throughout patient interactions and the majority of user engagement with the tool occurred outside of the workplace environment.

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Conflicts of Interest

None declared.

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Abbreviations

- CDS:** clinical decision support
- CT:** core trainee
- EBM:** evidence-based medicine
- FY:** foundation year
- JD:** junior doctor
- mCDS:** clinical decision support on mobile phones

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Original Paper

Mobile Phone-Connected Wearable Motion Sensors to Assess Postoperative Mobilization

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Abstract

Background: Early mobilization after surgery reduces the incidence of a wide range of complications. Wearable motion sensors measure movements over time and transmit this data wirelessly, which has the potential to monitor patient recovery and encourages patients to engage in their own rehabilitation.

Objective: We sought to determine the ability of off-the-shelf activity sensors to remotely monitor patient postoperative mobility.

Methods: Consecutive subjects were recruited under the Department of Neurosurgery at Columbia University. Patients were enrolled during physical therapy sessions. The total number of steps counted by the two blinded researchers was compared to the steps recorded on four activity sensors positioned at different body locations.

Results: A total of 148 motion data points were generated. The start time, end time, and duration of each walking session were accurately recorded by the devices and were remotely available for the researchers to analyze. The sensor accuracy was significantly greater when placed over the ankles than over the hips ($P < .001$). Our multivariate analysis showed that step length was an independent predictor of sensor accuracy. On linear regression, there was a modest positive correlation between increasing step length and increased ankle sensor accuracy ($r = .640$, $r^2 = .397$) that reached statistical significance on the multivariate model ($P = .03$). Increased gait speed also correlated with increased ankle sensor accuracy, although less strongly ($r = .444$, $r^2 = .197$). We did not note an effect of unilateral weakness on the accuracy of left- versus right-sided sensors. Accuracy was also affected by several specific measures of a patient's level of physical assistance, for which we generated a model to mathematically adjust for systematic underestimation as well as disease severity.

Conclusions: We provide one of the first assessments of the accuracy and utility of widely available and wirelessly connected activity sensors in a postoperative patient population. Our results show that activity sensors are able to provide invaluable

information about a patient's mobility status and can transmit this data wirelessly, although there is a systematic underestimation bias in more debilitated patients.

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KEYWORDS

mobilization; activity tracking; postoperative; physiotherapy; functional recovery; physical therapy; gait; neurorehabilitation

Introduction

Functional recovery refers to improvement in mobility and independence of activities of daily living (ADL) after hospitalization for surgery or acute illness. It is a widely used outcome measure, especially in postoperative patients and in those with neurological conditions. Mobilization is a cornerstone of rehabilitation therapy not only in the hospital and acute care settings, but also at home and in the community [1]. Whereas close supervision and monitoring generally allow health care professionals to track improvement in hospitalized patients, objective measures of recovery in the outpatient setting are lacking [2]. Novel and affordable physical activity sensors may finally provide such a measure, but their accuracy in patients with limited mobility is variable and the protocols for using them are not standardized.

Early in-hospital mobilization reduces the risk of conditions related to prolonged bed rest—pulmonary embolism, atelectasis, pneumonia, decubitus ulcers—and is associated with improved survival, decreased length of hospitalization, and improved psychological well-being [3-5]. Not only are many of these benefits seen in postoperative neurosurgical patients—both spine and cranial—but also in patients recovering from joint replacements, cardiac surgery, stroke, breast cancer, and those in the intensive care unit (ICU) [6-11]. Increased mobilization in the outpatient setting is associated with improved survival and functional status, and the degree of mobilization may be quantified by measures such as gait speed, which itself correlates with survival [12-16].

Commercially available activity sensors have tremendous potential to provide this data because recent technological advances have resulted in devices that are small, wearable, affordable, and able to relay their data wirelessly via patient mobile phones or wireless networks at home or in the hospital [15,16]. Certain sensors contain accelerometers, which measure physical activity—number of steps taken, distance ambulated, gait velocity—by calculating body movements in one, two, or three orthogonal planes [17]. They record continuously for days to weeks and produce data that, in turn, may be used to interpret the duration, intensity, frequency, and variations of the patient's physical activity over time. Most significantly, this data can be collected and analyzed in real time while the patient is in his or her home environment.

However, there is little consensus on how to use activity sensors to provide an *accurate* measure of patient mobility. To address this issue, we sought to evaluate the usability for remote assessment and accuracy of a common, widely used activity sensor to quantify postoperative mobility. We hypothesized that a wearable motion sensor may vary in accuracy depending on

where it is positioned on the patient's body [18] and the patient's degree of disability as it relates to gait [19,20].

Methods

Ethical Approval

This study complies with the Declaration of Helsinki. This research protocol has been approved by the Columbia University Medical Center Institutional Review Board (IRB) (protocol number AAA-M6702).

Study Population

A total of 27 consecutive subjects were prospectively recruited from a convenience sample of inpatients under the Department of Neurosurgery at Columbia University from November 2013 to July 2014. The patient subjects were a median of 3 days postoperative and were enrolled during their first or second inpatient physical therapy session provided by the Department of Rehabilitation and Regenerative Medicine. Of the 27 patients, 20 (74%) were postoperative spine patients (primarily laminoplasties, laminectomies, and microdiscectomies) and 7 (26%) had had craniotomies for tumors or vascular malformations. Additional patient characteristics are included in [Table 1](#) in the Results section. Inclusion criteria were patients who were ambulatory prior to hospitalization, able to follow commands, and able to ambulate at least 4 meters without stopping during the physical therapy session. Exclusion criteria were patients with extrapyramidal disorders, significant visual impairment, severe and debilitating pain, severe sensory neuropathies, vestibular dysfunction, and patients under 18 years of age. The study was approved by the Columbia University Medical Center IRB, and each subject provided informed consent for participation in the study. Each patient received full neurosurgical standard of care, and patient health information used in the study was used in accordance with Health Insurance Portability and Accountability Act (HIPAA) privacy policies.

A total of 10 healthy volunteer controls with no preexisting gait abnormalities were also included in the study as a comparison. Their characteristics can also be found in [Table 1](#).

Instrument

The activity sensor used was the FitBit Zip (produced by FitBit, San Francisco, CA). The device records data such as the number of steps taken and the time stamps of when these steps occurred, and automatically syncs to mobile phones (and other devices) via Bluetooth. The recorded data is uploaded online to a user-friendly personalized account, and is easily searchable by date and time with a resolution of 15-minute time intervals. FitBit is considered one of the leaders in the market of wearable activity sensors, and at a cost of under US \$60, the Zip model

is far more affordable than comparable devices [21]. The device detects movement by using a built-in 3-axis accelerometer and, according to the company, it may be worn in several locations including on a belt, in a pocket, or over the chest using an attachable clip. Time is recorded by a built-in clock, which syncs to the mobile phone to ensure accuracy. The device is small (25.5 x 28 x 9.65 mm), light (8 grams), has 4 to 6 months of battery life.

Criterion Standard

Two researchers (BT, EB) observed patients during each session with a physical therapist. Similar to methods used in previous studies [17], the gold standard for the actual number of steps was the average of the two values counted by each researcher using a mobile counting app.

Figure 1. Placement of the activity sensor.



Walking Course

Each patient was asked to ambulate at a self-selected pace down a flat level course that was set up with the 0-meter, 4-meter, and 10-meter lines marked, and then further than 10 meters if deemed safe and appropriate by the physical therapist. If the patient walked further, this total distance was also recorded. Immediately after standing up from bed, the patients were asked to ambulate to the 0-meter starting line, which was always within 1 meter of the foot of their bed.

Data Collection

The gold standard number of steps was counted from the 0-meter to 4-meter line, 0-meter to 10-meter line, and the 0-meter line to the total distance if the patient ambulated further. A digital stopwatch with 1/10-second resolution was also used to record the time elapsed during the 0-meter to 4-meter and 0-meter to 10-meter intervals. The activity sensors recorded the number of steps taken for the total distance ambulated, and the reading

Procedure With Accelerometer

Researchers

Patients were seen for standard inpatient physical therapy sessions with a licensed physical therapist and two researchers for the study. The two researchers were blinded to the type of surgery and the postoperative day.

Sensor Placement

Four activity sensors were placed on each patient with one FitBit Zip at each of the following locations: on the right and left hips over the anterior superior iliac spine, as suggested by the manufacturer and by previous studies [22], and laterally over the right and left ankles (see Figure 1) due to hypothesized increased detection of movement. The sensors were placed on each patient immediately before beginning the course at the 0-meter starting line.

from each of the four was documented. The 15-minute time interval corresponding to each physical therapy session was searched on the online account or the mobile app, and the number of FitBit-counted steps during that time was recorded; there were no overlapping intervals. Controls followed the same protocol except that they did not ambulate further than 20 meters.

Clinical Variables

Sensor Accuracy

The primary outcome was the accuracy of the sensors in terms of mobility assessment, which was assessed by comparing the total number of steps recorded by each tracker to the total number of steps counted by the researchers. We also verified the time accuracy of the sensor by comparing the recorded times—available on both the Web interface and mobile phone app—to those recorded by the researchers.

Patient Demographics

Recorded information included postoperative day, type of procedure (ie, spinal surgery or craniotomy), postoperative diagnosis, presence and degree of weakness on standard neurological exam, age, and gender (see [Table 1](#)).

Level of Physical Assistance

To assess the level of physical assistance that the patient required to safely ambulate, the 6-point, graded Functional Ambulation Category (FAC) (see [Multimedia Appendix 1](#)) was used, which ranges from a score of 0 (patient is unable to independently ambulate) to 5 (fully independent) [23]. The FAC has been shown to predict ambulation ability in poststroke patients, and it correlates with other measures of functional recovery [24]. The FAC was determined in accordance with the same physical therapist at each session. It was also documented whether the patient used a rolling walker as an assistive device.

Statistical Analysis

The total number of steps counted by the two researchers (gold standard) was compared to the steps recorded on the activity sensors using an intraclass correlation coefficient (ICC) [25]. This was performed for the sensors at all four bodily positions, the average of both ankles together, and the average of both hips together. The ICC was also calculated for subgroups based on the use of a rolling walker, FAC, and step length. To provide a more detailed analysis of the degree to which sensor accuracy is affected, the percent difference of sensor-recorded steps from the gold standard was calculated in terms of all four sensors, ankle average, and hip average. One-way analyses of variance (ANOVAs) were performed to compare the sensor difference

from the gold standard, using the null hypothesis that the difference equals 0%. After an approximately normal distribution was verified, Student's *t* tests—one sample, paired sample, or independent samples where appropriate—were performed to compare the sensor differences from the gold standard, again using the null hypothesis that the difference equals 0%, between hips and ankles within the subject groups, and between subjects and controls. The chi-square test, ANOVA, Fisher's exact test, independent Student's *t* tests, and the Mann-Whitney U test were used when appropriate.

To identify independent predictors of accuracy, a multivariate model was conducted that included the following variables: age, gait speed, step length, postoperative day (POD), and surgical group. All statistical analyses were performed with SPSS version 21.

Results

Overview

There were a total of 148 motion data points generated from 37 individuals—27 patients and 10 controls—who met inclusion and exclusion criteria for enrollment in the study. Characteristics of the patient subjects are shown in [Table 1](#). The 10 healthy controls had a median age of 27.5 years (interquartile range [IQR] 26.3-36.8), average gait velocity of 1.05 m/s (SD 0.83-1.19), and average step length of 0.646 m (SD 0.616-0.679). The devices recorded the correct date and time of all sessions, each lasting 10 to 15 minutes, with 100% accuracy. The data were visible on the mobile phones and were successfully uploaded online in 100% of cases.

Table 1. Characteristics of patient subjects (n=27).

Characteristic	Median (IQR ^a), n (%), or mean (SD)
Age in years, median (IQR)	57 (44-68)
Gender (male), n (%)	13 (48)
Walker used during session, n (%)	14 (52)
Average gait velocity (m/s) ^b , mean (SD)	0.260 (0.156-0.357)
Average step length (m) ^b , mean (SD)	0.232 (0.169-0.278)
Total distance walked (m), median (IQR)	50 (21-62)
Total steps ambulated ^c , median (IQR)	184 (127-255)
Postoperative day, median (IQR)	3 (2-5)
Functional Ambulation Category (FAC)^d, n (%)	
0	1 (4)
1	4 (15)
2	9 (33)
3	13 (48)
Surgical group, n (%)	
Spine	20 (74)
Craniotomy	7 (26)
Weakness (upper and/or lower extremity)^e, n (%)	
Right-sided only	2 (7)
Left-sided only	5 (19)
Both	5 (19)

^aInterquartile range (IQR).

^bCalculated during the 4- or 10-meter walk.

^cAs determined by researchers using digital counting app.

^dFAC is a measure of ambulation on a scale of 0 to 5; see [Multimedia Appendix 1](#) for details.

^eDetermined by physician on standard neurological exam.

Hip Versus Ankle Accuracy

In the subject group, the ankle sensors were more accurate in counting steps than the hip sensors when compared to the gold standard number of steps counted by the observers (ICC .837 vs .326, respectively). This inaccuracy was due to undercounting, since the hip sensors significantly underestimated the number of steps by -81.4% on average compared to the -26.1% underestimate seen in the ankle sensors ($P<.001$) (see [Table 2](#)). In approximately 50% of the subjects, one of the ankle trackers was accurate to within 15% (-15% to +15%). The underestimation in the subject group differed significantly from the respective ankle ($P=.01$) and hip ($P<.001$) recordings in the control group. Unlike in the subject group, the ankle and hip sensors in controls did not differ significantly from the gold standard, and they both had very good accuracy (ICC .890 and .863, respectively).

Effect of Clinical Variables

[Table 2](#) depicts the effect of the clinical gait variables on ankle tracker accuracy for the subject group. Although the ICCs appear comparable between the patients who used a rolling walker and

those who did not, there was a significantly greater underestimation in the recordings for patients who used a walker than those without a walker (-45.1% vs -5.6%, respectively; $P=.02$) (see [Figure 2](#)). All subjects had an FAC ≤ 3 , and the FAC appeared to affect the ankle tracker accuracy. Of the 27 subjects, 13 (48%) had an FAC of 3 (only standby guarding for potential falls), and 9 (33%) had an FAC of 2 (requiring assistance with balance or coordination). While the ICCs appear comparable for those subjects with an FAC of 3 or less, this was not the case for the mean difference. In the group with an FAC of 3, mean difference was only +0.78%, versus a significant underestimation in the more debilitated group with an FAC <3 which was -51.0% ($P<.001$). More specifically, as shown in [Figure 3](#), there was a significant underestimation in the group with an FAC of 2 (-46.2%, 95% CI -80.3 to -12.1) compared to the group with an FAC of 3 ($P=.02$). Step lengths >0.232 m were more accurately tracked than step lengths that were shorter. An ICC of .973 was found for the longer step lengths compared to .792 in patients whose step lengths were shorter than 0.232 m. Compared to the gold standard, the smaller step lengths had a significant underestimation (-46.4%, 95% CI -70.4 to -22.4; $P=.001$), whereas for step lengths >0.232 m, the

mean difference was not significantly different (+3.5%, 95% CI -13.5 to +20.6; $P=.65$).

Table 2. Intraclass correlation coefficient (ICC) and mean difference compared to the gold standard number of steps as counted by the researchers.

Sensor location and patient characteristic	ICC of number of steps (95% CI)	Mean difference, % (95% CI)	P (Student's t test or ANOVA ^a)
Hips—overall	.326 (-.214 to .684)	-81.4 (-93.2 to -69.5)	<.001 ^b
Ankles—overall	.837 (.630 to .927)	-26.1 (-43.9 to -8.2)	.006
Ankles—without walker	.791 (.304 to .937)	-5.6 (-27.0 to +15.8)	.58
Ankles—with walker	.815 (.193 to .947)	-45.1 (-71.5 to -18.5)	.003
Ankles—with walker, with correction factor of +50%	.773 (.292 to .927)	-17.6 (-57.4 to +22.2)	.57
Ankles—step length >0.232 m	.973 (.902 to .993)	+3.5 (-13.5 to +20.6)	.65
Ankles—step length <0.232 m	.792 (.288 to .932)	-46.4 (-70.4 to -22.4)	.001
Ankles—step length <0.232 m, with correction factor of +50%	.734 (.238 to .907)	-19.6 (-55.5 to +16.3)	.29
Ankles—FAC ^c =3	.816 (.377 to .945)	+0.78 (-20.9 to +22.5)	.94
Ankles—FAC=0,1,2	.801 (-.080 to .949)	-51.0 (-73.3 to -28.7)	<.001
Ankles—FAC=0,1,2, with correction factor of +50%	.803 (.387 to .937)	-26.5 (-59.9 to +7.02)	.15

^aAnalysis of variance (ANOVA).

^bValues in italics are statistically significant.

^cFunctional Ambulation Category (FAC).

Figure 2. Mean differences in ankle and hip tracker recording in subjects versus controls (left); mean differences in ankle and hip tracker recordings in subjects with and without a rolling walker (right).

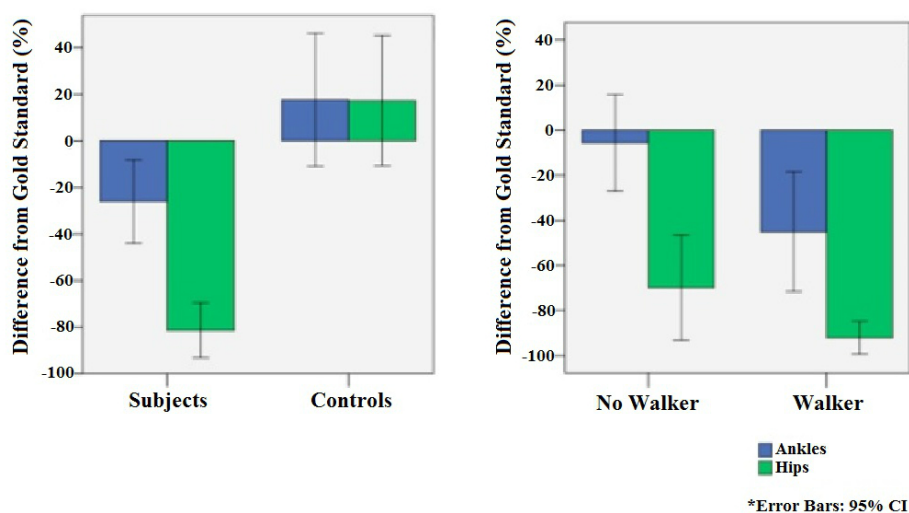
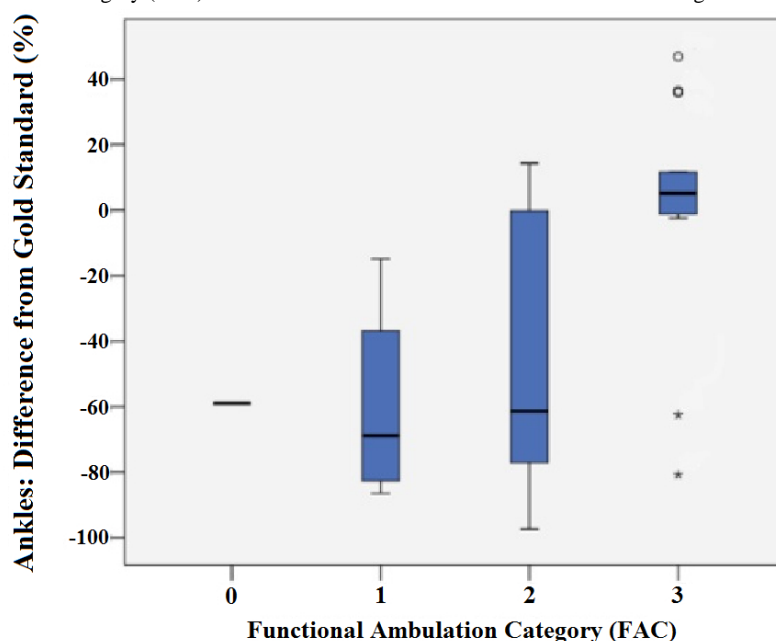


Figure 3. Functional Ambulation Category (FAC) in relation to ankle sensor mean differences from the gold standard.

Correction Factor

To show that the undercounting bias could be adjusted in patients with an FAC < 3, step length < 0.232 m, and those using a walker, we added 50% to the original step counts in these subgroups—the approximate underestimation in each case—and mean difference from the gold standard improved significantly (Table 2).

Multivariate Analysis

Table 3 demonstrates the multivariate analysis of clinical variables that found step length to be an independent predictor of overall tracker accuracy ($P=.03$). Figure 4 shows that there was a modest positive correlation between longer step length and improved ankle tracker accuracy ($r=.640$, $r^2=.397$). Although increased gait speed also correlated with increased ankle sensor accuracy, the relationship was weaker ($r=.444$, $r^2=.197$), and it lost statistical significance when we controlled for step length in the multivariate analysis.

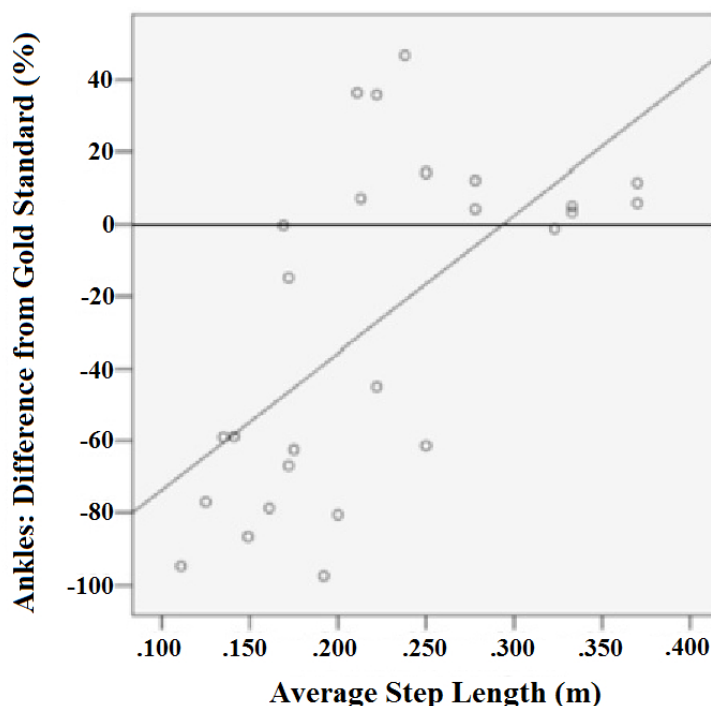
Table 3. Multivariate analysis of predictors of ankle sensor accuracy.

Variable	<i>P</i>
Age	.81
Postoperative day (POD)	.55
Gait speed	.44
Step length	.03 ^a
Surgical group	.75

^aValues in italics are statistically significant.

There were no significant differences observed between right-sided and left-sided trackers when comparing subjects with left-sided versus right-sided weakness. The total distance

ambulated also did not significantly affect the accuracy of the ankle trackers ($P=.39$).

Figure 4. Scatterplot of ankle sensor differences in relation to average step length.

Discussion

Principal Findings

We assessed the practicality and reliability of wearable, easy-to-use activity sensors in patients with limited mobility in the early postoperative period. Data from the rehabilitation sessions were remotely accessible by an online or mobile phone interface—an unprecedented technology that will provide health care professionals with the amount, duration, and timing of patient mobility at home and in the hospital. Although the activity sensors accurately tracked the time and duration of each session, in terms of step counting, our results highlight that ankle versus hip sensor placement, along with specific characteristics of patient mobility—use of an assistive device, step length, and FAC—affect the devices' ability to accurately reflect patient functional recovery.

Gait Parameters and Comparison to Previous Studies

As mentioned earlier, mobilization generally improves survival and functional outcome in a wide variety of patients recovering from surgery, neurological illness, and cancer, but accurately tracking mobility, especially in the outpatient setting, has been challenging. A patient's mobility can be graded by physical performance measures such as gait speed, which is a function of age, stature, and strength [26]. Patients who are more disabled tend to have slower gait speeds and have a higher risk of hospitalization and death related to immobility [2,8,12]. In a large longitudinal study of 34,000 adults, each 0.1 m/s increase in gait speed was independently associated with a lower risk of death with a hazard ratio of 0.90 (95% CI 0.89-0.91; $P < .001$) [12]. Although our subjects were relatively functional compared to many neurology and neurosurgery patients, who are often very debilitated in the acute period, our study is among the first to assess the use of commercial, wearable sensors in patients

with very slow gait speeds (IQR 0.156-0.357 m/s) and limited mobility. Most other studies have had a lower limit of 0.500 to 0.580 m/s [2,9,19] and, therefore, have not provided sufficient data on patients at risk of harmful consequences associated with decreased gait speed.

Sensor Reliability in Relation to Functional Status

We observed an underestimation of step counts in the less mobile subject population, likely because these patients tended to have a lower FAC, shorter step length, and need for a walker. These common clinical characteristics made patients' movements less pronounced, which were more difficult for the sensors to detect—especially those placed on the hips. On the other hand, the readings in the control group did not significantly differ from the gold standard, indicating that the sensor accuracy was greater than in the subject group. The higher accuracy in the control group, who had gait speeds in the normal range [26], was probably because those individuals had larger, more pronounced movements during ambulation which were more easily detected by the sensors. As a result, the placement of sensors on the hips (as suggested by the company) resulted in more accurate readings in controls because of normal, detectable hip motion that may be less pronounced in recovering patients. These results were not unanticipated, since the devices are marketed toward healthy, active individuals. That being said, we did note a degree of overestimation in the control group that was not statistically significant.

The tendency to underestimate in more slowly moving patients was also observed in a study where sensors undercounted by 19.1% to 32.1% when gait speeds were ≤ 0.800 m/s [27]. In one of the few studies that included patients with slow gait speeds, it was observed that a specialized, noncommercial sensor was more accurate in the control group but undercounted in older, frail stroke patients with gait speeds ≤ 0.470 m/s [28]. In our

study, although accuracy was related to gait speed, there was a stronger relationship to step length. In patients with a step length >0.232 m, the sensors were highly accurate compared to the gold standard (ICC .973, 95% CI .902-.993). Step length is known to have an effect on clinical characteristics, as it decreases with age and certain orthopedic injuries, and can influence postural stability [29]. As a clinical measure, it remains understudied compared to gait speed, although the two are physically and inherently related. Step length, therefore, may provide another important measure of a patient's mobility.

Within the subject group, sensor accuracy was strongest in patients who were more mobile, including those who ambulated without a walker or significant assistance from the physical therapist and, as mentioned, those with longer step lengths. This inverse relationship between amount of movement and degree of undercounting suggests that the sensors underestimate more as a patient's mobility and functional status worsen. The relationship between decreased accuracy of other accelerometers and poorer functional status, such as in patients with congestive heart failure and chronic obstructive pulmonary disease (COPD), was noted in a systematic review on the validity of activity sensors in patients with chronic disease [21]. Decreased mobility, in turn, is associated with poorer outcomes as described earlier. For this reason, a reliable assessment of mobility in this patient population is needed in order to monitor recovery and detect a decline in health that would require intervention.

Limitations

Some limitations of this study should be mentioned. Since this was a pilot study, our sample size was 27 subjects, although this is in the range of comparable previous studies [17-19,27,29,30], and we found a large effect size. Our data also had higher resolution than would be expected from the sample size because it included 148 readings from the sensors. As with previous studies, there was the possibility of human error in step counting, although this remains the gold standard. It may be stated that our results are less generalizable because all subjects were neurosurgical patients with postoperative gait impairment, but patients with preexisting gait disorders were excluded, and we found no effect of unilateral weakness on sensor accuracy. Since there is variation in the technology and software used to detect physical activity, measurements among sensors are not necessarily consistent with each other, and for this reason we only used one type of device. Regarding the device which was used in the study, FitBit Zip, it should also be mentioned that it has not yet been approved for medical purposes. It is only a matter of time, however, until wearable, commercially available activity sensors are used to improve patient care, as these sensors are far more affordable than comparable devices and have the potential for widespread use [21].

Conclusions

In conclusion, activity sensors generate low-cost data on patient recovery in the hospital and in the home environment. We have

shown that they are able to remotely monitor patient activity, although our results demonstrate that in order to develop research protocols which use activity sensors to reliably track patient mobility, the suitability of the sensors needs to be individually determined, as suggested by previous authors [31]. The technical characteristics of the accelerometer must be considered, and care must be taken when interpreting the results of data recorded on the devices. Additionally, in patients with limited mobility, one must clinically and mathematically account for certain factors—FAC, step length, use of assistive device—in order to use wearable sensors as a means of accurately assessing the degree of disability. The positioning of the sensor should also be carefully considered depending on the degree of to-and-fro movements. Our data may be utilized to determine the best way to standardize the use of activity sensors, and eventually provide the missing outpatient data needed to assess functional recovery.

Future Directions

Since impaired ambulation and limited mobility may occur in a wide variety of other diseases [12]—cardiovascular, pulmonary, musculoskeletal—wearable sensors have extensive potential across a broad range of medical fields. With the determinants of accuracy that we have outlined, sensors may soon be used not only by health care professionals to supplement acute care, but also by patients at home after discharge. Patients can wirelessly track their own recovery and mobility using feedback provided on the display screen of certain wearable devices, which provide real-time snapshots of activity level—number of steps taken, calories burned, and distance covered. This would allow patients to engage in their own recovery by aiming to achieve certain activity goals [32,33], and they may be further motivated to do so with the knowledge that they are being remotely monitored by their health care provider. In this manner, the activity sensors may prove to be a form of therapeutic intervention which promotes improvement in mobility and independent function [34,35]. In effect, reliable use of activity sensors will not only add to the repertoire of inpatient physical therapy measures, but will also provide much-needed longitudinal data to track patients as they recover in the outpatient setting. It will be possible for health care professionals to log on to a Web portal and see not only the trends of a patient's mobility over the course of weeks to months, but also the minute-to-hour variations in activity throughout the day from which bed rest or inactivity could be inferred. In fact, a similar accelerometer has been used to track patients for several days after having received cardiac surgery [36]. Using information from our research, future studies will be able to develop a reliable protocol for using wearable sensors and enroll patients on a large scale. Outpatient data from the sensors could then be compared to a variety of standard outcome measures such as the Modified Rankin Scale, Barthel Index, and quality-of-life scales.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Functional Ambulation Category (FAC).

[[PDF File \(Adobe PDF File\), 18KB - mhealth_v3i3e78_app1.pdf](#)]

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Abbreviations

ADL: activities of daily living

ANOVA: analysis of variance

COPD: chronic obstructive pulmonary disease

FAC: Functional Ambulation Category
HIPAA: Health Insurance Portability and Accountability Act
ICC: intraclass correlation coefficient
ICU: intensive care unit
IQR: interquartile range
IRB: Institutional Review Board
POD: postoperative day

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Original Paper

The Effectiveness of Mobile Phone-Based Care for Weight Control in Metabolic Syndrome Patients: Randomized Controlled Trial

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Abstract

Background: Overweight and obesity, due to a Westernized diet and lack of exercise, are serious global problems that negatively affect not only personal health, but national economies as well. To solve these problems, preventative-based approaches should be taken rather than medical treatments after the occurrence of disease. The improvement of individual life habits, through continuous care, is thus a paramount, long-term treatment goal. This study describes the effects of ubiquitous health care (uHealth care) or SmartCare services in the treatment of weight loss and obesity.

Objective: The aim of this study is to evaluate the effect of SmartCare services on weight loss compared to the effects of existing outpatient treatments in obese patients with metabolic syndrome.

Methods: Metabolic syndrome patients who met the inclusion/exclusion criteria were enrolled in the study and randomized into an intervention or control group. The intervention group was provided with remote monitoring and health care services in addition to the existing treatment. The control group was provided with only the existing treatment. Pedometers were given to all of the patients. Additionally, mobile phones and body composition monitors were provided to the intervention group while body weight scales were provided to the control group. The patients visited the hospitals at 12 and 24 weeks following the baseline examination to receive efficacy and safety evaluations.

Results: Mean weight reduction from baseline to week 24 was measured as a primary efficacy evaluation parameter and was found to be 2.21 kg (SD 3.60) and 0.77 kg (SD 2.77) in the intervention and control group, respectively. The intervention group had a larger decrement compared to the control group ($P<.001$). Among the secondary efficacy evaluation parameters, body mass index (BMI) ($P<.001$), body fat rate ($P=.001$), decrement of waist measurement ($P<.001$), and diet habit ($P=.012$) improvement ratings from baseline to week 24 were found to be superior in the intervention group compared with the control group. The proportion of patients whose body weight decreased by $\geq 10\%$, lipid profiles, blood pressure, prevalence of metabolic syndrome, change in the number of metabolic syndrome elements, smoking rate, drinking rate, and physical activity were not statistically significant between the groups.

Conclusions: The efficacy of SmartCare services was confirmed as the intervention group that received both SmartCare services and the existing treatment had superior results compared with the control group that only received the existing treatment. Importantly, no specific problems with respect to safety concerns were observed. SmartCare service is thus an effective way to control the weight of obese patients with metabolic syndrome.

Trial Registration: Clinicaltrials.gov NCT01344811; <https://clinicaltrials.gov/ct2/show/NCT01344811> (Archived by Webcite at <http://www.webcitation.org/6alT2MmIB>)

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KEYWORDS

metabolic syndrome X; obesity; diet; exercise; mobile health; health information management

Introduction

Obesity increases the prevalence of diabetes mellitus type 2, metabolic syndrome, cardiovascular diseases, and the mortality rate [1]. Metabolic syndrome is a condition in which various cardiovascular and metabolic risk factors are simultaneously present because of insulin resistance, obesity, and other factors, causing cardiovascular diseases, the main causes of death [2,3]. The specific cause of metabolic syndrome is unknown, but it is important to control body weight because obesity and insulin resistance are suspected to be fundamental causes [4,5]. Furthermore, a substantial amount of research has reported that the occurrence of diabetes or macroangiopathy, a complication of diabetes, can be reduced by actively losing weight at the beginning of the disease, reinforcing the importance of reducing body weight and body fat through life habit improvements [2]. Obesity has been reported as the most important factor associated with metabolic syndrome. Therefore, it is necessary to recognize obesity as an individual disease and to treat it as such [6]. In 2014, the World Health Organization (WHO) reported that more than 1.9 billion adults, 18 years and older, were overweight. Of those, over 600 million were obese. Worldwide, the proportion of adults with a body mass index (BMI) of ≥ 25 kg/m² increased between 1980 and 2013 from 28.8% to 36.9% in men, and from 29.8% to 38.0% in women [7]. According to the Korea National Health and Nutrition Examination Survey (KNHANES), a domestic epidemiologic survey performed by the Ministry of Health and Welfare, national obesity prevalence increased from 26.9% in 1998 to 32.0% in 2011 [8].

With the population aging and standards of living increasing, interest in personal health is on the rise. With respect to the advent of a ubiquitous era of advanced information technology, the field of ubiquitous health (uHealth) care, where information technology is combined with medical technology, is considered to be the new high-value industry of the future. uHealth care refers to the medical service that provides disease prevention, diagnosis, treatment, and care anytime and anywhere without physically visiting a hospital. In contrast to current medical concepts, which emphasize care and treatment after the onset of disease, uHealth care, along with the advancement of modern medicine, has the potential to discover and treat diseases in their early phases through pre-diagnosis and prevention [9]. Thus, uHealth care is developing into a broad concept with long-term sustainability for healthy living due to the improved quality and efficiency of medical services.

To prevent and control obesity, an exercise and diet intervention is necessary. Among a number of intervention strategies, a comprehensive body weight control strategy conducted on entire populations is effective in reducing medical costs and the

economic burden of obesity [5,10-13]. Attempts to manage exercise and diet intake, the two key goals for weight loss, in real-time have been performed with limited means through phone, email, and short message service (SMS) text messaging [14-16]. However, as mobile phones became more prevalent and apps with concepts from uHealth care were introduced, studies were conducted that continued to develop and evaluate the efficacy of mobile phone-based apps [17-20].

This clinical trial was planned as a multicenter, randomized, parallel, and open-label study to evaluate the effect of uHealth care service (hereinafter referred to as SmartCare) on weight loss in obese patients with metabolic syndrome. A 24-week randomized controlled trial was conducted to determine whether SmartCare would be more effective in treating metabolic syndrome compared with the standard care in the hospital.

Methods

Recruitment

Of the male and female subjects aged ≥ 20 who visited one of the two general hospitals (Seoul National University Hospital and Severance Hospital) in Seoul, obese patients with metabolic syndrome were recruited. Those whose BMI was ≥ 25 kg/m² and who met at least 3 of the 5 following requirements were defined to have metabolic syndrome and were recruited as a subject in this trial.

According to the Adult Treatment Panel (ATP) III criteria using waist circumference cut-off modifications for Asian populations as suggested by the Asia-Pacific guidelines [21], metabolic syndrome is defined as having at least 3 of the following factors (1) central obesity (waist circumference ≥ 90 cm in men and ≥ 80 cm in women), (2) hypertriglyceridemia (triglyceride (TG) ≥ 150 mg/dL), (3) high-density lipoprotein cholesterol (HDL-C) < 40 mg/dL in men and < 50 mg/dL in women, (4) hypertension (blood pressure $\geq 130/85$ mmHg or taking antihypertensive medication), and (5) hyperglycemia (fasting plasma glucose (FPG) ≥ 100 mg/dL or taking antidiabetic medication).

The WHO Regional Office for the Asia Pacific Region recommends defining obesity in Asians as those with a BMI of ≥ 25 kg/m². The Korean Society for the Study of Obesity also studied the cutoff of BMI for obesity-related disease [22] and adopted the WHO-recommended definition. Now, Korean government organizations officially use this definition when defining and implementing health policies regarding obesity in Korea.

Subjects taking thyroid hormone or anti-obesity medicine, which can affect weight, insulin-dependent diabetes, patients with liver function abnormality (liver somatic index > 3 times the normal maximum level) or renal function impairment (creatinine level

>1.5 times the normal maximum level), pregnant women, and inpatients were excluded from this study.

Subjects were recruited through installing institutional review board- (IRB-) approved banners, posters, and leaflets in the hospital lobby. As an incentive for the registered test participants (both intervention and comparison groups), all expenses for medical treatment, medicine, transportation, and communication (mobile phones) were provided from the national project budget.

Eligible participants were assigned to the 2 groups with equal probability according to a randomization code. The randomization code was prepared by a block randomization method stratified (according to the enrolling clinical centre) by a statistician in a clinical trial centre (C&R Research, Seoul, South Korea). This study was an open labelled trial, blinding was not done.

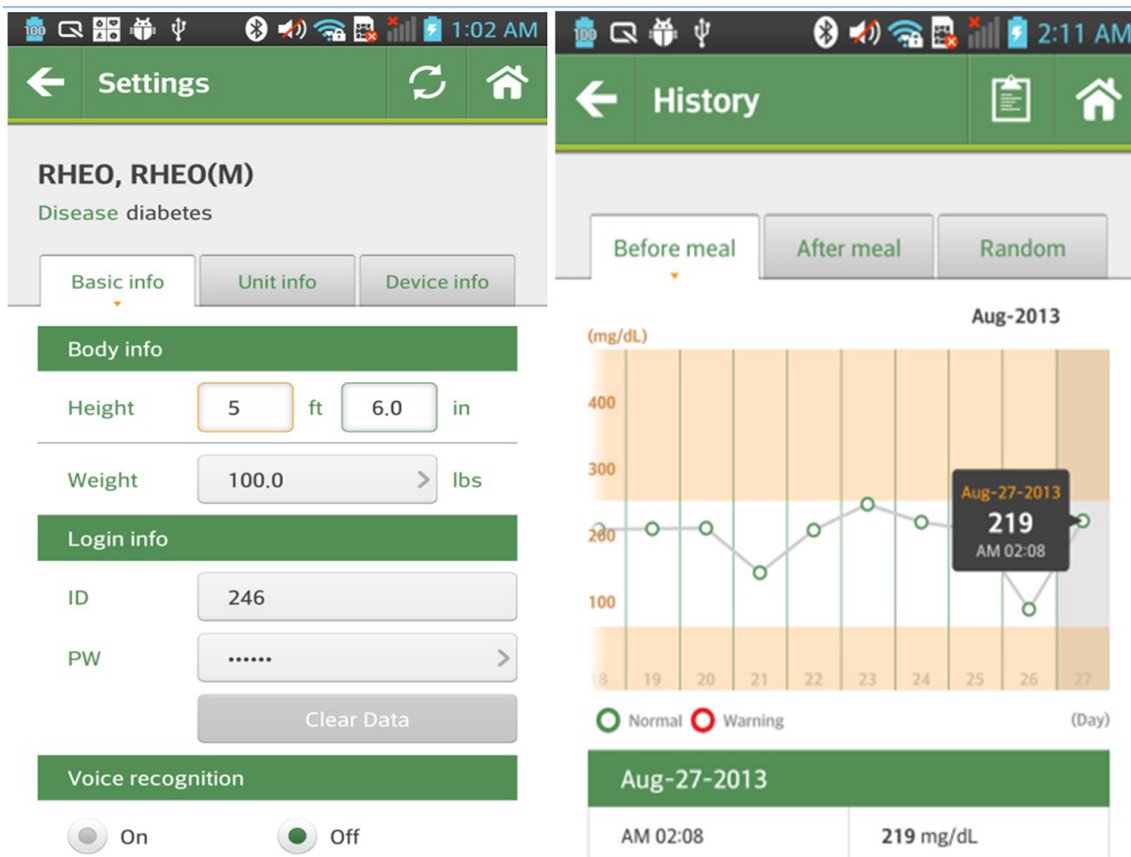
The Institutional Review Board of Seoul National University Hospital approved this study (IRB number: h-1009-095-333).

Intervention Group

Mobile phones for remote monitoring, body composition monitors (InBody IH-U070B) and pedometers were provided to the subjects assigned to the intervention group. Each subject measured his or her own body weight and body composition using the provided body composition monitor at the same time every day if possible (a minimum of 3 times per week), and before breakfast after waking up. After measuring the relevant values with the body composition monitor, the transmission

terminal (Bluetooth) of the remote monitoring device, juxtaposed near the transmission terminal of the mobile phone transmitted the measurement data to the central server in the SmartCare center via a wireless network. Each subject carried a pedometer from the time they woke up until they went to bed. The activity level, indicated as the number of steps taken, was checked at the same time every day, if possible, and entered into the mobile phone (inputting before bed was recommended). Then, the entered data were automatically transmitted to the central server in the SmartCare center. Physicians or healthcare personnel at the SmartCare center could retrieve the hospital admission information, treatment records, name of diagnosed diseases, diagnostic examinations and functional test results, and prescription information of the test subjects by connecting to the hospital information system with the consent of the subjects. The central server in the SmartCare center transmitted the feedback based on the measured body weight and body composition to the mobile phones of the subjects according to the algorithm of the clinical decision support system (CDSS). The subjects were able to immediately check the interpretations and recommendations based on their measured values through their mobile phones (Figure 1). The educated consultants (nurse, exercise prescriber, and clinical dietitian) in the SmartCare center provided various health consultations through the patients' telephone inquiries concerning disease management, health education, recommended exercise, medication, and proper nutrition. Also, monthly and weekly health reports based on the individual patient's measured values and life habit records were sent directly to the patients through the SmartCare system.

Figure 1. Examples of the SmartCare app.



Comparison Group

Body weight scales and pedometers were provided to the subjects assigned to the control group. Body weight journals were distributed to the subjects, and each subject self-measured and recorded his/her daily weight and waist size (a minimum of 3 times per week) at the same time (before breakfast) using waist circumference. Also, they wore a pedometer during daily activities, which started from the time of waking up in the morning until bedtime in the evening. They were instructed to check and record their daily walking amount on the record sheet just before sleep.

Additionally, the subjects in the control group visited the hospitals on the same schedule as that of the intervention group and received anthropometry, consultations with physicians, and information about their nutrition and exercise.

Study Design

The subjects who met the exclusion criteria and were excluded from the trial included diabetic patients receiving treatment, patients with diseases that might affect body weight, or those who continued to take prescribed medications. The selected subjects were randomized into a control group that received basic information on increasing physical activity and controlling diet habits, or an intervention group that received remote

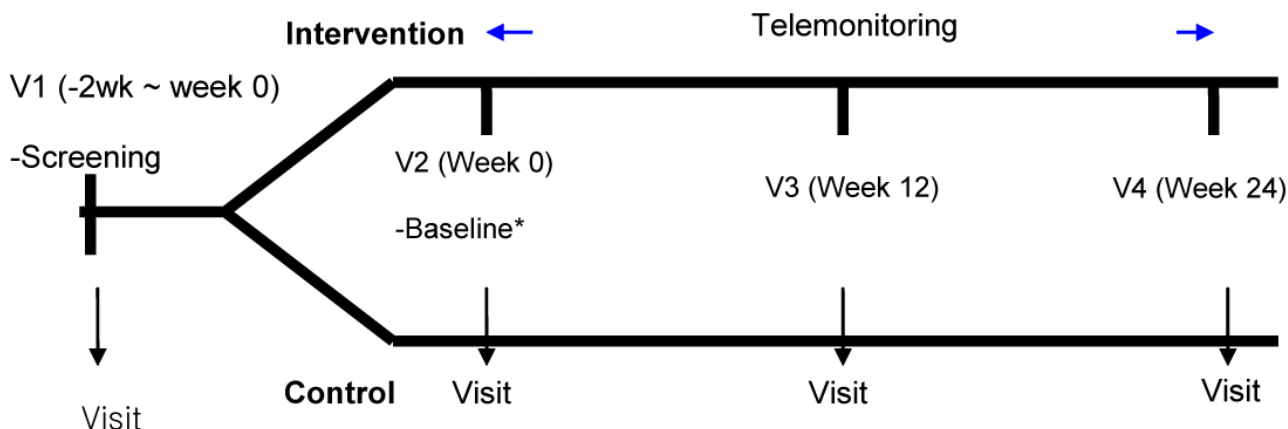
monitoring and uHealth care service (SmartCare) in addition to the existing treatment. Pedometers were given to all of the patients. Additionally, mobile phones and body composition monitors were provided to the intervention group, and body weight scales were provided to the control group.

The equipment (mobile phones, weight scales, and pedometers) were provided to the patients for free through the fund for the national project.

The subjects were asked to visit the hospitals 4 times during the 24-week period. Except when screening was performed, their body weight, body composition, and blood pressure were checked. A hematology test was performed and changes in their life habits (eg, diet intake and physical activity) were checked 3 times during the test period; once on the date the subjects were randomized, once in week 12, and once in week 24 (Figure 2).

Analysis consisted of 2 group sets: intention-to-treat (ITT) and per protocol (PP). The ITT set included all of the subjects who were enrolled in this clinical trial and were randomized. When analyzing efficacy, they were included in the treatment group into which they were randomized, regardless of the actual treatment they received. Among the subjects included in the ITT set, those who completed this clinical trial without material breach of the protocol were included in the PP set.

Figure 2. Study flowchart and design.



Measurement

When screening was performed, the demographic information (age, gender, smoking, drinking, and others), medical history, and medication history of the subjects were investigated and recorded. Additionally, an electrocardiogram (ECG) was performed at the screening visit after resting for at least 5 minutes. When clinically significant test results were observed, the investigator determined whether to enroll the subject in the experiment.

The laboratory tests were conducted at screening, baseline, week 12, and week 24, and the tests included alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatinine, lipid profile (total cholesterol, HDL-C, and TG), fasting blood sugar (FBS), and baseline glycosylated hemoglobin (HbA1c). However, ALT, AST, and creatinine tests were performed only

at screening to determine trial eligibility. Lipid profiles and blood glucose tests were performed after fasting.

Weight change was the primary outcome and was evaluated with percent body fat at baseline, week 12, and week 24 and measured by nurses using a portable bioelectrical impedance analysis device (InBody U20, Seoul, Korea).

The level of physical activity was assessed and categorized using the International Physical Activity Questionnaire (IPAQ) at baseline, week 12, and week 24. The amount of physical activity each week was calculated with a continuous variable, the Metabolic Equivalent of Task (MET) using the following equation:

$$\text{Total MET min/week} = [\text{walking METs} \times \text{min} \times \text{days}] + [\text{moderate METs} \times \text{min} \times \text{days}] + [\text{vigorous METs} \times \text{min} \times \text{days}]$$

Concerning the method for measuring the caloric intake variables, daily meal record cards (3-day recall dietary assessment) were distributed to the subjects during their initial visit and the subjects were instructed to write their own 3-day meal record just before the baseline visit, the next visit after 12 weeks, and the final visit after 24 weeks. The self-completed daily meal records were collected from the subjects during their final visit and the dietitian performed the calorie calculation using the nutrient evaluation program CAN-Pro 3.0 software (The Korean Nutrition Society, 2006) [23].

Statistical Analysis

Each group initially consisted of 167 subjects chosen using a 5% significance level, 90% power, and estimating the mean difference in weight change between the 2 groups to be 1.81 kg (SD 4.81 and 5.36 kg). Considering a 25% drop out rate, the final sample size consisted of 223 subjects for each group (N=446 subjects) [24-27].

Descriptive statistics including the number of observed subjects, mean, and median (range) of body weight measured at baseline, week 12, and week 24, and the changes in measured values at week 24 compared to baseline were presented for each group. To identify the difference between the groups with respect to body weight changes at week 24 compared to the baseline, analysis of covariance (ANCOVA), including the clinical trial institution and the body weight at baseline as covariates, was performed.

For continuous data, such as changes in BMI, body fat percentage, waist measurement, lipid profile, blood pressure, the number of metabolic syndrome elements, diet intake (kcal), physical activity, number of steps taken, and weight to measure physical activity, descriptive statistics including the number of observed subjects, mean, and median (range) were presented for each group. To identify the difference between the groups at week 24 compared to the baseline, ANCOVA or rank transformation ANCOVA was performed. When conducting ANCOVA, the clinical trial institution and the baseline values of relevant parameters were set as covariates.

For categorical data including the ratio of the subjects whose body weights decreased by $\geq 10\%$, the changes in the prevalence rates of metabolic syndrome and the changes in life habits (ie, smoking and drinking, the frequency, rates, and 95% confidence

interval were presented for each group. To identify the difference in rates between the groups at weeks 12 and 24, the Cochran-Mantel-Hansel (CMH) test was performed using the clinical trial institution as a covariate.

To identify the satisfaction level of the subjects (only for intervention group), the scores of the satisfaction survey items related to the usage convenience of the devices were measured at weeks 12 and 24, and descriptive statistics including the number of observed subjects, mean, and median (range) on the measured scores were presented.

The adverse events occurring after randomization were collected and analyzed. The frequency, percentage, and 95% confidence intervals of the adverse events and serious adverse events were presented. To find the difference between the groups in the frequency of adverse and serious adverse events, Pearson's chi-square test or Fisher's exact test was performed. The adverse and serious adverse events were coded according to the Medical Dictionary for Regulatory Activities (MedDRA) system organ class (SOC) and preferred term (PT), and the number of types, frequency, and the number of cases of the coded adverse events were presented. Additionally, the numbers of adverse events occurrences and percentages were presented by severity, and a detailed statement on the serious adverse events was presented.

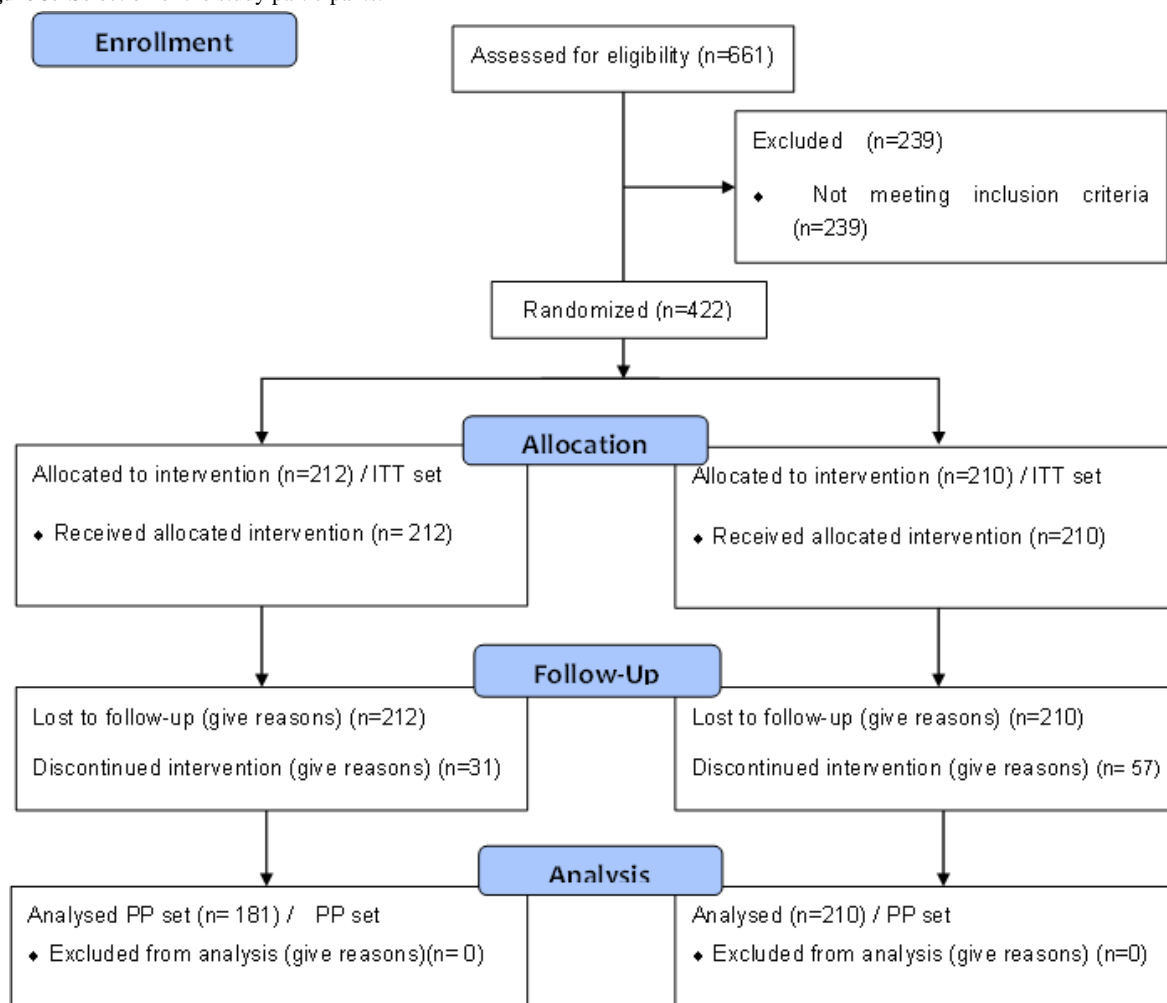
All analyses were conducted using STATA version 12.1 (StatCorp, Houston, TX) for Windows software. *P* values less than .05 were considered statistically significant.

Results

Subject Participation

During the clinical trial, a total of 661 subjects went through screening, and 442 of them were identified as subjects with metabolic syndrome. Subjects were randomized into the intervention (N=212) or control (N=210) group. Therefore, the ITT set included a total of 422 subjects. Because a total of 31 (14.6%, 31/212) subjects dropped out of the intervention group during the observation period of 24 weeks, 181 (85.3%, 181/212) subjects completed the trial. A total of 57 (27.1%, 57/210) subjects dropped out of the control group, and 153 (72.9%, 153/210) subjects completed the trial. Thus, the PP set included a total of 334 subjects (Figure 3).

Figure 3. Selection of the study participants.



Demographic Data and Characteristics of Subjects Prior to Treatment

The conditions of the subjects before providing medical service were compared between groups, including the demographic information of the subjects included in the ITT set. The mean ages were 46.78 years (SD 13.11) for the intervention group and 50.35 years (SD 14.24) for the control group, indicating a statistically significant difference in the age distribution between the groups ($P=.008$). However, there was no significant difference between the 2 in terms of age groups ($P=.269$). The number of male and female subjects in the intervention group were 113 (53.3%, 113/212) and 99 (46.7%, 99/212), respectively. In the control group, the number of male subjects was 102 (48.6%, 102/210) and the number of female subjects was 108 (51.4%, 108/210) demonstrating no statistically significant difference in gender distribution between the groups ($P=.331$). The mean BMI was 29.42 kg/m² (SD 3.53) for the intervention group and 29.40 kg/m² (SD 3.39) for the control group, indicating no statistically significant difference in the distribution of BMI between the groups ($P=.934$).

With respect to the education level of subjects in the 2 groups, 136 (64.2%, 136/212) subjects in the intervention group were “college graduates or higher”, whereas 109 (51.9%, 109/210)

in the control group were “college graduates or higher”. Statistically significant differences in education levels were observed among the “elementary school graduates” and “college graduates or higher” ($P=.001$). Moreover, body weight ($P=.343$), height ($P=.131$), smoking ($P=.475$), and drinking ($P=.726$) were not statistically significantly different between the 2 groups ([Multimedia Appendix 1](#)).

Efficacy Evaluations

Primary Efficacy Evaluation

The body weights at baseline, week 12, and week 24 were summarized in the descriptive statistics, and the body weight changes at week 24 compared to baseline were assessed. In the ITT set, the mean body weights of the intervention group at baseline and week 24 were 81.13 kg (SD 14.77) and 77.87 kg (SD 13.99), respectively. The mean body weight at week 24 decreased by 2.21 kg (SD 3.60) compared to the weight at baseline, which was statistically significant ($P<.001$). The mean body weights of the control group at baseline and week 24 were 79.74 kg (SD 15.28) and 77.02 kg (SD 13.33), respectively. The mean body weight at week 24 decreased by 0.77 kg (SD 2.77) compared to baseline, which was statistically significant ($P<.001$). In the comparison between the groups, the mean body weight change of the intervention group at week 24 compared

to baseline was significantly higher than that of the control group ($P<.001$) (Table 1).

In the PP set, the mean body weights of the intervention group at baseline and week 24 were 79.93 kg (SD 13.55) and 77.64 kg (SD 13.91), respectively. The mean body weight at week 24 decreased by 2.29 kg (SD 3.62) compared to baseline, which was statistically significant ($P<.001$). The mean body weights

of the control group at baseline and week 24 were 77.89 kg (SD 13.68) and 77.02 kg (SD 13.28), respectively. The mean body weight at week 24 decreased by 0.86 kg (SD 2.84) compared to baseline, which was statistically significant ($P<.001$). As in the ITT set, the mean body weight change of the intervention group at week 24 compared to baseline was significantly higher than that of the control group ($P<.001$) (Table 2).

Table 1. Changes in weight (baseline versus 24 weeks) in the ITT set.

Weight, kg	Intervention group	Control group	Between groups <i>P</i> value
Baseline			
n	212	209	
Mean (SD)	81.13 (14.77)	79.74 (15.28)	
Median	79.85	76.90	
Min, max	55.20, 144.00	54.00, 141.10	
Week 12			
n	196	179	
Mean (SD)	77.85 (13.46)	76.67 (13.26)	
Median	76.85	74.10	
Min, max	49.80, 135.70	53.40, 118.10	
Week 24			
n	196	181	
Mean (SD)	77.87 (13.99)	77.02 (13.33)	
Median	77.35	75.10	
Min, max	50.10, 141.00	53.20, 117.90	
Change W24^a			
n	196	181	
Mean (SD)	-2.21 (3.60)	-0.77 (2.77)	<.001 ^b
Median	-2.10	-0.70	
Min, max	-17.00, 5.60	-20.40, 6.60	
Within group, <i>P</i> value	<.001 ^c	<.001 ^c	

^aChange W24=week 24–baseline

^bANCOVA using the site and baseline weight as covariates

^cPaired *t* test

Table 2. Changes in weight (baseline versus 24 weeks) in the PP set.

Weight, kg	Intervention group	Control group	Between groups <i>P</i> value
Baseline			
n	181	153	
Mean (SD)	79.93 (13.55)	77.89 (13.68)	
Median	79.10	74.70	
Min, max	55.20, 135.40	54.00, 120.10	
Week 12			
n	181	152	
Mean (SD)	77.62 (13.38)	76.61 (13.21)	
Median	76.80	74.00	
Min, max	49.80, 135.70	53.40, 118.10	
Week 24			
n	181	153	
Mean (SD)	77.64 (13.91)	77.02 (13.28)	
Median	76.80	75.00	
Min, max	50.10, 141.00	53.20, 117.90	
Change W24^a			
n	181	153	
Mean (SD)	-2.29 (3.62)	-0.86 (2.84)	<.001 ^b
Median	-2.10	-0.80	
Min, max	-17.00, 5.60	-20.40, 6.60	
Within group <i>P</i> value	<.001 ^c	<.001 ^c	

^aChange W24=week 24–baseline^bANCOVA using the site and baseline weight as covariates^cPaired *t* test

Secondary Efficacy Evaluation

Among the secondary efficacy evaluation parameters, BMI, rate of body fat, decrement of waist measurement, and diet habit improvement from baseline to week 24 were superior in the intervention group compared with the control group (body fat rate $P=.001$, diet habit $P=.012$, and others $P<.001$). In particular, the mean BMIs of the intervention group in the ITT set at baseline and week 24 were 29.42 kg/m² (SD 3.53) and 28.33 kg/m² (SD 3.46), respectively. The mean BMI at week 24 decreased by 0.83 kg/m² (SD 1.31) compared to baseline, which was statistically significant ($P<.001$). The mean BMIs of the control group at baseline and week 24 were 29.40 kg/m² (SD

3.39) and 28.74 kg/m² (SD 2.88), respectively. The mean BMI at week 24 decreased by 0.28 kg/m² (SD 1.03) compared to baseline, which was statistically significant ($P=<.001$). In the comparison between the groups, the change in BMIs of the intervention group at week 24 compared to baseline was significantly higher than that of the control group ($P<.001$) (Table 3).

A similar trend was observed in the PP set (Table 4). However, the ratio of the patients whose body weight decreased by $\geq 10\%$ and the lipid profile, blood pressure, prevalence of metabolic syndrome, change in the number of metabolic syndrome elements, smoking rate, drinking rate, and physical activity were not statistically significantly different between the groups.

Table 3. Changes in BMI (baseline versus 24 weeks) in the ITT set.

BMI, kg/m ²		Intervention group	Control group	Between groups <i>P</i> value
Baseline				
	n	212	209	
	Mean (SD)	29.42 (3.53)	29.40 (3.39)	
	Median	28.70	28.90	
	Min, max	24.90, 46.80	24.90, 41.80	
Week 12				
	n	196	179	
	Mean (SD)	28.35 (3.25)	28.59 (2.84)	
	Median	27.85	28.10	
	Min, max	22.10, 40.10	24.00, 38.90	
Week 24				
	n	196	181	
	Mean (SD)	28.33 (3.46)	28.74 (2.88)	
	Median	27.55	28.20	
	Min, max	22.60, 41.40	23.90, 39.70	
Change W24^a				
	n	196	181	
	Mean (SD)	-0.83 (1.31)	-0.28 (1.03)	<.001 ^b
	Median	-0.80	-0.20	
	Min, max	-5.80, 2.20	-6.70, 2.40	
Within the group <i>P</i> value		<.001 ^c	<.001 ^c	

^aChange W24=week 24–baseline^bANCOVA using the site and baseline weight as covariates^cPaired *t* test

Table 4. Changes in BMI (baseline versus 24 weeks) in the PP set.

BMI, kg/m ²	Intervention group	Control group	Between groups <i>P</i> value
Baseline			
n	181	153	
Mean (SD)	29.18 (3.13)	29.08 (2.90)	
Median	28.60	28.80	
Min, max	25.00, 41.40	25.00, 39.70	
Week 12			
n	181	152	
Mean (SD)	28.34 (3.23)	28.60 (2.76)	
Median	27.80	28.10	
Min, max	22.10, 40.10	24.00, 38.50	
Week 24			
n	181	153	
Mean (SD)	28.32 (3.44)	28.74 (2.81)	
Median	27.50	28.30	
Min, max	22.60, 41.40	23.90, 39.70	
Change W24^a			
n	181	153	
Mean (SD)	-0.86 (1.32)	-0.33 (1.04)	<.001 ^b
Median	-0.80	-0.30	
Min, max	-5.80, 2.20	-6.70, 2.40	
Within the group <i>p</i> -value	<.001 ^c	<.001 ^c	

^aChange W24=week 24–baseline

^bANCOVA using the site and baseline weight as covariates

^cPaired *t* test

Subject Satisfaction

The convenience of device usage, satisfaction with the SmartCare center service, and overall satisfaction of the remote monitoring were determined at weeks 12 and 24, based on a 5-point scale where 5 corresponded to highly satisfied. At week 12, the convenience of device usage, satisfaction with the SmartCare center service, and overall satisfaction of the remote monitoring were found to be 3.54 (SD 1.02), 4.08 (SD 0.86), and 3.93 (SD 0.86), respectively. At week 24, the satisfaction with the convenience of device usage was 3.52 (SD 0.99), SmartCare center service was 4.14 (SD 0.88), and overall satisfaction of the remote monitoring was 3.92 (SD 0.85).

Safety Results

The rates of adverse events in the intervention group and control group were 14.2% (30/212, 43 cases) and 13.3% (28/210, 40 cases), respectively. The rates of serious adverse events in the intervention group and control group were 1.4% (3/212, 3 cases) and 2.4% (5/210, 5 cases), respectively. Due to serious adverse events, the intervention group showed 1 case of ankle fracture, and the control group showed 1 case of dislocated vertebra, stress urinary incontinence, and knee operation.

After the physical examination, no subject in either of the 2 groups had abnormalities at week 24 after showing no abnormalities at baseline.

Pulse reduction at week 24 compared to baseline was 2.84 beats/min (SD 10.01) for the intervention group and 0.94 beats/min (SD 8.47) for the control group. The difference between the groups was statistically significant ($P=.049$), but such a change is considered not to be directly related to SmartCare.

Discussion

Principal Findings

To the best of our knowledge, this study was the first domestic government project to estimate the usefulness of SmartCare in managing chronic disease. Weight decrement after 24 weeks from the baseline, a primary efficacy evaluation parameter, was 2.21 kg (SD 3.60) for the intervention group and 0.77 kg (SD 2.77) for the control group, and the intervention group showed a higher rate of reduction compared to the other group ($P<.001$). Among the secondary efficacy evaluation parameters, BMI, body fat rate, decrement of waist measurement, and diet habit

improvement ratings after 24 weeks were superior in the intervention group (body fat rate $P<.001$, diet habit $P=0.012$, and others $P<.001$). The proportion of patients whose body weight decreased by $\geq 10\%$, the lipid profiles, blood pressure, prevalence of metabolic syndrome, change in the number of metabolic syndrome elements, smoking rate, drinking rate, and physical activity were not significantly different.

uHealth care, an abbreviation for ubiquitous health care, refers to a health care medical service in which information and communication technologies are combined with medicine so that patients can be provided with prevention, diagnosis, treatment, and follow-up services anytime and anywhere, even if they do not directly visit hospitals [28,29]. uHealth care is a medical service developed to collect real-time health-related information without limits pertaining to time or location, and to perform continuous monitoring and treatment to examine health conditions in advance and prevent diseases, rather than solely providing treatment after the onset of disease. Because of the sudden increase in medical costs due to population aging and the increase of patients with chronic diseases in modern society, the need for the development of such a service is increasing, as is the need to build a cost-effective medical system and improve the quality of health and medical treatment services [30].

This clinical trial was designed in consideration of such situations. Here, we compared the SmartCare service (uHealth care) with the existing treatment to evaluate the effect of the service on body weight, as well as its safety in obese patients who need constant monitoring.

Overweight and obesity due to a Westernized diet and lack of exercise are serious problems all over the world and have adverse effects not only on personal health but also on national economies. To solve these problems, an approach including prevention should be taken, rather than relying only on medical treatment after the occurrence of disease. In addition, long-term treatments such as improving individual life habits through continuous care are paramount [31].

Metabolic syndrome is a disease caused by insulin resistance, which is usually linked to overweight and obesity. Thus, weight control is vital for this condition. To lose weight, exercise and a controlled diet are absolutely important [5,11,32,33]. Practicing diet therapy can cut down on fat as well as lean body mass. This drops the basic metabolic rate, easily causing the yo-yo effect where the patient gains weight even from small food intake.

Comparison With Prior Work

Various attempts to prevent obesity have been made, including a case where healthy eating habits and adequate exercise to maintain reduced weight were carried out in a community setting [34,35]. Cases where competition among members to maintain healthy lifestyles and to lose weight was encouraged with the use of aggressive measures have been reported in a timely fashion with the introduction of telemedicine [9]. However, the exchange of food and exercise information through the Internet was found to be more effective in weight loss and maintenance

than traditional methods of self-maintenance and self-management [36].

This clinical trial paired the SmartCare service together with the existing treatment (intervention group) to only the existing treatment (control group) and compared the mean change in body weight at week 24 to baseline between the 2 groups. The test results showed significantly higher changes in body weight in the intervention group than in the control group, proving that the SmartCare service shows higher efficacy when combined with the existing treatment than when only the existing treatment was provided. Additionally, we obtained results consistent with the primary efficacy evaluation in BMI, body fat rate, and waist measurements, which are directly related to obesity and body weight. In the satisfaction survey for the SmartCare service, convenience of device usage, satisfaction with the SmartCare Center service, and overall satisfaction with remote monitoring, all received responses of were 'satisfactory' or 'very satisfactory' from $\geq 50\%$ of the users. Studies conducted in other countries have found similar results. These studies showed that various methods implemented to motivate patients to increase physical activity, control their diets, and maintain healthy life habits mostly produced positive results [16,20,37-44].

Study Strengths and Limitations

Based on the number of times information was entered on the mobile phone for diet intake and the amount of exercise, the subgroup analysis of this study revealed that the scope of weight loss was considerably increased. Through this revelation, the level of interest in using uHealth in real-time was found to be an important variable that can heavily influence the level of weight loss. The difference between this study compared to previous studies from abroad is that the mean age of the subjects was between the mid-40s to the early 50s, older than the ages of the subjects included in the other studies. Thus, this study is meaningful in that it showed that the concept of uHealth is not the exclusive property of younger generations who use advanced devices. It showed that anyone who uses a mobile phone in modern society could use uHealth accordingly.

However, the fact that highly educated young individuals were assigned to the intervention group, despite the random selection, may work as a selection bias when evaluating the effects of SmartCare. Nonetheless, this research also revealed that the number of people who failed in the control group was twice that of the intervention group, thereby suggesting the possibility that SmartCare increased participants' adherence to a weight loss program compared to weight loss means using traditional methods.

On the other hand, the rates of the subjects whose body weight decreased by $\geq 10\%$, lipid profiles (total cholesterol, HDL-C, low-density lipoprotein cholesterol (LDL-C), and TG), changes in systolic and diastolic blood pressure, rate of patients with metabolic syndrome, change in the number of metabolic syndrome elements, smoking rate, and drinking rate were not statistically significantly different between the intervention and control groups. There are a few possible causes for this observation. First, subjects with reduced weight during the initial phase of the study showed a tendency to have slight increases in weight towards the latter phase of the study. Second, it is

difficult to confirm whether eating habits, specifically the control of calories and salt intake, improved compared to the increased physical activity and weight loss effect. The risk factors of metabolic syndrome are expected to decrease when the effects of weight reduction are sustained for a long period of time, and such benefits can be confirmed with a longer research plan for weight maintenance. Furthermore, if the reduction can be quantitatively proved through feedback regarding the controlled salt and total calorie intake to improve eating habits, it may be possible to observe the number of metabolic syndrome factors, such as blood pressure and the change in the lipid profile, of the participants through subgroup analysis.

Conclusions

Through analyzing obesity evaluation indexes such as BMI and including weight, body fat rate, and waist measurements, we found that the SmartCare service is an effective way to control the weight of obese patients with metabolic syndrome.

The positive effects of the development of uHealth on the medical field can influence not only health care providers but also various fields, including health care centers and network operators, can provide medical service anytime and anywhere without patients having to visit hospitals during operating hours, and can provide individually customized service for health improvement and disease prevention for identical conditions in contrast to the usual patient-doctor relationship [45].

Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Demographic characteristics of the patients at baseline in the ITT set.

[PDF File (Adobe PDF File), 119KB - [mhealth_v3i3e83_app1.pdf](#)]

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Abbreviations

- ALT:** alanine aminotransferase
- ANCOVA:** analysis of covariance
- AST:** aspartate aminotransferase
- BMI:** body mass index
- FBS:** fasting blood sugar
- FPG:** fasting plasma glucose
- HbA1c:** baseline glycosylated hemoglobin
- HDL-C:** high-density lipoprotein cholesterol
- IRB:** institutional review board
- ITT:** intention-to-treat
- MET:** Metabolic Equivalent of Task
- PP:** per protocol
- TG:** triglyceride
- uHealth:** ubiquitous health
- WHO:** Who Health Organization

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Original Paper

Efficacy of a Text Message-Delivered Extended Contact Intervention on Maintenance of Weight Loss, Physical Activity, and Dietary Behavior Change

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Abstract

Background: Extending contact with participants after the end of an initial intervention is associated with successful maintenance of weight loss and behavior change. However, cost-effective methods of extending intervention contact are needed.

Objective: This study investigated whether extended contact via text message was efficacious in supporting long-term weight loss and physical activity and dietary behavior change in breast cancer survivors.

Methods: Following the end of an initial 6-month randomized controlled trial of a telephone-delivered weight loss intervention versus usual care, eligible and consenting intervention participants received a 6-month extended contact intervention via tailored text messages targeting a range of factors proposed to influence the maintenance of behavior change. In this single-group, pre-post designed study, within group changes in weight, moderate-to-vigorous physical activity (Actigraph GT3X+ accelerometers), and total energy intake (2x24 hour dietary recalls) were evaluated from baseline to end of initial intervention (6 months), end of extended contact intervention (12 months), and after a no-contact follow-up (18 months) via linear mixed models. Feasibility of implementation was assessed through systematic tracking of text message delivery process outcomes, and participant satisfaction was assessed through semistructured interviews.

Results: Participants at baseline (n=29) had a mean age of 54.9 years (SD 8.8), body mass index of 30.0 kg/m² (SD 4.2), and were recruited a mean 16.6 months (SD 3.2) post diagnosis. From baseline to 18 months, participants showed statistically significantly lower mean weight (-4.2 kg [95% CI -6.0 to -2.4]; $P<.001$) and higher physical activity (mean 10.4 mins/day [95% CI 3.6-17.2]; $P=.003$), but no significant differences in energy intake ($P=.200$). Participants received a mean of 8 text messages every 2 weeks (range 2-11) and reported a high rate of satisfaction.

Conclusions: In comparison to interventions without extended contact, results suggest text message-delivered extended contact may support the attenuation of weight regain and promote the maintenance of physical activity.

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KEYWORDS

weight; physical activity; diet; mobile telephone; intervention; behavior change; maintenance; SMS; mhealth; textmessaging

Introduction

Maintaining a healthy body weight, engaging in regular physical activity, and eating a healthy diet are important for reducing the risk of chronic disease [1-3]. Behavioral lifestyle interventions are effective at promoting initial weight loss [4] and supporting physical activity (PA) and dietary behavior change [5,6]. However, maintaining improvements in these outcomes is often more difficult to achieve [7,8]. Regain in weight and relapses in health behaviors are common following the end of intervention. Trials indicate an average of 0.3 kg of weight is regained per month post intervention [9,10], and up to 50% of initial weight loss is regained within 1 year post intervention [11]. The challenge in maintaining weight loss has been largely attributed to the failure in maintaining PA and dietary improvements [12].

Extending contact with participants after an initial intervention has been found to improve weight loss maintenance [13,14] and support long-term PA and dietary behavior change [5,15]. A recent review of extended contact interventions delivered via telephone or face-to-face contact reported overall average weight regain was 3.2 kg less than in the corresponding control groups over approximately 18 months follow-up [13]. However, extended contact interventions delivered via face-to-face and telephone can be costly and time consuming [16,17], while Web-based delivery has been associated with poor participant retention and engagement [18,19]. Mobile phone text messaging may be an ideal extended contact intervention delivery modality due to its cost-effectiveness and ability to provide highly tailored support to participants in “real-time” [20,21]. Emerging evidence supports the feasibility and acceptability [22] and efficacy [23,24] of providing text message-delivered extended contact interventions to promote the maintenance of weight loss. However, no studies to date have explored the efficacy of a text message-delivered extended contact intervention to promote longer-term weight loss and associated PA and dietary behavior change.

This study aimed to assess the feasibility, acceptability, and efficacy of a 6-month text message-delivered extended contact intervention on the maintenance of weight loss and PA and dietary behavior change. This single-group, pre-post-designed study provided estimates of the effect sizes that may be achieved in a text message-delivered extended contact intervention and an opportunity to explore the relationship between text message dose and changes in weight and behavioral outcomes. The study aims were addressed in the context of the Living Well after Breast Cancer feasibility trial—a pilot randomized controlled trial evaluating a 6-month telephone-delivered weight loss intervention (versus usual care) for breast cancer survivors. Participants completing the 6-month telephone-delivered intervention were invited to receive a further 6-month intervention delivered via text messages. Long-term changes in weight, PA, and diet were evaluated within this intervention group. The maintenance of weight loss and associated behaviors is particularly important for breast cancer survivors as increasing evidence suggests that obesity, physical inactivity, and a poor diet quality are associated with increased risk of cancer recurrence and mortality [25-29].

Methods

Study Design

Participants in the Living Well after Breast Cancer feasibility trial completed a baseline assessment and were randomized to the initial telephone-delivered intervention (n=45) or usual care group (n=45). Those completing the initial telephone-delivered intervention (n=40) were invited to participate in the text message-delivered extended contact intervention. This sample size was insufficient to allow further randomization to an extended contact intervention versus control group. Assessments were conducted at baseline, 6 months (end of initial intervention), 12 months (end of extended contact intervention), and 18 months (end of no-contact follow-up). The Living Well after Breast Cancer feasibility trial and extended contact intervention were conducted at The University of Queensland in Brisbane, Australia. Ethical approval was obtained from the Human Research Ethics Committee of The University of Queensland and Queensland Health Research and Governance Unit.

Participant Recruitment

The Living Well after Breast Cancer feasibility trial aimed to recruit overweight and obese women who had recently completed treatment for stages I-III breast cancer [30]. Women aged 18-75 years who had been diagnosed with stages I-III breast cancer in the previous 9-18 months and were living within a 50 km radius of the state capital, Brisbane, were identified from the Queensland Cancer Registry. Eligible women had a body mass index (BMI) of 25-40 kg/m² (ie, overweight or obese), had completed primary cancer treatment (ie, surgery, radiation, chemotherapy), and could speak sufficient English to participate in the intervention. Women were excluded if they had been diagnosed with ductal carcinoma in situ (stage 0) or with distant metastatic disease (stage IV), had a previous diagnosis of invasive breast cancer, had been diagnosed with any other cancer in the past 5 years, had contraindications to participating in unsupervised PA due to poor health or a medical condition, or self-reported a mental health condition that would interfere with their participation in the study. Women currently using or planning to use weight loss medications or those who had or were planning bariatric surgery were also excluded. To be eligible for the extended contact intervention, participants needed to own a mobile phone and be able to read a text message sent to that phone. Those eligible and agreeing to participate provided written, signed consent for the initial and extended contact intervention phases.

Initial Weight Loss Intervention (Baseline to 6 Months)

The initial intervention aimed to promote weight loss through the combination of increased PA, reduced energy intake, and behavioral change strategies [14,31]. Intervention participants were mailed program materials (workbook, self-monitoring diary, scales, pedometer, calorie counter book) at the start of the intervention and received up to 16 telephone calls (6 x weekly calls followed by 10 x biweekly calls) from a coach using motivational interviewing techniques [32]. Coaches were Accredited Practising Dietitians [30] who received additional

training in motivational interviewing and exercise promotion. Participants were encouraged to aim for the targets of (1) weight loss of between 5-10% [33], (2) increasing moderate-vigorous PA to at least 30 minutes per day (210 minutes per week) [34], and (3) improving dietary behaviors (reducing energy intake by 2000 kJ [500 kcal] per day; <30% of total energy intake from fat; <7% of total energy from saturated fat; 5 servings of vegetables per day; 2 servings of fruit per day) [35,36]. Participants were provided with a target kilojoule intake (between 5000-7500 kJ/day [1200-1800 kcal/day]) based on their baseline weight and age [37].

Extended Contact Intervention (6-12 Months)

The extended contact intervention was primarily delivered via individually tailored mobile phone text messages. The aim of this phase of the intervention was to promote sustained and/or ongoing improvements in weight loss and PA and dietary behavior change from the initial intervention. The design of the extended contact intervention was informed by literature on maintenance of weight loss and behavior change [38-40], a 2-week qualitative, formative study on text message usefulness and language with the target group (n=8), and Social Cognitive Theory [41].

At the start of the extended contact intervention, participants completed a tailoring telephone call with their coach to gather information to determine individual preferences for the content, timing, and frequency of text messages. The tailoring call and the resulting text messages focused on supporting participants to reach a longer-term (ie, 6 weeks) weight loss/weight maintenance goal and a short-term (ie, weekly) goal focused on either PA and/or dietary behaviors. To support participants to reach these goals, the text messages targeted self-regulation skills through nine evidence-based strategies [36,42-44]: prompt SMART (Specific, Measurable, Attainable, Realistic, Timely) goal setting, prompt self-assessment of goal attainment, provide feedback, prompt self-reward, prompt self-monitoring, prompt relapse prevention, prompt "real-time" planned behavior, prompt preparatory and planning behavior, and prompt barrier identification and solutions. Each of these strategies were discussed with the coach during the tailoring call, and individual's responses (eg, self-nominated reward for reaching goal) were recorded and used to tailor the content of the text messages. These behavior change strategies were targeted in five different types of text messages (Table 1).

Message dose (ie, frequency) and timing (ie, day of week and time of day) were tailored to each participant for each of the five message types (Table 1). All participants received a minimum dose of 21 text messages over the 6-month

intervention, including 12 weight self-monitoring, three goal checks for weight, three goal resets for weight and, depending on whether participants chose to focus on PA and/or dietary behaviors, they also received three goal resets for PA and/or three for diet (see examples in Table 1). In addition to this minimum dose, participants could choose to receive additional messages targeting PA and/or dietary behaviors, including goal checks (maximum for each behavior n=24) and cues for planned behaviors (maximum for each behavior n=48; Table 1).

The frequency of weight self-monitoring messages was based on research that supports regular self-monitoring of weight for long-term weight loss [38]. The frequency of texts for goal check for weight and goal reset for weight and behavior were at six weekly intervals to regularly encourage participants to reflect on the suitability of their SMART goals based on recent changes. Based on our formative study, the frequency of the goal checks for behavior change and cues for planned behaviors were to make regular, but not overwhelming, contact.

Participants were encouraged to reply to goal check messages for weight, physical activity, and/or diet (Table 1). If participants responded to these messages, a tailored goal check reply message was sent (Table 1). When participants replied to a goal check message in the requested format (ie, yes/no), the software sent an automatically tailored response. If participants replied to a goal check message in an unexpected format, the software was unable to send an automatic reply. In this case, an email was sent to the research team to manually trigger the correct reply or, where necessary, individual messages could be written and sent directly to participants if the triggered response was not appropriate. For example, if a participant reported being ill, the reply would mirror the preset content but was reworded to acknowledge the illness and send well wishes. This was done to ensure that the close rapport developed between participants and their coaches was maintained to ensure the accountability and "humanness" of the program was upheld (an important factor identified in formative research).

Participants were also encouraged to reply to the goal reset messages (Table 1), and these data were used to update the tailoring information about their goals, but they did not receive a tailored response. Individually tailored message content and sending schedules were entered into a Web-based software program specifically built for this study that interfaced with a commercial telecommunication gateway through MessageMedia Pty Ltd to allow the sending and receiving of messages to individual participants. To ensure message content remained relevant, participant tailoring information was updated during a 12-week tailoring telephone call with their coach.

Table 1. Examples of how self-regulation strategies were targeted across the five different types of text messages.

Text message type	Strategies targeted in this type of message	Example	Minimum dose over 6 months			Frequency		
			Weight	PA	Diet	Weight	PA	Diet
Self-monitoring of weight	Prompt self-monitoring	If u havent weighed yourself in the last 2 weeks Karen then do it today! Amy	12	N/A	N/A	Biweekly	N/A	N/A
Goal check	Prompt self-assessment of goal attainment	How r u going Karen? Reach ur goal 2 walk 3x30mins? Text me back yes or no. Amy	3	0	0	Once in weeks 6, 18, 24	Maximum 1 per week (participant determined)	Maximum 1 per week (participant determined)
Goal check reply	Provide feedback Prompt self-reward Prompt relapse prevention Prompt “real-time” planned behavior Prompt self-monitoring Prompt preparatory and planning behavior Prompt barrier identification and solutions	Yes example: Fantastic Karen! Regular exercise will help u control ur weight. Remember 2 buy a magazine & reward yourself 4 ur excellent effort. Amy No example: Don't worry Karen. Think about what got in the way & plan 4 it this week. Work around ur barriers 2 achieve ur goals. Amy	Triggered by participant's reply			Triggered by participant's reply		
Goal reset	Prompt SMART goal setting	Reflect on ur exercise goals Karen. Eventually u want 2 aim for 7x30mins exercise/week & more is better. Text me back with a new goal! Amy	3	3	3	Once in weeks 6, 18, 24	Once in weeks 6, 18, 24	Once in weeks 6, 18, 24
Cues for planned behavior	Prompt “real-time” planned behavior Prompt self-monitoring Prompt preparatory and planning behavior Prompt barrier identification and solutions	Want 2 feel more energised Karen? Make time 2 walk 3x30mins this week & feel the difference. Amy	N/A	0	0	N/A	Maximum 2 per week (participant determined)	Maximum 2 per week (participant determined)

Data Collection and Outcomes

Feasibility Measures

Feasibility of implementation was assessed in relation to uptake of the intervention (ie, consent rate and characteristics of those who consented to the extended contact intervention), and process outcomes related to the delivery of the extended care intervention (ie, the number of messages sent, the rate of replies to goal check and goal reset messages, the rate of researcher intervention required to trigger goal check replies or alter content of text messages, and the duration of the initial and check-in telephone calls).

Efficacy Measures

Overview

Data were collected at baseline, 6, 12, and 18 months by trained research staff. Data collection involved an in-person assessment, two telephone interviews, and wearing an activity monitor for a period of 7 days. Intervention participants received printed, tailored feedback on weight and behavioral outcomes following all assessments.

Weight

Weight was measured in duplicate, without shoes or heavy clothing, using standard calibrated scales (nearest 0.1 kg).

Physical Activity

Physical activity was measured using a tri-axial accelerometer (GT3X+, Actigraph), worn for 7 consecutive days during waking hours. Data were used to determine minutes per day spent in moderate-vigorous PA (counts ≥ 1952) [45,46]. Average moderate-vigorous PA on valid days (ie, 10+ hours of wear) was then multiplied by 7 to yield a weekly estimate.

Energy Intake

Energy intake was measured using two, unprompted 24-hour dietary recalls (recalling 1 weekday and 1 weekend day). The dietary recalls were conducted via telephone using FoodWorks Interview (version 1, 2009, Xyris Software), based on a 5-stage multipass method [47]. Participants were provided with a food model booklet to assist in portion size estimation and food quantities. Dietary intake was analyzed using Foodworks Professional Edition (version 6, 2009, Xyris) nutritional analysis software to determine total daily energy intake. The average of energy intake over the 2 recalled days was used.

Participant Acceptability Measures

At the 12-month assessment, participants were invited to participate in a one-on-one semistructured interview to assess satisfaction with the extended contact intervention. A 5-point Likert scale was also used to assess the helpfulness of the text messages (from 1 “very unhelpful” to 5 “very helpful”).

Statistical Analyses

The sample size for the extended contact intervention was determined by the number of participants completing the initial intervention ($n=40$). Data analysis was performed using SPSS for Windows (version 21), and statistical significance was set at $P<.05$ (two-tailed). Changes from baseline at 6, 12, and 18 months for each outcome are reported. Change scores (follow-up minus baseline) had approximately normal distributions. Changes from 6 to 12 months and from 12 to 18 months are also reported. Data were analyzed, separately for each outcome, using linear mixed models, with random intercepts for each subject to account for repeated measures. Models included time (baseline, 6, 12, or 18 months) and adjusted for baseline values, age, income, time since diagnosis, and chemotherapy treatment.

These latter variables were included to correct for observed changes in group composition between 6, 12, and 18 months caused by dropout [48]. This method was used to handle missing data rather than baseline-value-carried-forward, which can overstate maintenance by not allowing participants who drop out to experience any decline (or gain). The association of dose of number of text messages received (treated as a continuous variable) with change in weight and PA and diet from baseline was examined by adding this variable to the linear mixed models. Process outcomes were evaluated descriptively. Participant acceptability was determined through semistructured interview questions, and thematic analysis of the qualitative interview data followed a systematic and iterative process [49]. This technique involved identifying major themes and categories from each participant and then examining common and uncommon themes across the complete dataset.

Results

Feasibility Outcomes

Participant Recruitment and Characteristics

Figure 1 shows the flow of participants through the study. A total of 45 women were randomized to the initial intervention, with 40 (88%) completing the 6-month assessment. Of these women, 36 were eligible to participate in the extended contact phase and 30 (83%) consented to participate, with one participant later becoming ineligible due to a recurrence. Twenty-five (86%) extended contact intervention participants completed the 12-month assessment, and 23 (79%) completed the 18-month assessment.

Participants at baseline had a mean age of 54.9 years (SD 8.8), a BMI of 30.0 kg/m²(SD 4.2), and were recruited a mean 16.6 months (SD 3.2) post diagnosis and 7.1 (1.4) months post treatment completion (Table 2 [50]). Compared to participants who completed all follow-up assessments ($n=23$), participants who withdrew ($n=6$) were more likely to be younger (mean 56 years vs 49 years), have a lower BMI (mean 30.5 kg/m² vs 28.2 kg/m²), be employed (65% vs 100%), and were less likely to have a high household income (32% vs 17%).

Figure 1. Flow of participants from baseline to the final 18-month assessment.

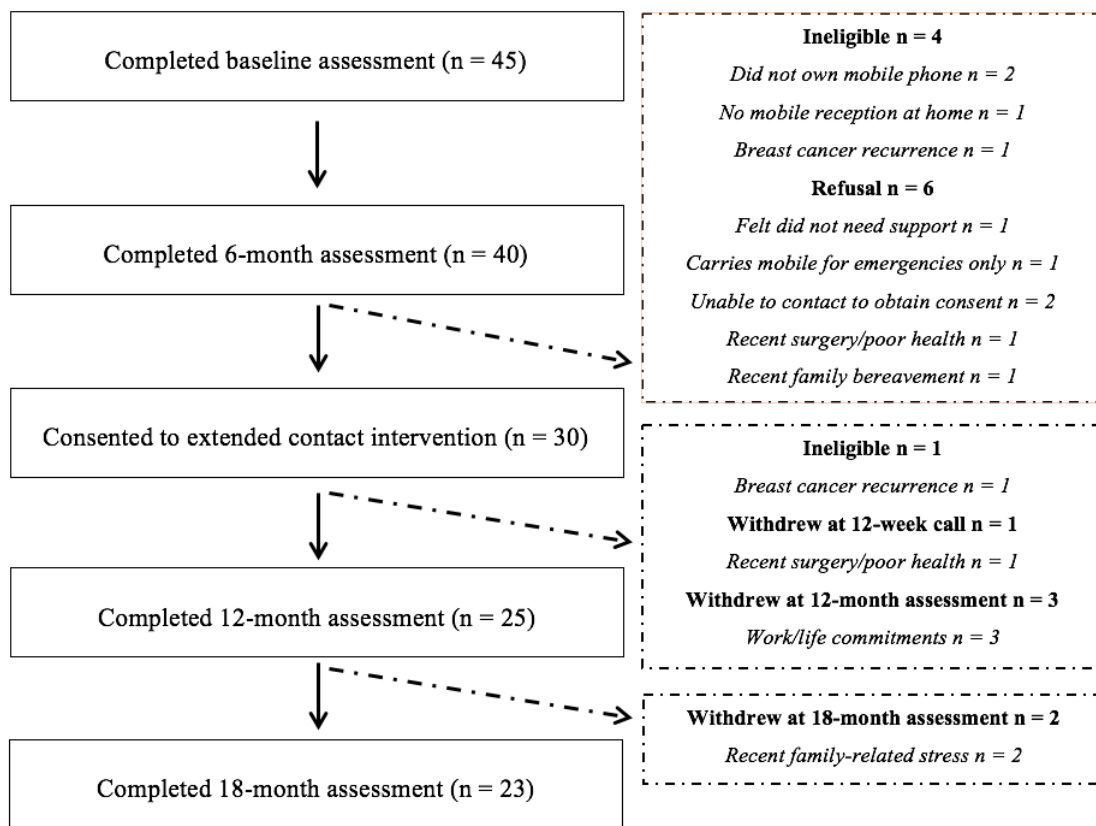


Table 2. Baseline characteristics of participants who consented to the extended contact intervention (n=29).

Characteristics	Mean (SD) or % (n)
Age in years	54.9 (8.8)
Weight in kg	81.8 (13.1)
BMI, kg/m ²	30.0 (4.2)
Time in months	
Since diagnosis	16.6 (3.2)
Since treatment	7.1 (1.4)
Caucasian	97% (28)
Married/living together	83% (24)
High household income (>AU\$2391+/wk) ^a	28% (7)
Education	
Completed high school	76% (22)
Completed tertiary education	34% (10)
Employed (full-time, part-time, casual)	72% (21)
Post-menopausal	59% (17)
Stage	
Stage I	48% (13)
Stage II-III	52% (14)
Treatment	
Mastectomy	38% (11)
Chemotherapy	62% (18)
Radiation	79% (23)
Endocrine therapy	69% (20)

^aHousehold income of >AU\$2391+ / week is within the top two quintiles based on the Australian population [50].

Extended Contact Intervention Process Outcomes

Participants chose to receive text messages focused on both PA and diet (n=12), or focused only on PA (n=11) or diet (n=6). Completing participants (n=25) received an average of 74 (range 25-135) text messages over the 6-month intervention. This equated to an average of approximately 8 text messages every 2 weeks (range 2-11), typically consisted of one weight self-monitoring, three cues for planned behavior, two goal checks, one tailored goal check reply, and one goal reset. Overall, participants replied to every two in three goal check messages (67% response rate), and every one in five goal reset messages (20% response rate). Less than half of the overall goal check reply messages were automatically sent to participants (41%), with researcher intervention required most of the time to either trigger the appropriate “yes” or “no” goal check reply (36%) or alter the content of the message to be appropriate to the participant reply (23%).

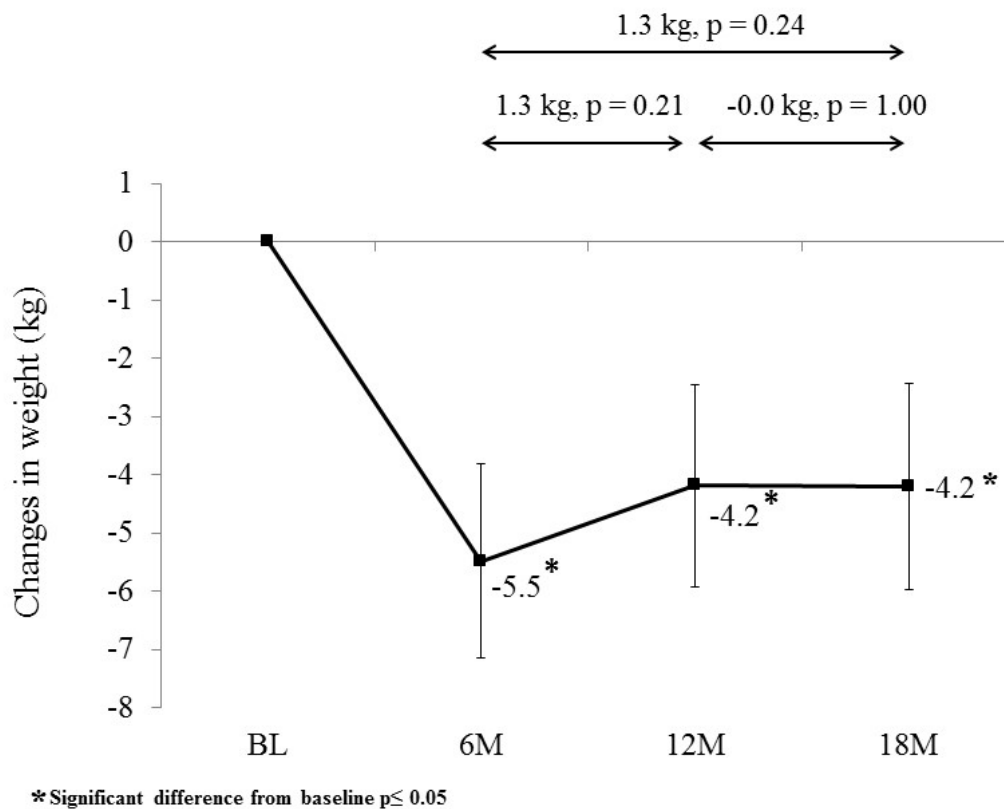
The initial telephone consultation with the coach lasted 22 minutes on average (minimum-maximum: 11-40 minutes). The 12-week check-in telephone call lasted 16 minutes on average (minimum-maximum: 8-31 minutes), and 88% of participants (n=22) used this call to update their goals or alter their text message content. The requested changes during this call were

mostly to change the behavioral focus of messages (eg, from PA- to diet-focused; n=3), or to increase (n=2) or decrease (n=2) the frequency of messages received. Two participants were not able to be contacted to receive a 12-week check-in telephone call, and their tailoring information remained the same for the full 6 months.

Efficacy Outcomes

Weight

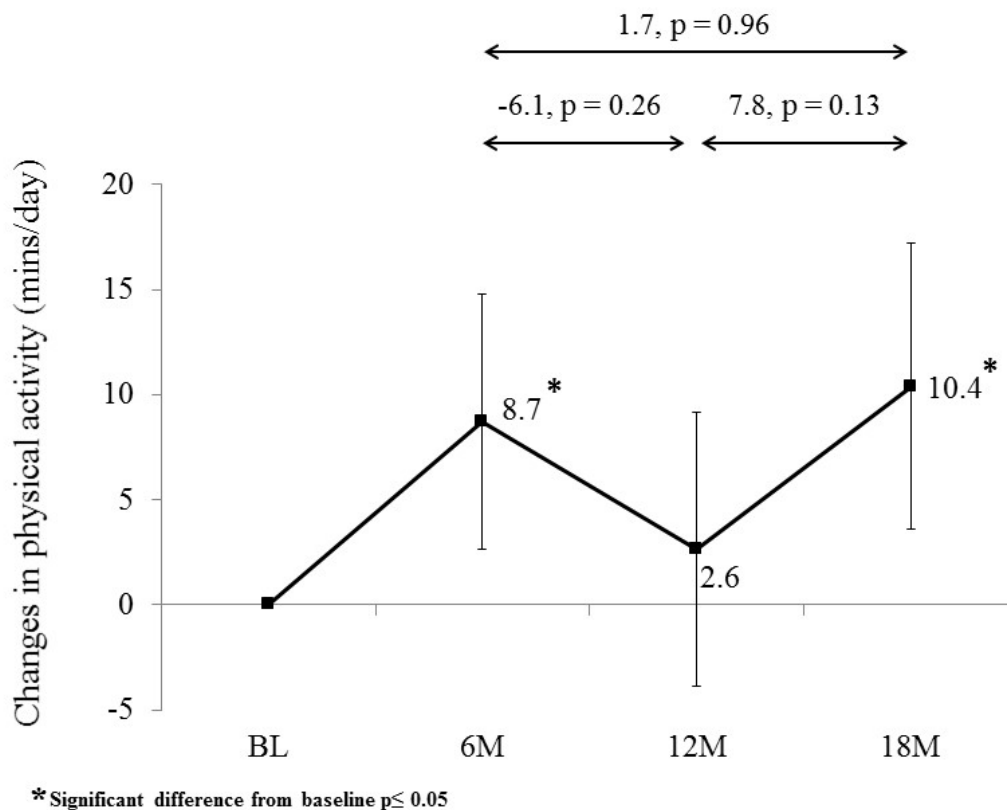
Overall, mean weight at 6, 12, and 18 months was statistically significantly lower than baseline (Figure 2; Multimedia Appendix 1). There was a small but non-significant increase in weight during the extended contact intervention (1.3 kg [95% CI -0.5 to 3.1]; $P=.211$), with weight remaining relatively stable over the no-contact follow-up period (-0.1 kg [95% CI -1.9 to 1.8]; $P=1.000$). Participants lost a mean of 6.8% (95% CI 4.7-8.8) of baseline weight during the initial intervention and regained 1.6% (95% CI -0.6-3.8) of baseline weight (23.5% of initial weight lost) during the extended contact intervention. At 18 months, participants had statistically significantly lower mean weight (-4.2 kg [95% CI -6.0 to -2.4]; $P<.001$) compared to baseline and on average had lost 5.2% (95% CI 3.0-7.4) of body weight.

Figure 2. Change in weight (kg) from baseline (BL) to 6 months (6M), 12 months (12M), and 18 months (18M) follow-up.

Physical Activity

Participants significantly increased their moderate-to-vigorous PA from baseline at 6 and 18 months (Figure 3; Multimedia Appendix 1). Physical activity at 12 months was not

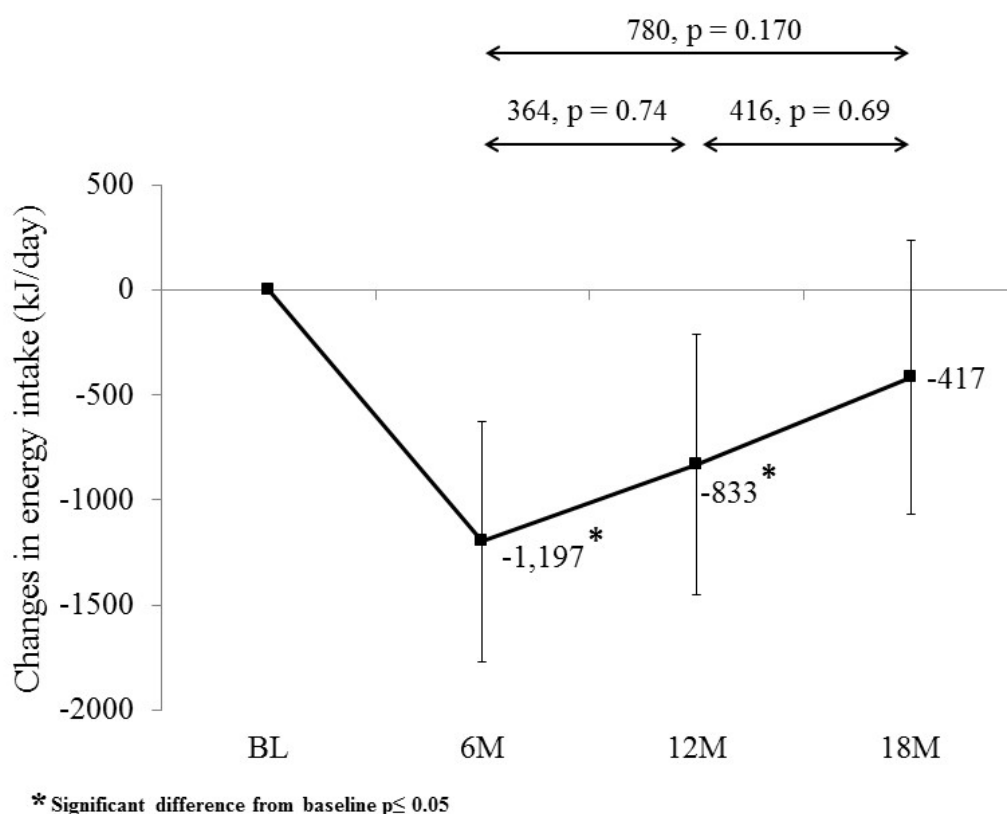
significantly different to baseline. Physical activity decreased but not significantly during the extended contact intervention (-6.1 mins/day [95% CI -14.9 to 2.8]; $P=0.260$) and increased but not significantly during the no-contact follow-up (7.8 mins/day [95% CI -1.6 to 17.2]; $P=0.132$).

Figure 3. Change in physical activity (mins/day) from baseline (BL) to 6 months (6M), 12 months (12M), and 18 months (18M) follow-up.

Diet

Participants significantly decreased their energy intake from baseline at 6 months and 12 months (Figure 4; Multimedia Appendix 1). Energy intake at 18 months was not significantly different to baseline. Energy intake increased, but not

statistically significantly, during both the extended contact intervention (364 kJ/day [95% CI -609 to 1338]; 87 kcal/day [95% CI -146 to 320]; $P=0.735$) and the no-contact follow-up (416 kJ/day [95% CI -620 to 1451]; 99 kcal/day [95% CI -148 to 347]; $P=0.690$).

Figure 4. Change in energy intake (kJ/day) from baseline (BL) to 6 months (6M), 12 months (12M), and 18 months (18M) follow-up.

Text Message Dose

Each additional text message received per week was associated with 9.5 minutes per day (95% CI 3.1-15.8; $P=0.004$) more PA at 18 months. There was no significant association between weekly text message dose and change in weight (1.3 kg [95% CI -0.3 to 2.8]; $P=0.098$) or change in energy intake (279 kJ/day [95% CI -157 to 716]; 67 kcal/day [95% CI -37 to 171]; $P=0.198$).

Participant Acceptability Outcomes

Of the 25 participants completing the extended contact intervention, 80% reported the extended contact as either “very helpful” (6/25, 24%) or “helpful” (14/25, 56%), and 20% (5/25) reported the extended contact as “neither helpful nor unhelpful”. The majority of women reported in the semistructured interviews that the text messages primarily served as a prompt or reminder for a specific behavioral cue to action, fostered accountability to keep on track, and that the text message content was sufficiently personalized. Overall, participants highly valued the goal check reply messages and the 12-week check-in telephone call as they provided a “human” element of contact important for ongoing feedback and accountability.

Discussion

Principal Considerations

The aim of this study was to explore the feasibility, acceptability, and efficacy of a 6-month text message-delivered

extended contact intervention in promoting the maintenance of weight loss and PA and dietary behavior change in breast cancer survivors who completed an initial 6-month telephone-delivered weight loss intervention. Overall, results suggest extended contact may have helped to attenuate weight regain and promote the maintenance of long-term change in PA. The highly tailored text message-delivered extended contact intervention was also feasible to deliver and acceptable among this sample of primarily older breast cancer survivors.

Importantly, mean weight at 18-months follow-up was significantly lower than at baseline (approximately 5.2% of initial body weight loss). Evidence from a large number of previous weight loss trials suggests that average weight regain following an intervention is in the order of 0.3 kg per month post intervention [9,10] or approximately 50% of weight lost is regained within 12 months post intervention [51]. In comparison, the magnitude of weight regain observed here was considerably less (approximately 0.1 kg per month or 23.5% regain of initial weight loss over a 12-month period). This study adds to the limited evidence to date on the efficacy of text messaging to support weight loss maintenance.

Donaldson et al [23] examined a 3-month text message-delivered extended contact weight loss intervention following an initial 3-month face-to-face weight loss intervention, finding that it resulted in an additional 1.6 kg weight loss at the end of the extended contact intervention compared to a regain of 0.7 kg weight regain in the no-contact control group [23]. A 1-month text message-delivered behavior change intervention following

a commercially available weight loss program reported 87% of participants regained less than 3% of initial weight loss at 3-months follow-up [24]. However, these studies focused on relatively short-term maintenance outcomes making comparison with outcomes here difficult [23,24]. Together, these findings provide emerging support for the use of text messaging to deliver extended contact interventions to promote weight loss maintenance.

Reporting on changes in PA and energy intake (the behaviors that underpin weight loss maintenance) following extended contact interventions has been limited. Overall, studies suggest that changes in PA are largely maintained at the end of an extended contact intervention [9,52-57], but maintenance of dietary behavior change appears more challenging [9,56,57]. Contrary to these previous findings, PA in this study had relapsed by the end of extended contact but rebounded by follow-up, while the opposite pattern of behavior was observed for energy intake. This inconsistent pattern of PA and dietary behavior change to weight change is mirrored in findings from the broader weight loss maintenance literature [9,56,57]. However, it is important to acknowledge the long-standing caveat of correlating changes in PA and diet as measured at a single point in time with more cumulative changes in weight.

Determining significant dose-response relationships between text message dose and behavioral outcomes may help inform the development of future extended contact interventions. Every additional text message received per week in this study was associated with a mean increase of more than 1 hour of PA per week at follow-up. This suggests the dose of extended intervention contact received may influence the maintenance of long-term behavior change outcomes but has yet to be examined in other studies. A larger scale intervention that allows personalized tailoring could examine the minimum dose of text messages received whereby a significant maintenance effect is no longer observed.

The acceptability of the delivery modality to the target group also influences intervention success [7]. Consistent with findings from previous studies exploring text message-delivered extended contact interventions to promote the maintenance of weight loss and behavior change [22,23], satisfaction ratings were high. Notably, the intervention completion rate was higher than previously reported in a younger population (86% vs 58%; [23]). This is promising given skepticism regarding the suitability of text message-delivered interventions in older adults [58].

Participants received a wide range of text message doses, and this reflects the feasibility to deliver a highly tailored extended contact intervention. Participant engagement with replying to messages was high, although researcher intervention was often required to provide suitably tailored feedback. Future text message-delivered extended contact interventions should

integrate more sophisticated software and programming approaches, such as those applied in mobile phone app behavior change tools to improve automation while maintaining a high level of participant tailoring [59,60]. However, our qualitative findings suggest that technology-driven interventions should maintain an element of “human” connection to foster ongoing participant satisfaction and accountability. A highly automated text message-delivered extended contact intervention may therefore need to be supplemented with additional non-automated contact, such as that delivered via telephone or email.

Limitations

A number of study limitations should be considered in interpreting the results. This study was largely exploratory as it was not feasible to re-randomize participants following the initial intervention due to the small sample size in the larger trial in which this study was embedded. Thus, comparison to a true control group was not possible. Establishing intervention acceptability among an older population group such as breast cancer survivors is a strength of the study but may also limit the generalizability of results to broader populations. Measurement error may have contributed to differences in patterns and magnitude of behavioral outcomes. Comparisons of behavior change outcomes to previous literature were difficult due to the limited number of studies that report post-intervention behavioral outcomes. This highlights the importance of future studies including post-intervention assessments to further examine how patterns of behavior change may influence weight loss maintenance.

Conclusions

In summary, findings from this study support the feasibility, acceptability, and provide preliminary evidence on efficacy of a text message-delivered extended contact intervention to promote the maintenance of weight loss and PA among a predominately older female subgroup. There is a growing evidence base supporting the utility of text messaging as an intervention delivery modality [20,21,61,62], with this study being the first to report on outcomes of a text message-delivered extended contact intervention to support long-term maintenance of weight loss and behavior change. Results suggest providing extended contact via text messaging after an initial intensive weight loss intervention may help attenuate weight regain and promote long-term physical activity behavior change compared to what otherwise would be observed without extended contact. Randomized controlled trials with larger and more diverse samples are needed, along with comparative effectiveness and cost-effectiveness trials comparing text messaging with other delivery modalities that might be suited to extended contact interventions (eg, mobile phone apps).

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Mean changes in weight, physical activity, and diet from baseline (BL) to 6 months (6M), 12 months (12M), and 18 months (18M) follow-up.

[[PDF File \(Adobe PDF File\), 36KB - mhealth_v3i3e88_app1.pdf](#)]

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Abbreviations

BMI: body mass index

PA: physical activity

SMART: Specific, Measurable, Attainable, Realistic, Timely

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Original Paper

A New App for At-Home Cognitive Training: Description and Pilot Testing on Patients with Multiple Sclerosis

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Abstract

Background: Cognitive impairment is common in people with neurological diseases and severely affects their social and professional life. It has been shown that intensive and personalized cognitive rehabilitation (CR), based on working memory exercises, leads to improved cognitive status of healthy and cognitive-impaired subjects. New technologies would help to promote accessible, at-home, and self-managed CR interventions.

Objective: The aim of this paper is to describe the design of Cognitive Training Kit (COGNI-TRAcK), an app for mobile devices, to self-administer an at-home, intensive, and personalized CR intervention based on working memory exercises, and test its disposability-to-use (usability, motivation to use, compliance to treatment) on cognitive-impaired patients with multiple sclerosis (MS).

Methods: COGNI-TRAcK includes user-friendly interfaces for personal data input and management and for CR intervention configurations. Inner routines automatically implement adaptive working load algorithms and allow data processing and analysis. A dedicated team developed COGNI-TRAcK with C# programming language, by using the platform Xamarin Studio 4.0.10 for Android (API level 15 and following). Three exercises based on working memory are now available. To assess the disposability-to-use of the system, patients with MS were selected as likely users due to the young age of disease onset. Cognitive-impaired patients with MS (N=16) with a mean age of 49.06 years (SD 9.10) and a mean score of 3.75 (SD 1.92) on the Expanded Disability Status Scale (EDSS) were submitted to an 8-week at-home intervention administered by the app. The intervention consisted of 5 daily scheduled 30-minute sessions per week. Disposability-to-use of COGNI-TRAcK was investigated by means of a questionnaire administered to patients at the end of the training.

Results: The adherence to the treatment was 84% (33.4/40). Of the patients with MS, 94% (15/16) understood the instructions given, 100% (16/16) felt independent to use COGNI-TRAcK at home, 75% (12/16) found the exercises interesting, and 81% (13/16) found the exercises useful and were motivated to use the app again. Moreover, during the exercises, patients with MS were highly motivated to perform well (mean score 3.19/4, SE 0.16), experienced rather low levels of stress (mean score 2.19/4, SE 0.26), were not bored (mean score 1.81/4, SE 0.30), and felt amusement (mean score 2.25/4, SE 0.23).

Conclusions: As COGNI-TRAcK is highly usable, motivating, and well-accepted by patients with MS, its effectiveness can now be investigated. To improve COGNI-TRAcK, new releases should contain more working memory exercises, have enhanced

perceived amusement, and promote Internet communication procedures for data transfer and fostering remote control of the intervention.

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KEYWORDS

tablet; mobile phone; mobile device; cognitive rehabilitation; cognitive impairment; working memory; self-management; adaptive working load algorithms; usability

Introduction

Cognitive impairment is common in people with neurological diseases [1,2] and it can deleteriously impact their occupational profile, social participation, and quality of life [3,4]. The alleviation of deficits on cognitive functioning is the main goal of cognitive rehabilitation (CR), and research should address the best way to administer CR to patients.

Recently, many studies on CR demonstrated that a training based on working memory produced relevant positive effects on cognitive status [5]. Working memory is defined as a limited capacity storage system involved in maintenance and manipulation of information over short periods of time, and it is involved in the execution of higher-order daily cognitive activities (ie, reading, learning, and mental calculation) [6]. Working memory capacity has been traditionally thought to be constant in healthy adults, although differences were observed depending on education level, age, and potential deficits in cognitive status. Actually, some recent studies demonstrated that a specific training of working memory not only produced an improvement in specifically trained aspects but a more general gain of working memory [6-8]. Furthermore, a training of working memory seems to positively influence a wide range of cognitive functions. In particular, a transfer effect was found on attention [9,10], cognitive inhibition [11], non-verbal reasoning [12], reading [11], and arithmetic [13,14]. In a review conducted by Takeuchi et al [5], the authors stressed the importance of several factors that may affect training efficacy. Interestingly, besides task types, subject motivation and arousal status, an adaptive working load (adjusting the task difficulty to the subjects' performance), and the intensiveness of training (quantity of training per day per week) were mentioned as crucial features of working memory training [12,15,16].

It has been clearly shown that an adaptive and intensive working memory training produces significant changes in healthy subjects' brain structure (white and gray matter) associated with an improvement in cognitive functions [16,17]. In addition, working memory impairments can also limit and/or restrict participation in daily activities [18].

In an era of inadequate economic resources to invest in health care, it is not possible to guarantee a constant and intensive outpatient administration of CR, seriously limiting the effects of the interventions. Indeed, proper CR programs based on traditional tools (eg, paper and pencil) require qualified professionals, outpatient facilities, and intensive treatment sessions which often lead to economic burdens at the expense of the user or the health care system. In this context, it would be desirable to promote a new CR management system in which

clients, remotely supervised and assisted by their team through procedures based on an Internet network, can self-administer at-home rehabilitation programs. Computerized systems may be particularly suitable to attain this aim by guaranteeing very efficient and user-friendly CR tools that could be used at-home by patients either independently (eg, at early stages of neurological disease), confined to their home by disease progression, or other clinical constraints. In particular, computer-based CR tools usually implemented on laptops and/or desktop computers, have been shown to be effective in improving cognitive functions in patients with stroke [19], Alzheimer's disease [20], or multiple sclerosis (MS) [21], confirming that they could be considered an excellent option for CR. With recent technological innovations, researchers are challenged to quickly develop cognitive treatment programs for mobile phones and tablets, thus making home-based CR exercise management and the (self)-administration of intensive CR interventions more feasible to patients and their caregivers. However, particular attention must be taken when implementing algorithms for automatic working load adaptation and automatic procedures for intensiveness regulation that most current computer-based CR tools do not incorporate.

The aim of the present study is to describe Cognitive Training Kit (COGNI-TRAcK), a mobile phone and tablet-based app for the home, or self-administration, of an actual intensive CR intervention based on working memory exercises. The main feature of COGNI-TRAcK is the implementation of automatic adaptive working load algorithms and procedures for intensiveness regulation.

A pilot test on patients with MS was performed to evaluate the adherence to a self-administered CR intervention and its disposability-to-use (usability, motivation to use, compliance to treatment). Patients with MS were chosen as a testing population for two main reasons. First, since approximately 40-65% of patients with MS show disabling cognitive impairments [22] involving memory, complex attention, information processing speed, executive functions, and visuospatial abilities [2], systems for intensive cognitive interventions are required. Second, MS affects patients of all ages making them the ideal end-users of our system. Indeed, studies showed that most of patients with MS are <65 years old [23], an age group consisting of digital natives and digital immigrants and considered the most probable technology consumers [24].

In fact, the evaluation of adherence and disposability-to-use is fundamental to propose a future, large-sample study that examines the effectiveness of a CR intervention with COGNI-TRAcK on patients with MS using specific clinical outcomes.

Methods

Overview

COGNI-TRAcK allows patients to have access to tailored CR interventions at any time of the day, thus increasing adherence to the scheduled rehabilitative treatment. In order to assess disposability-to-use, a tablet version of the COGNI-TRAcK app was tested on cognitively-impaired patients with MS recruited at the Italian Multiple Sclerosis Society (AISM) Rehabilitation Centre of Genoa (Italy). Ethical approval for the pilot testing was obtained from the Ethics Committee of Azienda Ospedaliera San Martino, Genoa, Italy, in 2011.

Development of the COGNI-TRAcK App

Overview

The development team first met in January, 2012 to discuss the project plan. An information technology (IT) specialist wrote the software program for COGNI-TRAcK with C# programming language using the platform Xamarin Studio 4.0.10, the version customized to create apps for the Android operating system (version 4.0, API level 15 and following). The development team met on a bi-weekly basis to resolve issues and review the progress of the software. A stakeholder team composed of the development team, a psychologist, and 3 patients (not included in the pilot testing) met 4 times during the development of COGNI-TRAcK and considered the final version suitable for patients with MS.

COGNI-TRAcK includes the following 4 main parts (1) the graphic user interface (GUI) allowing the administrator (eg, the clinician) to add personal data of new patients, to retrieve and to manage them, to set parameters of the working memory exercises, and to select general options of configuration ([Multimedia Appendices 1-4](#)), (2) the database, (3) routines for data processing, and (4) routines implementing adaptive working load algorithms. COGNI-TRAcK was conceived and designed with a modular structure able to evolve by adding new modules, such as exercises for working memory or other cognitive rehabilitative functions and electronic forms for compiling standardized scales for clinical evaluation.

Although not validated here as this study focused on disposability-to-use, the app was designed with a feature allowing for Internet-based data transfer between the device and a server installed at the rehabilitation unit for remote monitoring and management by the clinical team.

Working Memory Exercises Section

Overview

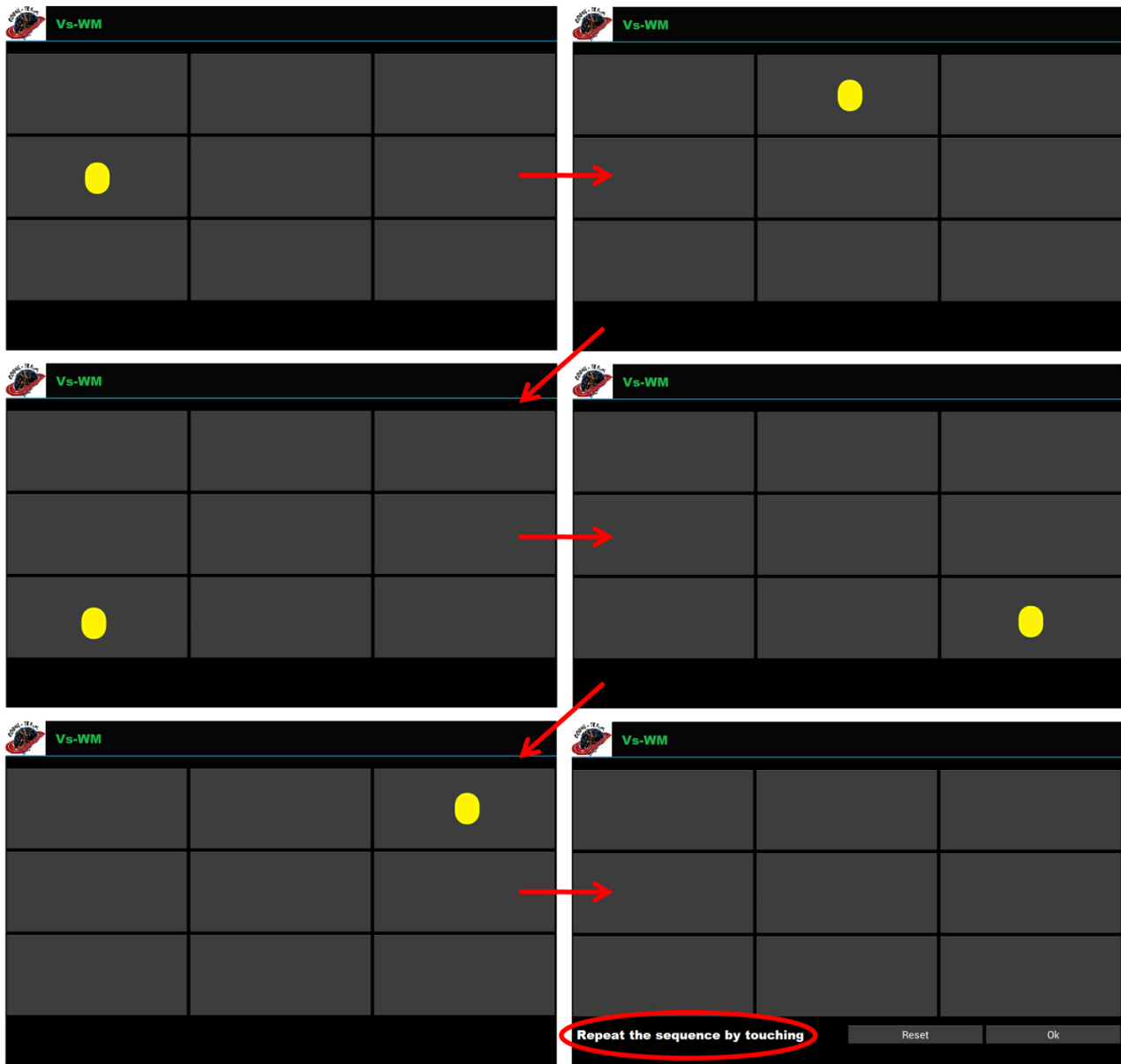
The working memory exercises section enables access to the editing of several exercise types. For each exercise type, records can be created and saved into the database, each one containing a specific configuration of parameters.

During the treatment protocol setting, the administrator directs the patient to the appropriate records in the database. Each record can be assigned more than once and each assignment corresponds to a trial that the patient will have to execute. In this modality of assignment, the administrator must set the complete protocol treatment in advance. This modality, however, does not use adaptive working load algorithms and is not preferred because the effectiveness of the rehabilitation intervention cannot be guaranteed. Therefore, the preferred way to set up a rehabilitation intervention is to make use of adaptive working load algorithms where the administrator has to assign only the starting record for each exercise type, corresponding to the first trial that the patient will perform. At the end of the first trial, a new record is automatically generated into the database and then assigned to the patient. This new record contains a new configuration of parameters calculated on the output of the applied adaptive working load algorithm. Increments or decrements in parameter values depend on the performance of the patient. The automatically generated record results are linked specifically to the patient and will not be assigned to another subject. To date, COGNI-TRAcK implements the following 3 types of working memory exercises.

Visuospatial Working Memory

In this type, patients have to remember a random sequence of visual stimuli (colored circles) presented one at a time in a grid-like interface; after the last stimulus presentation, they are asked to correctly reproduce the sequence by touching the corresponding locations on the device screen ([Figure 1](#)).

Figure 1. An example of visuospatial working memory (Vs-WM) exercises in which patients have to remember a random sequence of 5 circles consecutively presented (the temporal order is defined following the direction of the arrows). Task-specific parameters for Vs-WM include grid size (minimum 2x2; maximum not defined), number of stimuli composing the sequence (minimum 1; maximum not defined), and the rate of stimuli presentation. Adaptive working load algorithms could operate on all the task-specific parameters to increment the difficulty level.

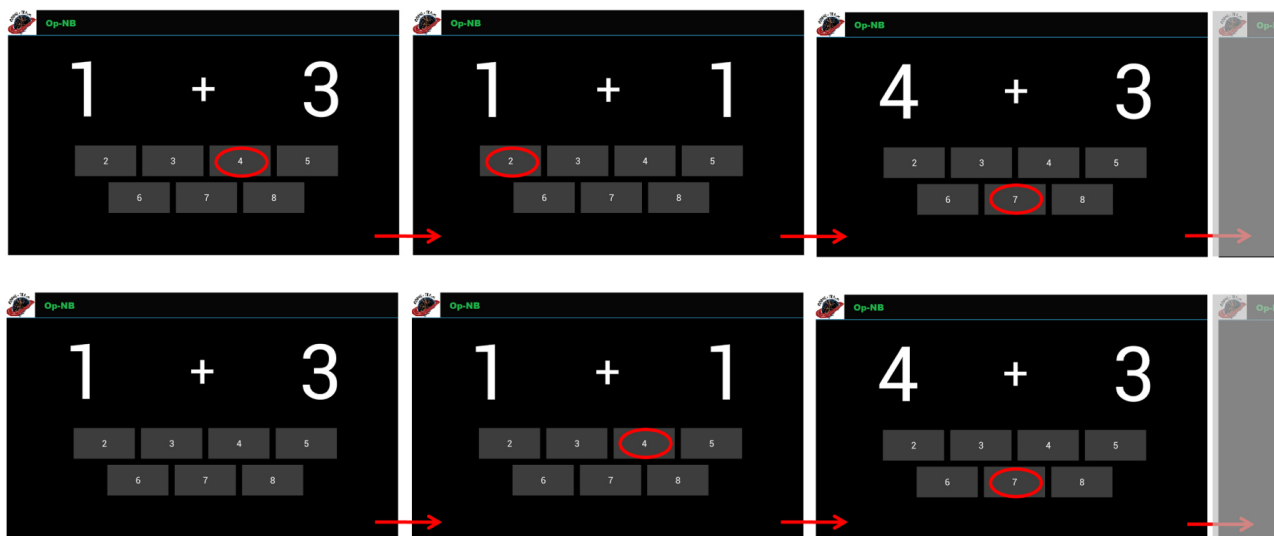


Operation N-Back

For this exercise type (Op-NB), a pair of numbers are presented on the screen (eg, 1+4) and if N=0 (Operation 0-back), then the patients have to quickly touch the button corresponding to their correct sum. After each answer a new random stimulus (ie, a

pair of numbers) appears. However, if N=1 (or higher), patients have to watch the pair of numbers, memorize them, and answer the correct result deferred by one (or more) new pairs. Thus, patients have to touch the button corresponding to the sum of N stimuli ago (Figure 2).

Figure 2. Examples of the operation N-back (Op-NB) exercises. The upper panel represents the operation 0-back (N=0) level of difficulty, whereas operation 1-back (N=1) is shown in the bottom panel. All the digits from 1 to 9 can appear on the screen and, consequently the sums range from 2 to 18. However, it is possible to reduce the difficulty of the task by limiting the digit span. Besides digit span, other task-specific parameters have to be taken into account such as the value of N (minimum 0; maximum not defined) and the rate of stimulus presentation. In Op-NB, adaptive working load algorithms operate only on N and rate of stimulus presentation.



Dual N-Back

In the dual N-back (D-NB) exercise type, patients have to look at a stimulus consisting of a digit from 1 to 4 on the screen. The stimulus appears in one of 4 adjacent cells placed in a row. If N=0 (Dual 0-back), the patients are asked to touch, as quickly as possible, both the response button corresponding to the appeared digit and the button indicating the cell in which the digit appeared. The red buttons (1, 2, 3, and 4), indicating the digit, are on the lower left corner of the screen and should be touched with the left hand. The green buttons (5, 6, 7, and 8), indicating cell position (5 represents the left-most cell and 8 the right-most cell), are found on the lower right corner of the screen

and should be touched with the right hand. After each answer a new stimulus randomly appears. However, as for Op-NB, patients have to defer the answer according to the N value (Figure 3).

There are a fixed maximum number of trials for the Op-NB and D-NB exercise types; automatically created from the starting record, this parameter remains the same and is not subjected to the adaptive working load algorithms. Another crucial parameter not modified by the adaptive working load algorithm is the threshold of correct answers (in percentage) under which a trial is considered “not valid”. This parameter is independently set for the different types of exercises.

Figure 3. Examples of the dual N-back (D-NB) exercise. The upper panel shows the D-NB difficulty level when N=0 (“Dual” 0-back), whereas the lower panel shows N=1 (“Dual” 1-back). Here, patients have to watch the stimulus, memorize it, and touch the buttons corresponding to the digit and cell deferred by one new stimulus. Task-specific parameters are N (minimum 0; maximum not defined), and the rate of stimuli presentation, both susceptible to modifications by the adaptive working load algorithms.



General Setting Section

After the exercise is assigned, general information can be set. In the panel for general setting, it is possible to set the daily maximum time of training for each exercise type (expressed in minutes). Consequently, in CR interventions in which an adaptive working load algorithm is checked, the total number of trials executed by the patient is not predictable as it depends on presentation rate of the stimuli and is adapted following the patients' performances.

Several other important temporal options can be selected in the general setting section including the total duration of the CR interventions (expressed in weeks) and the maximum number of days a week allowed for the training (expressed in days). These options are particularly crucial in determining the intensiveness of the training and the possibility to administer personalized treatment. Moreover, in this section, the administrator can switch ON the User-check, activating the USER-modality that presents a more user-friendly interface to the patient. If User-check is switched ON, at each next tablet restart, COGNI-TRAcK is automatically loaded in the USER-modality that gives direct access to the training exercises for the selected patient. This modality is implemented in order to limit patient-device interactions and access to other apps or to the general settings of the tablet. As well, this modality allows patients to be completely autonomous in performing the treatment with only little experience in using portable devices, thus making at-home, self-interventions possible. The administrator can also switch OFF the User-check, returning to the ADMIN-modality for all the procedures reserved for the team supervising the training program.

Database

All the information entered in COGNI-TRAcK is stored in a database structure managed by SQLite database management system. The database structure consists of the following 3 sections (1) "Patients" containing the personal data of the patients, (2) "Exercises and Treatments" containing the records specific of each exercise type, the information of assignment, the checks of the adaptive working load algorithms, and the length of the CR intervention, and (3) "Settings" containing general COGNI-TRAcK configuration features.

Tables are consistently correlated according to an entity-relationship model. Each table is identified by a minimal set of uniquely identifying attributes (primary key) which point to indexes in other tables, establishing the relationships.

Routine for Data Processing and Adaptive Working Load Algorithms

Raw data recorded by COGNI-TRAcK are made available for data processing. After each trial execution, raw data are saved into a text file stored in a dedicated folder automatically created during the installation procedure. Routines for data processing are applied to elaborate raw data after each trial, to calculate the percentage of total correct answers to the stimuli, and to match it with the percentage threshold used to consider a trial "valid" or "not valid". When one or more consecutive trials are "valid" or "not valid", adaptive working load algorithms define a new record with the parameters adapted for the next trial (see

Working Memory Exercises section). For each new record, the adaptive algorithms automatically modify one or more task-specific parameters depending on the level of difficulty.

A dedicated button generates a report containing the processed data of every task executed by the selected subject. Besides the date and time of task execution, description of exercise type, and paradigm parameters, the report contains the number of correct, incorrect, or missed answers given and the difficulty level achieved by the subjects.

The raw data and/or results text file can be exported to an external storage device. Moreover, through an Internet connection, the files can be backed up on the server at the rehabilitation unit for remote monitoring by the medical team. The backup can occur after each trial if the connection is activated during the training, or all the files not yet backed up can be sent when the connection is next activated.

Study Design

Overview

In order to validate disposability-to-use of COGNI-TRAcK, a pilot test on patients with MS was performed by setting a specific training program with adaptive working load algorithms. A survey on its usability, motivation to use it, and compliance to the COGNI TRAcK treatment was performed at the end of the CR intervention.

Patients

A group of 16 patients with MS (3 men and 13 women) was recruited from the AISM Rehabilitation Centre of Genoa (Italy). The following inclusion criteria were considered for the recruitment process (1) a diagnosis of MS clinically defined following the McDonald criteria [25], (2) the absence of relapsing in the last 3 months, and (3) a performance lower than -1 SDs from the mean of one of the tests included in the Rao's Brief Repeatable Battery of Neuropsychological Tests (BRB-N) [26]. The BRB-N is the most widely used instrument to assess cognitive functioning in patients with MS and it is shown to be reliable and sensitive to identify disturbances of cognitive domains in these patients [27]. Normative values and correction factors refer to the Italian validation of the BRB-N, published by Amato et al [28].

The mean age of the patients was 49.06 years (SD 9.10, range 33-67) and their mean education was 11.75 years (SD 3.41, range 8-18). Of the patients, 9 were affected by a relapsing-remitting form of MS and 7 by a progressive form. The mean value of the Expanded Disability Status Scale (EDSS) [29], a method of quantifying disability in MS, was 3.75 (SD 1.92, range 1-6.5), and the mean disease duration was 161.69 months (SD 109.56, range 20-374). All the recruited patients performed a score lower than -1.5 SD in at least 2 tests of the BRB-N (see [Multimedia Appendix 5](#)). All of the patients were familiar with the basic usage of electronic devices such as personal computers or portable devices (ie, mobile phones or tablets).

All the patients that participated in this study gave informed consent. The study was conducted in accordance with the Declaration of Helsinki (1964) [30].

Training Program

The participants performed an 8-week, home-based training program of working memory exercises, scheduled in 5 daily sessions per week (40 sessions total), and each session lasting 30 minutes. This training schedule was planned in accordance to the study conducted by Takeuchi and colleagues [16], where they showed that a similar program administered to healthy subjects not only improved cognitive performance but induced a related brain structure recovery [16]. However, rather than the subjects executing the training every day of the week and more than once daily, we limited the training to only 5 sessions per week and one session a day. This schedule was chosen in order to avoid inducing central fatigue; in fact, central fatigue is a very limiting symptom experienced and reported by 60-90% of patients with MS [31].

All 3 types of working memory exercises implemented in COGNI-TRAcK (Vs-WM, Op-NB, and D-NB) were presented during each training session for about 10 minutes each. The starting level (starting record) for each type of exercise was set equal for all patients and the difficulty level varied according to the adaptive working load algorithm. The following algorithm was adopted: for every trial detected as "valid" the level of the task increased by 1 and a new record was automatically created. If 3 trials in a row were detected as "not valid", the level of the task decreased by 1 and a new record was automatically created. Accordingly, after the first and the second trial detected as "not valid", no new records were created and the last used was adopted for the next trial. A trial was considered "valid" if the percentage of total correct answers was $\geq 100\%$ for Vs-WM, $\geq 80\%$ for Op-NB, and to $\geq 75\%$ for D-NB, thresholds set according to the training program validated by Takeuchi [16].

For all 3 types of exercises, the level of difficulty was varied first until the rate of stimuli presentation reached a threshold (1 stimulus per second for Vs-WM and 1 stimulus every 3 seconds for Op-NB and D-NB), and then by changing the other task-specific parameters (number of stimuli for Vs-WM and N

for Op-NB and D-NB). In Op-NB and D-NB, the number of stimuli increased with increasing N using the following mathematical formula:

$$\text{Number of stimuli} = (N+1) \times 5$$

According to this formula, when $N=2$, the number of stimuli is 15. In order to make the CR intervention more comfortable, participants were allowed to execute the daily 30-minute sessions at their preferred time of day.

The recruited patients underwent a practice session during which a neuropsychologist provided an explanation about COGNI-TRAcK functions and use, and provided detailed working memory exercise instructions. The neuropsychologist did not provide the system to start the intervention until he/she was sure that the patient was independent.

Outcomes

After the 8-week training program, a questionnaire the on usability of the system, motivation to use it again, and compliance to the treatment with COGNI-TRAcK was administered to each patient (Textbox 1), similar to previous studies on web-based CR tools [32]. The first 5 yes/no questions (Q1-Q5) investigated whether the patients felt ready to use COGNI-TRAcK at home after the practice session, whether they found the training interesting and useful, and whether they were motivated to use it again. Questions 6-9 (Q6-Q9) were multiple choice and required a single response from 1 (low) to 4 (high), indicating the level of motivation, stress, boredom, and amusement perceived while executing the exercises. The 4 possible answers in the multiple choice questions were "High", "Medium", "Low", and "Not at all".

As well, the percentage of days of completed training out of the total number of day in the 8-week period was calculated to assess the adherence to treatment (100% corresponded to the 40 sessions). Only the patients completing ≥ 32 sessions (80%, 32/40) were included in the analysis.

Textbox 1. Questionnaire assessing the usability, motivation, and compliance (disposability-to-use) of COGNI TRAcK.

Questions

- Yes/no questions
 - Q1: Were the instructions on COGNI-TRAcK use given in the practice session clear and easy to follow?
 - Q2: After the practice session, did you feel independent to use COGNI-TRAcK?
 - Q3: Did you find the exercises interesting to you?
 - Q4: Did you find the training useful to you?
 - Q5: Are you motivated to use COGNI-TRAcK again?
- Multiple choice questions
 - Q6: What level of motivation to well perform did you feel during the exercises execution?
 - Q7: What level of stress did you feel during the exercises execution?
 - Q8: What level of boredom did you feel during the exercises execution?
 - Q9: What level of amusement did you feel during the exercises execution?

Results

All the patients included in the data analysis performed the minimum of 32 sessions, with a mean adherence of 84% (33.4/40).

Results from the questionnaire showed that 15 participants (94%, 15/16) understood the instructions given in the practice session (Q1), all participants (100%, 16/16) felt independent to use COGNI-TRAcK at home (Q2), 12 participants (75%, 12/16) found the exercises interesting (Q3), and 13 (81%, 13/16) also

found the exercises useful for their clinical condition (Q4). After the 8-week training program, 13 patients (81%, 13/16) felt motivated to use COGNI-TRAcK again in the clinical practice (Q5) (Figure 4). Moreover, during the execution of the exercises, the patients felt highly motivated to perform well as the mean score for Q6 was 3.19 (SE 0.16). The patients experienced low levels of stress since the mean score for Q7 was 2.19 (SE 0.26) and were not bored as the mean score for Q8 was 1.81 (SE 0.30). As well, the mean score for Q9 demonstrating amusement was 2.25 (SE 0.23) (Figure 5).

Figure 4. Results from the questionnaire on the usability of COGNI-TRAcK. The columns show the percentages obtained in the first 5 questions referring to usability and motivation.

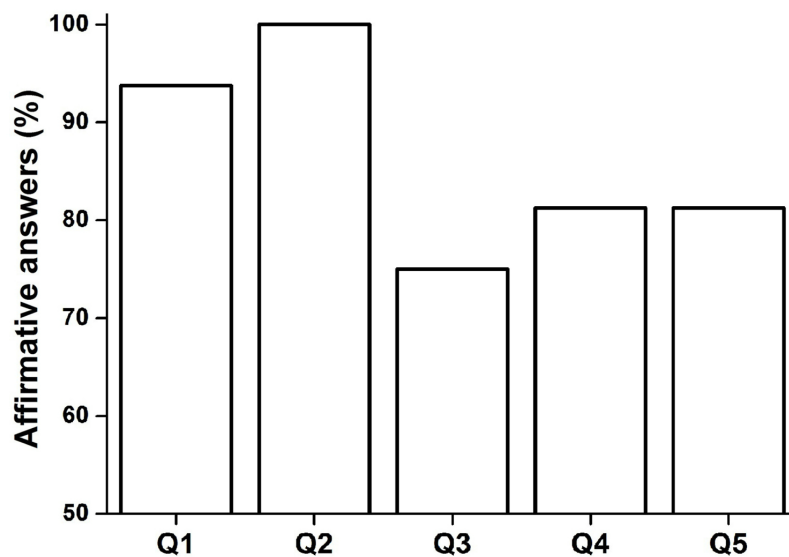
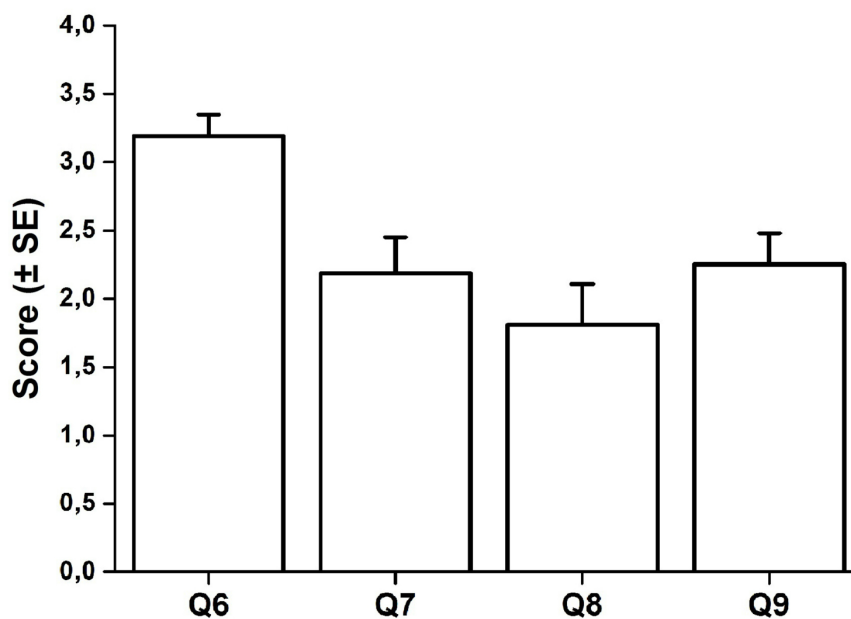


Figure 5. Results from the questionnaire on the motivation and compliance to use COGNI-TRAcK. The columns indicate the mean value obtained for compliance on a scale from 0 to 4.



Discussion

Principal Findings

Cognitive impairments often affect people with neurological disease [1,2], worsening their quality of life and reducing their occupational profile and social participation [3,4]. This is particularly constrictive for young patients, such as those with MS, which would like to remain independent as long as possible from the time of diagnosis, be active in the social context, and hope to maximize outpatient time fostering at home, self-administered interventions. In this context, CR would play a crucial role in reducing or maintaining the impairment stable, and facilitating the process of reintegration of these persons [19-21]. Thus, research focused on finding new ways to administer more usable CR interventions, to make them more effective, and to ensure a high adherence to the treatments is imperative. Rehabilitation researchers (ie, physicians, therapists, and bioengineers) should define and design new low-cost tools.

In this context, technology-based products such as mobile phones and tablets would meet these main requirements for future CR. COGNI-TRAcK is a tool meeting that meets these requirements since it is based on economic, accessible, and widely-used technological devices (mobile phones and tablets). COGNI-TRAcK presents an easy-to-use graphic user interface that allows for the self-administration and self-management of a home-based CR intervention and fulfills key factors such as adaptation and intensiveness of the working load that improve treatment effectiveness [5].

The present study assessed disposability-to-use of COGNI-TRAcK by investigating its usability, motivation for future use, and compliance to the treatment in patients with MS by an ad hoc questionnaire. Results show that this new system was very well received by patients with MS as deduced by the high adherence to the treatment. In fact, 84% of the total scheduled training sessions were completed by the patients, suggesting that this tool could be proposed for a CR intervention for patients with MS. As highlighted by the first 4 questions (Q1-Q4) in the opinion questionnaire, the app is highly usable. In fact, only one patient did not find the COGNI-TRAcK

instructions given during the practice session clear and easy to follow (Q1). However, after probing deeper, it was revealed that the patient was referring to difficulties in correctly performing the exercises as instructed rather than difficulties with the general use of COGNI-TRAcK. Moreover, all patients felt independent to self-manage the training at home (Q2). In our opinion, this is a crucial result since previous studies in expectancy and usage of mobile technologies in the clinical environment revealed that a remarkable concern expressed by patients is that the use of mobile phones and tablets might be too complicated when it comes to health issues [24]. Of the subjects, 75% found the proposed exercises interesting (Q3) and >80% revealed that the training was useful (Q4). This important result shows that participants did not feel only the ludic aspects of COGNI-TRAcK but had an invested interest in performing the training and recognized the importance in stabilizing or ameliorating their personal cognitive performances. The question about motivation showed that the participants were highly stimulated to use COGNI-TRAcK again and adopt this tool in their clinical practice.

In general, compliance, investigated through the last part of the questionnaire (Q6-Q9), was found to be high. In fact, the participants felt highly motivated in performing the exercises (Q6), whilst the levels of perceived stress (Q7) and boredom (Q8) were low. However, low levels of amusement were experienced, suggesting that new expedients to increase interest and perceived amusement during exercise execution, such as graphical renovation, are required in order to enhance COGNI-TRAcK compliance.

Conclusions

We demonstrated that COGNI-TRAcK, a tool for personalized cognitive intervention (self-administration), is highly usable, motivating, and well-accepted by patients with MS. We are now ready for a large-scale deployment of COGNI-TRAcK and are particularly interested in validating both its neurological aspects (eg, therapeutic effectiveness and effect on brain structure and function) and technological features such as Internet communication procedures for the data transfer to a central server.

Acknowledgments

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Conflicts of Interest

None declared.

Multimedia Appendix 1

The main panel of COGNI-TRAcK consists of icons on the left to access the "Patients" and "Setting" sections. On the right, icons to access working memory exercises are displayed. The dashed icons represent new exercises that can be added to the app in future releases.

[[JPG File, 355KB - mhealth_v3i3e85_app1.jpg](#)]

Multimedia Appendix 2

Shown here is a view of COGNI-TRAcK used by the administrator where a new patient can be added and where the data of existing patients can be retrieved and managed.

[[JPG File, 246KB - mhealth_v3i3e85_app2.jpg](#)]

Multimedia Appendix 3

The "Treatment Assignment" section of COGNI-TRAcK shown here is used by the administrator to assign exercises for new trials of the rehabilitative treatment.

[[JPG File, 418KB - mhealth_v3i3e85_app3.jpg](#)]

Multimedia Appendix 4

The "Results" panel of COGNI-TRAcK is used by the administrator to see the results of already performed trials.

[[JPG File, 318KB - mhealth_v3i3e85_app4.jpg](#)]

Multimedia Appendix 5

The BRB-N performances obtained by the patients involved in the pilot testing. All the recruited subjects performed a score lower than -1.5 SD (red bolded colour) in at least 2 tests of the BRB-N (SRT-LTS: Selective Reminding Test-Long Term Storage, SRT-CLTR: Selective Reminding Test-Consistent Long Term Retrieval, SRT-D: Selective Reminding Test-Delayed, SDMT: Symbol Digit Modalities Test, PASAT-3: Paced Auditory Serial Addition Test-3 s, PASAT-2: Paced Auditory Serial Addition Test-2 s, SPART: SPATial Recall Test, SPART-D: SPATial Recall Test-Delayed, WLG: World List Generation).

[[JPG File, 1MB - mhealth_v3i3e85_app5.jpg](#)]

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Abbreviations

- BRB-N:** Brief Repeatable Battery of Neuropsychological tests
- COGNI-TRAcK:** Cognitive Training Kit
- CR:** cognitive rehabilitation
- D-NB:** dual N-back exercise type
- EDSS:** Expanded Disability Status Scale
- MS:** multiple sclerosis
- Op-NB:** operation N-back exercise type
- Vs-WM:** visuospatial working memory exercise type

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Original Paper

Mobile Phone App Aimed at Improving Iron Intake and Bioavailability in Premenopausal Women: A Qualitative Evaluation

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Abstract

Background: Low iron intake can lead to iron deficiency, which can result in impaired health and iron-deficiency anemia. A mobile phone app, combining successful dietary strategies to increase bioavailable iron with strategies for behavior change, such as goal setting, monitoring, feedback, and resources for knowledge acquisition, was developed with the aim to increase bioavailable iron intake in premenopausal women.

Objective: To evaluate the content, usability, and acceptability of a mobile phone app designed to improve intake of bioavailable dietary iron.

Methods: Women aged 18-50 years with an Android mobile phone were invited to participate. Over a 2-week period women were asked to interact with the app. Following this period, semistructured focus groups with participants were conducted. Focus groups were audio recorded and analyzed via an inductive open-coding method using the qualitative analysis software NVivo 10. Themes were identified and frequency of code occurrence was calculated.

Results: Four focus groups (n=26) were conducted (age range 19-36 years, mean 24.7, SD 5.2). Two themes about the app's functionality were identified (frequency of occurrence in brackets): interface and design (134) and usability (86). Four themes about the app's components were identified: goal tracker (121), facts (78), photo diary (40), and games (46). A number of suggestions to improve the interface and design of the app were provided and will inform the ongoing development of the app.

Conclusions: This research indicates that participants are interested in iron and their health and are willing to use an app utilizing behavior change strategies to increase intake of bioavailable iron. The inclusion of information about the link between diet and health, monitoring and tracking of the achievement of dietary goals, and weekly reviews of goals were also seen as valuable components of the app and should be considered in mobile health apps aimed at adult women.

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KEYWORDS

cell phones; telemedicine; mobile apps; iron; behavior therapy; focus groups; goals

Introduction

Iron deficiency (ID) is the most prevalent micronutrient deficiency in the world [1]. Insufficient iron can impair oxygen transport due to a reduction in hemoglobin, which in turn can

result in impaired mental function, chronic fatigue, impaired aerobic metabolism, decreased work performance, decreased thermoregulation, and decreased immune function [2-4]. ID and iron-deficiency anemia can also negatively affect

neuropsychological factors such as mood, cognitive functions, learning ability, and memory [5-8].

Women of reproductive age are at risk of ID due to blood loss via menstruation, low dietary iron intake, and high gestational requirements [9,10]. A few small-scale, resource-heavy, dietary interventions have been shown to increase iron stores in women whose iron stores are low [3,11,12].

Mobile phone apps have potential as a flexible, tailored, customizable, wide-reaching, cost-effective, and accepted means of health promotion [13]. Apps have the ability to incorporate the most effective components of behavior change, such as goals, self-efficacy, self-monitoring, feedback, tailoring, and planning, into a platform that is user friendly, engaging, and flexible [14,15]. Because of the potential of apps to reach a wide audience, we have recently developed an app aimed at increasing women's intake of bioavailable iron in order to improve iron status. The app has been developed based on dietary interventions that have improved iron status and components of behavior change, which have proven effective in dietary behavior change [3,11,12]. This app will be used in a randomized controlled trial investigating the feasibility of increasing iron intake via supplements or dietary intake using mobile phone apps (ACTRN12613000912785). Pending the outcomes of this trial, the app is intended for wide release and will be made available through various venues such as the iTunes app store and Google Play store.

While apps have the potential to bring dietary and lifestyle interventions to large populations, their efficacy is currently unknown. Prior to the use of this novel app in a randomized controlled trial, usability and functionality of the app should ideally be tested in the target population of premenopausal women. Such information can help to optimize app functionality and effectiveness, to ensure content quality, and to understand the app's potential for health and behavior change [16-18]. Modifying the development of this app based on initial feedback from potential end users is consistent with recommendations that state a high level of usability is essential to ensure uptake and adoption of health promotion apps [19].

The aim of this study is to evaluate the content, usability, acceptability, and functionality of a mobile phone app designed to improve bioavailable iron intake in premenopausal women. The findings from this study will be used to inform the refinement of the app and add to the evidence base of desired features of apps designed to promote dietary change.

Methods

Study Design

This study descriptively explored user preferences for an app designed to improve intake of bioavailable iron in

premenopausal women. Participants were provided with a link to download the mobile phone app and were asked to use the app at their leisure over at least a 2-week period, during which time they were asked to read information, play games, set goals, and take photos of meals. Continued use of the app was encouraged via a reminder email sent to each participant during the trial period. Following this 2-week period, semistructured focus group discussions were conducted to determine users' opinions of the app.

Mobile Phone App Development

The content of the Women's Iron, Zinc, and Energy (WIZE) app was developed based on a systematic review of the literature on dietary factors influencing iron status in combination with findings from 2 dietary intervention studies investigating dietary strategies to increase iron status in women [11,20-22]. In addition to providing information on rich sources of dietary iron, the app also included recommendations to increase iron-fortified food intake, consume foods rich in vitamin C with meals, and avoid consumption of tea and coffee with meals, based on previous studies highlighting efficacy [11,20-23]. The app incorporated successful strategies of behavior change such as those found in social cognitive theory [24], the health belief model [25], and self-determination theory [26]. Strategies for behavior change that were utilized by the app included goal setting, monitoring, feedback, self-motivation, and strategies for knowledge acquisition.

The app delivered iron-related nutrition information in 7 fact sheets, which were designed to increase knowledge of dietary sources of iron and the relationship between iron and health. In addition to increasing participant knowledge about iron, it was hoped that informing users about the detrimental health effects of low iron levels would help to make iron status personally important to users. It is theorized that this would promote self-motivation within users and further encourage behavior change.

The use of games has previously been shown to encourage knowledge uptake; therefore, games (word search and word jumble) were included to develop further iron-related knowledge and facilitate participant engagement and use of the app [27,28]. One goal per week was established (eat 2 iron-fortified products each day, eat 50 mg of vitamin C with meals, aim to eat 12 points of iron each day, and drink coffee and tea at times other than during meals), which aimed to increase iron intake and absorption through gradual implementation of dietary change. To assist women in meeting these goals, a goal tracker was included to record adherence and to monitor participant progress toward each of the goals. The photo diary function was included to help participants monitor and review their food intake if they found they were not meeting specific goals. Screenshots of the app are shown in Figures 1-3.

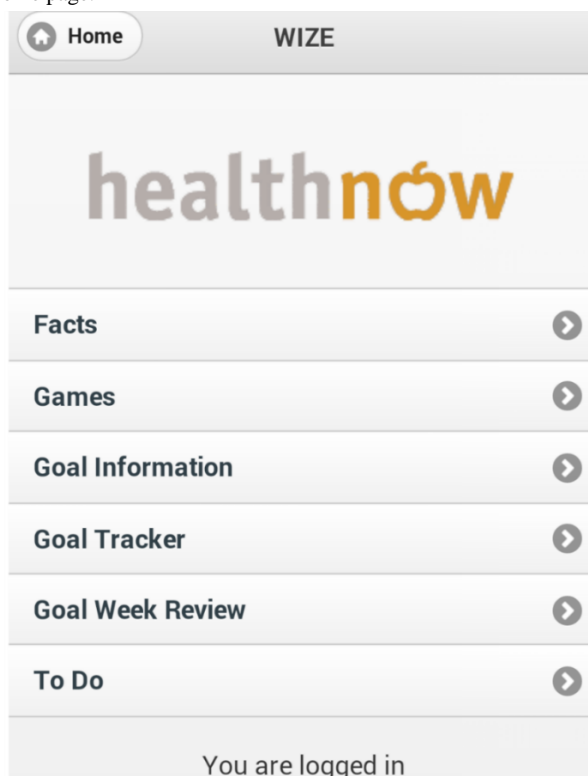
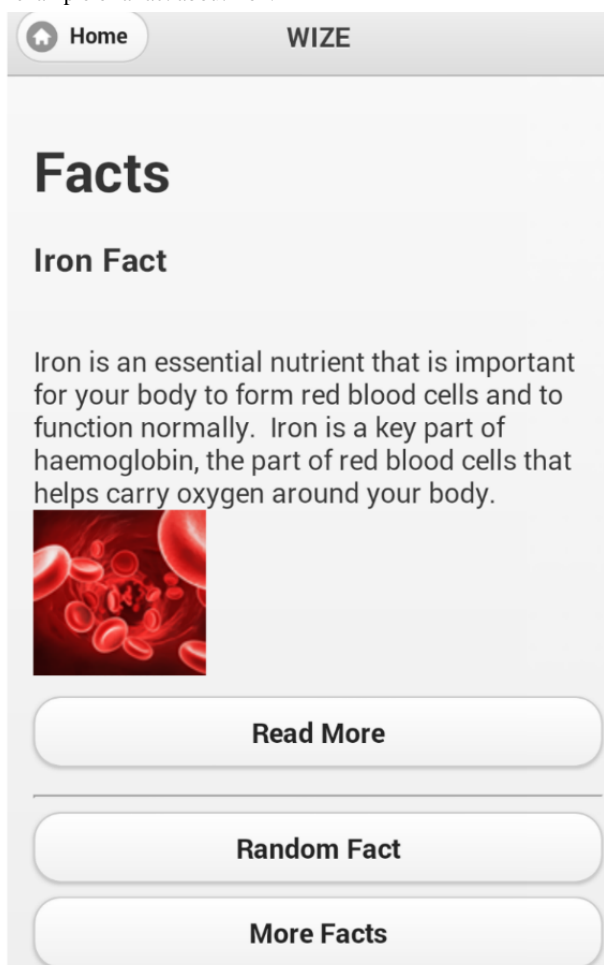
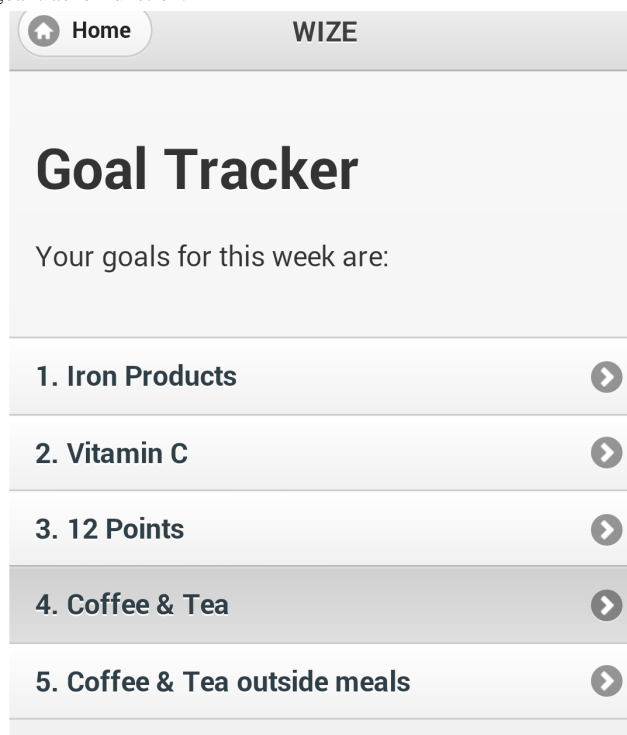
Figure 1. Screenshot of app illustrating home page.**Figure 2.** Screenshot of app providing an example of a fact about iron.

Figure 3. Screenshot of app showing goal tracker function.

Participants

As it is intended that this app be widely available to all premenopausal women interested in increasing intake of bioavailable iron, the current study was open to all women between the ages of 18 and 50 years, irrespective of iron status. However, to use the app, participants were required to have access to an Android mobile phone and be able to communicate in English. Participants were recruited via convenience sampling through flyers placed around Deakin University, Melbourne Burwood Campus, Australia; supermarkets in the surrounding area; free advertisements placed on Facebook pages and Deakin University Student Association club websites; and via presentations given before lectures. All participants filled in a brief background questionnaire collecting information about their age, highest level of education achieved, current degree and major (if studying), current app use (How often do you use apps? What kind of apps do you use? Would you pay for an app?), and current employment status. Ethics approval was granted from Deakin University, Australia and all participants provided written informed consent.

Focus Groups

After using the app for at least 2 weeks, each participant attended 1 focus group discussion lasting no longer than an hour, and consisting of 6-7 participants per group. Focus group discussions were conducted by 2 researchers with one leading the discussion and the second recording field notes. Verbal data from the focus groups were collected through audio recordings. During the focus group discussion, participants were asked about their likes and dislikes, and reasons for each, for each section of the app. They were also asked about their opinions on the look and feel of the app, content and ease of use, and any suggestions they had to improve the app.

Data collection continued until saturation occurred, which was when no new themes or ideas were emerging from the data [29]. The same researcher (DM) led each focus group.

Analysis

To help ensure research quality and rigor, approaches highlighted by Braun and Clarke [30] and Fade [31] were employed throughout the study. Audio recordings of the focus groups were transcribed verbatim and anonymized, and a thematic analysis was undertaken [30]. NVivo 10 (QSR International) qualitative research software was used to help manage data and aid analysis [32]. Following familiarization with the data, initial codes were generated in a systematic fashion. Data were collected relevant to each code and themes were then identified and reviewed [30]. An inductive open-coding method was utilized [30]. Codes generated included usability, technological errors, games, facts, and goal tracker. Responses could be coded to more than 1 theme; for example, to both the usability and games themes. Frequencies of code occurrence were then calculated. Samples of analyzed sections of the data were double checked by a second researcher (AOB) to help eliminate bias and ensure accuracy.

Results

Participants

Twenty-six participants attended the focus group discussions. The age range of participants was 18-36 years (mean 24.7, SD 5.2). Participants' iron levels and whether they were pregnant or breastfeeding were unknown. All quotes are presented in intelligent verbatim.

Themes

Two themes (Table 1) were identified from the focus groups with regard to functionality: technological issues/usability and

interface and design. Four themes (Table 1) about the specific components of the app were identified, which included facts, games, goals, and photo diary.

Table 1. Themes and their frequency of occurrence (represented in parentheses). Quotes presented in intelligent verbatim.

	Theme	Examples
App component	Facts (78)	<i>I thought they (facts) were straightforward. I thought they (facts) really seemed to be to the point and provided most of the information I think you needed. [R3, FG3]</i> <i>There were facts that I didn't know, which was really cool. [R3, FG4]</i>
	Games (46)	<i>Yeah I thought it was cute, a really cool idea cause it's a health app and health apps don't really have games. Yeah I really liked it (the games), I thought it was cute. [R2, FG1]</i> <i>I didn't really get into (the games), I did a couple of the games and things but I did find them very simple and not very useful for me. [R3, FG3]</i> <i>Yeah a bit more interactive actually was kind of learning. [R4, FG4]</i> <i>Yeah no real sense of achievement for knowing what a word was. [R3, FG1]</i>
	Goals (121)	<i>I wasn't sure what that meant (in reference to a goal about coffee and tea) and it didn't give much advice. This is the suggested strategy or step that you can take. [R6, FG3]</i> <i>Yeah I don't think it is so much the goal itself is unachievable but the understanding and facilitating (of the goal) could be hard for sure. [R5, FG2]</i> <i>...you just want a reminder. [R3, FG4]</i>
	Photo Diary (40)	<i>What would you get out of it (photo diary) though? [R1, FG1]</i> <i>Yeah you can hardly tell by a photo though. [R3, FG1]</i>
Functionality	Interface and design (including pictures) (134)	<i>I liked the plain interface on the first page but I think more images throughout would have made it a little bit more exciting. [R2, FG3]</i> <i>I kind of felt like you were entering it in when you did something for the day, then you had to enter it (completed goals) again when you achieved the goal. Can't they (goals and goal tracker) just be linked? I just feel like they (goals and goal tracker) should link. [R3, FG1]</i>
	Usability (86)	<i>Mine (app) got a bit slow sometimes. [R4, FG2]</i> <i>Well I had some issues when logging in, at first it took me about ten attempts to log in, but now it's kept me logged in and that's fine. [R2, FG2]</i>

App Components

Facts

Most participants thought that the facts were succinct, interesting, easy to understand, informative, and were considered by many participants as the best component of the app. Participants wanted more facts and the possibility of an extended information section if they were particularly interested in a specific fact.

Maybe a bit more points (in the facts). Not just one thing about iron, maybe a few things. Just a little bit more information. [R7, FG1]

Games

Participants' opinions of the games were mixed. Many participants suggested that the games could provide further education; for example, through a quiz. It was believed this would help to reinforce information provided within the facts and increase the knowledge acquired by participants. In addition, participants believed that an incentive should have been provided to help them achieve a sense of accomplishment once a game was finished or after a correct answer.

Goals

Users considered the goals unclear; participants would have liked more details and further clarification of the goals, which was not provided. Participants did not know how to go about achieving these goals and were frustrated that the app did not explain what the goals were or how to achieve them.

I feel there wasn't maybe enough information (in the goals) about what it was that we needed to answer the question, so it was 12 points of iron and I don't know what that means. [R4, FG1]

Many participants believed that having prompts or *little pop-up reminders* for the goals would help them remember to complete and enter their goals into the app. One suggestion from participants was to have the weekly goal be an overview of the daily goals instead of having to reenter the details of the completed daily goals into the weekly goal section. Alternatively, instead of having a weekly goal, participants suggested providing an overview of progress in achieving goals and feedback or strategies to help achieve goals.

Being able to upload to tell it what you have eaten and stuff and having it tell you if you have achieved your goals or not, and it would give you a message confirming that you have achieved your goal for that

week or that day, a little bit more satisfaction, congratulating you almost. [R4, FG1]

Photo Diary

Many participants were unreceptive to the notion of using the photo diary component of the app, as they questioned the intent and function of this component. Participants did not believe the photo diary function would be helpful in increasing consumption of high-iron products or meals and did not understand how it could help in facilitating them to achieve their goals.

What was the actual intent of the photo diary? [R2, FG1]

Functionality

Overall, participants enjoyed the concept of being able to use an app to increase bioavailable iron.

I definitely would (use the app) cause it's not something I would normally keep track of myself so having an app it's ... cause I am pretty bad with all that kind of health and all that sort of stuff so I liked it, but it needs to be refined. [R4, FG2]

However, due to user interface and design issues, they thought the current app was too cumbersome to use, and would not use it themselves.

Interface and Design

Participants described the interface as simple and basic. This was stated as the preferred interface design for an app of this platform. Participants thought it would be good to be able to personalize or tailor the app to the individual.

I think the actual icon for the app was a little bit misleading. It was called WIZE, I was just looking for it this morning, and I was like, what is this. [R3, FG2]

A hindrance and disliked aspect was the difficulty in navigating through the app (eg, no back button, *clunkiness*, and the inability of participants to edit their inputted daily goals) as well as a lack of color and visuals within the app, giving it a *clinical* appearance. Some participants described the games as a *drag* that did not *entice* the user to keep playing them or using the app. Most participants believed the addition of more pictures, colors, optional noises, and visuals would help to *jazz it up* (the interface).

Usability

Participants believed there was decreased usability of the app due to the lack of prompts and reminders, which would enable them to remember to use the app and track goals. Additionally, providing feedback or reviews of user goal progression were considered necessary components to ensure that participants would be motivated to continue to use the app.

You're not getting the feedback (of how you are progressing) so I was yeah. [FG2, R2]

Suggestions

Numerous suggestions were mentioned during the focus group discussions, including the addition of a back button, and

inclusion of more colors and pictures to help decrease *clunkiness* and improve the interface and design of the app. Including more facts, additional games, and clarification of dietary goals are examples of suggestions previously mentioned.

Discussion

Principal Findings

The purpose of this study was to undertake a formative evaluation and identify user preferences for an app designed to improve intake of dietary iron, with the aim to aid app development and ultimately to enhance app uptake and efficacy. This information can also be used to assist in the development of a range of mobile health (mHealth) apps targeting individuals within the studied demographic (women aged 18-50) to undertake dietary change. Overall, participants liked the concept of an app focused on iron and commented that they would find it useful to help track their iron intake. This reinforces the notion that there is a market for an iron-specific app and that the target audience for the app (a population at-risk for ID) have a desire to track and improve their iron status via dietary interventions. Previous studies have shown that dietary and lifestyle interventions utilizing the app platform have also been met with similar positive reception [33-37]. These results suggest that the use of apps for health is accepted by the general population and users have a desire for uptake.

Knowledge

Participants wanted more facts and information, as well as the option to have an additional information section, highlighting that the majority of participants did have a desire for knowledge about iron and health. This desire for knowledge is positive, as it has been shown that knowledge is one of many influences that can affect eating behavior [38]. However, knowledge will fail to be effective when not combined with other behavior change strategies [39]. This was discussed during the focus groups, as many participants found the information was not sufficiently connected with easily understood goals or dietary recommendations.

Games have the potential to increase user knowledge, user interactivity, and engagement with the app, while maintaining engagement [27,28]. Thus, to help further knowledge acquisition while maintaining engagement, an information-seeking platform could be integrated into the games.

Feedback, Prompts, and Reminders

Users enjoyed the features of monitoring and tracking behavior, setting goals, and the ability to review progress. Many users stated that feedback was an important component that they would like to see incorporated into the app. This is consistent with the findings of similar research that young adults like monitoring and tracking features [40-42]. Feedback has been highlighted as an integral part of successful behavior change and should be incorporated into interventions delivered through apps [43].

Participants described that they wanted prompts as a reminder to use the app and complete goals. This is consistent with the literature, which indicates that prompts can be considered helpful

and useful, may increase motivation, and may remind users of their goals [42,44]. However, reminders and prompts have also been considered annoying, as reminders that are perceived to be too frequent may be viewed as unnecessary [40,42]. Differences in the perceived value of reminders may be due to differences in frequency of use, as reminders considered to be unobtrusive or minimally disruptive have been positively received in other studies [45]. It is important that the user has the ability to tailor the frequency of reminders to ensure that they do not become intrusive and are found to be helpful [42].

Participants mentioned that they would like the app to be personalized and tailored to the individual. The ability to tailor the frequency of messages and the content of feedback has been a recurring theme among participants in previous studies. This research has indicated that a health app should be tailored to ensure it is flexible enough to adapt to a user's lifestyle [33,42]. It has been noted that instant feedback may place too much pressure on users and may frustrate them if they are not achieving their goals [46]. There is also evidence that interventions with individually tailored material have greater retention rates and result in participants spending more time engaged with the interventions [44,47]. Therefore, it is recommended that tailoring or personalization be incorporated into the app during redevelopment.

Self-Monitoring and Goals

Many users did not understand a few of the goals, emphasizing that goals should not assume user knowledge and should ideally be simple and explained in significant detail to ensure that they are understood and are achievable by the user. Goals that are considered general, which do not provide feedback to notify users on goal progression, have been shown to be less effective than goals that are specific [48].

Many participants suggested that they would have liked the weekly goal review to be an overview or report about progress toward their goals, ideally in graphical form. This finding is not unique; participants in other health-related research on weight and diabetes management have similarly found monitoring to be valuable [49,50]. It has also been found that app users prefer graphical feedback to feedback in other formats [42]. Thus, it may be beneficial for feedback and monitoring in the app to be displayed in a graphical format, which is possible through the mobile phone app platform [42].

Participants stated that rewards would encourage engagement with the app and adherence to dietary goals. Rewards that recognize an achievement may help to motivate participants to

continue to use the app and help to maintain user engagement [44,51].

Functionality

Interface and Design

Mobile app simplicity has been highlighted as one of the most important features for health intervention apps. Simplicity, as indicated by a simple user-friendly interface, has been shown to encourage continued use of health apps [19,33]. This study reinforced this notion as the simple interface was considered a positive attribute of the app. The importance of an attractive user interface has been emphasized in previous studies and was demonstrated in this study, as many participants stated that the lack of color or visuals within the app did not entice them to or discouraged them from using it [41,44]. Therefore, to help engage users the addition of pictures and colors is recommended.

In addition, it appears that personalization or customization of the app was important to participants as it was brought up numerous times. Customization may increase the interactivity that participants have with the app and allow the app to be tailored to an individual [19].

Usability

The longer someone engages with an intervention, the more likely the intervention is to be effective [52]. To ensure engagement time, it is recommended that interventions be interactive, tailored, and relevant to participants [52,53]. Discontinued use of mHealth has been attributed to lack of usability and perceived usefulness of the intervention [54,55]. Participants wanting to discontinue using our app due to usability and functionality issues (eg, no back button, *clunkiness*, and the inability to edit inputted daily goals) reinforces the notion that usability is a key component of mHealth uptake. In addition, it has been shown that users must find apps usable and useful to engage in long-term use; thus, it is important that the platform is engaging and entices participants to spend time using the actual intervention [52,56].

Implementation of Modifications

Modifications based on the suggestions from participants in this study were made to the WIZE app. Additional colors and pictures were added throughout the app to increase its appeal; additional links between components of the app were added to increase usability; the goals were clarified and restructured; and games were modified to include further information about iron. Postmodification screen shots of the app can be seen in [Figures 4 and 5](#).

Figure 4. Screenshot of app illustrating home page postmodification.

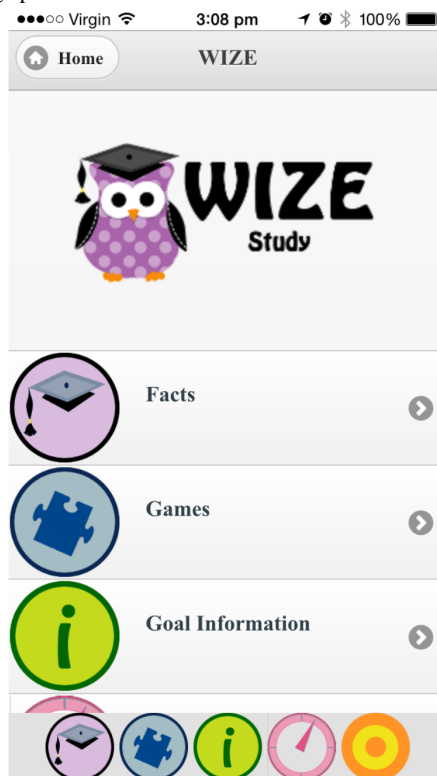
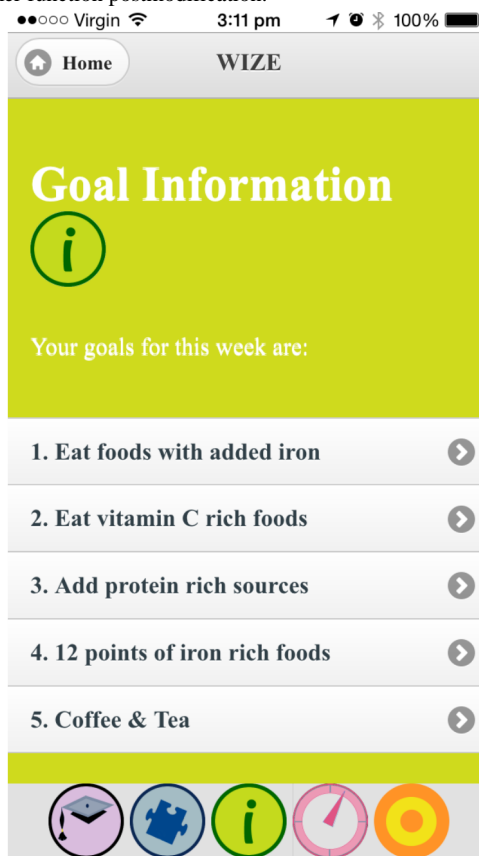


Figure 5. Screenshot of app showing goal tracker function postmodification.



Limitations

The majority of participants were recruited from one area of Deakin University, Melbourne Burwood Campus, Australia;

therefore, it is unknown if these views are reflective of the broader population. The sample was predominately younger females with a high level of education. Participants having access for only 2 weeks before participating in a focus group

may have resulted in different opinions than if the app had been used over a 4-week trial (the period over which goals were designed to be implemented). A further potential limitation was that the app was only available on the Android mobile phone platform. Users of this specific platform may not represent all mobile phone users.

Conclusion

Participants expressed interest in an app to increase their intake of bioavailable iron and data obtained aided the redevelopment

of the app. In terms of components, goals, feedback, and self-monitoring were considered valuable and should be incorporated into future app interventions. The value of implementing other features such as reminders and prompts is unclear and may depend on the individual. Information and insights obtained from this study help to clarify the acceptability and user preferences of apps as a platform for behavior change interventions and may help guide and inform the development of future app interventions.

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Conflicts of Interest

None declared.

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Abbreviations

ID: iron deficiency

mHealth: mobile health

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Review

Low Quality of Free Coaching Apps With Respect to the American College of Sports Medicine Guidelines: A Review of Current Mobile Apps

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Abstract

Background: Low physical activity level is a significant contributor to chronic disease, weight dysregulation, and mortality. Nearly 70% of the American population is overweight, and 35% is obese. Obesity costs an estimated US\$ 147 billion annually in health care, and as many as 95 million years of life. Although poor nutritional habits remain the major culprit, lack of physical activity significantly contributes to the obesity epidemic and related lifestyle diseases.

Objective: Over the past 10 years, mobile devices have become ubiquitous, and there is an ever-increasing number of mobile apps that are being developed to facilitate physical activity, particularly for active people. However, no systematic assessment has been performed about their quality with respect to following the parameters of sound fitness principles and scientific evidence, or suitability for a variety of fitness levels. The aim of this paper is to fill this gap and assess the quality of mobile coaching apps on iOS mobile devices.

Methods: A set of 30 popular mobile apps pertaining to physical activity programming was identified and reviewed on an iPhone device. These apps met the inclusion criteria and provided specific prescriptive fitness and exercise programming content. The content of these apps was compared against the current guidelines and fitness principles established by the American College of Sports Medicine (ACSM). A weighted scoring method based on the recommendations of the ACSM was developed to generate subscores for quality of programming content for aerobic (0-6 scale), resistance (0-6 scale), and flexibility (0-2 scale) components using the frequency, intensity, time, and type (FITT) principle. An overall score (0-14 scale) was generated from the subscores to represent the overall quality of a fitness coaching app.

Results: Only 3 apps scored above 50% on the aerobic component (mean 0.7514, SD 1.2150, maximum 4.1636), 4 scored above 50% on the resistance/strength component (mean 1.4525, SD 1.2101, maximum 4.1094), and no app scored above 50% on the flexibility component (mean 0.1118, SD 0.2679, maximum 0.9816). Finally, only 1 app had an overall score (64.3%) above 50% (mean 2.3158, SD 1.911, maximum 9.0072).

Conclusions: There are over 100,000 health-related apps. When looking at popular free apps related to physical activity, we observe that very few of them are evidence based, and respect the guidelines for aerobic activity, strength/resistance training, and flexibility, set forth by the ACSM. Users should exercise caution when adopting a new app for physical activity purposes. This study also clearly identifies a gap in evidence-based apps that can be used safely and effectively to start a physical routine program, develop fitness, and lose weight. App developers have an exciting opportunity to improve mobile coaching app quality by addressing these gaps.

KEYWORDS

apps; fitness; mHealth; mobile coaching; obesity; quality; weight loss

Introduction

Background

Low physical activity levels significantly contribute to chronic disease, obesity, and all-cause mortality [1,2]. Since 2003, the prevalence of overweight and obesity in the United States has remained high [3]. As much as 68.5-75.3% of all adults 20 years of age or older are overweight or obese [3]. The annual health care burden attributable to obesity comprises 21% of the US health care expenditures [4]. The prevalence of overweight and obesity has not declined in the last decade [3,5], indicating that current strategies to address the problem in the general population have remained unsuccessful.

While it is known that increasing participation in regular exercise can help control body weight and reduce the risk of multiple comorbidities [2,6], it is estimated that only 20.6% of Americans actually meet the current recommendations of 2.5 hours minimum of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity activity/week [7]. Among the barriers to exercise participation are the disparity in face-to-face access to health care professionals with expertise in lifestyle management, resources needed for a personal coach, and lack of knowledge of exercise principles necessary for someone to design their own training regimen [8-11]. Technological developments in the last 10 years have generated new strategies to broaden access to physical activity resources. Emerging evidence suggests that leveraging digital media may be an effective method to deliver health behavior interventions [12-14]. Electronic interface (Internet based) and mobile interface (either mobile phone or smartphone) are popular platforms [15,16]. Mobile phone and mobile phone ownership are accelerating quickly among young people and the general population [17]. Mobile technologies offer opportunities to mitigate the increasing disparity of access to affordable and even free resources [18,19]. There is an estimated 100,000 health care-related mobile apps [20]. Among these 100,000 apps, there is a fauna of apps to facilitate physical activity, including heart rate monitors, step counters, training logs, diet monitoring, and coaching.

American College of Sports Medicine Guideline Overview

The American College of Sports Medicine (ACSM) [21] is the leading organization involved in the development and modification of exercise programming based on the cumulative evidence pertaining to exercise on health and fitness. The ACSM recommends that exercise programs should include key training elements of the frequency, intensity, time, and type (FITT) principle. Exercise programs should progress at a rate appropriate to the individual's beginning fitness level and specific health or fitness goals. General exercise sessions

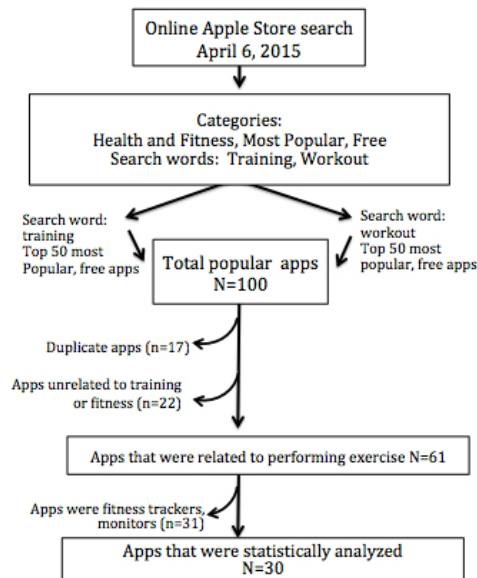
typically include a warm up, conditioning and/or strengthening, a cool-down, and safety considerations. The successful translation of the ACSM guidelines into the mainstream of public use is dependent in part on the quality of information on the electronic media platforms accessed by the public. Presently, it is unclear whether the free mobile coaching apps available to the public provide adequate, accurate information of exercise programming for the beginning exerciser wishing to control body weight and manage comorbidities. Therefore, the goal of this investigation was to assess the quality of the most popular free health-related apps with respect to the general exercise program guidelines of the ACSM.

Methods

App Selection Process

As of 2014, Google Android (51.7%) and Apple iOS (38.9%) share over 90% of the mobile operating system market in the United States [22]. The choice of apps on both mobile operating systems reached 1.3 million and 1.2 million apps, respectively. However, popular apps are usually implemented cross-platform, and are therefore available on both app stores. Hence, our search was restricted to apps from the Apple store. For portability issues, we focused on apps that were available for iPhone, rather than other Apple devices such as iPad. Because we were primarily interested in assessing apps that could be used by the public without a financial burden, we restricted our search to apps that were available for free. Figure 1 illustrates our process of screening and selecting the relevant iPhone coaching apps for this analysis.

App stores are highly dynamic. Apps are added on a regular basis, and the ranking of popular apps changes weekly. The queries presented here were performed on April 6, 2015. We wanted to assess apps that would provide some workout or training programs. Thus, we selected the keywords "workout" and "training" and restricted our search to "health and fitness" free apps in the Apple store. A set of 50 apps was generated for each keyword term. The 2 sets of apps were merged. Because 17 duplicates existed, a list of 83 apps was generated. A prefiltering of the apps was performed by the study team to discard apps that were clearly not exercise prescriptive. The agreement among the study team was unanimous for discarding 22 apps from inclusion into the review. Examples of these irrelevant apps were for pregnancy, sleep quality, or menstrual cycle tracking. Of the 61 apps that were reviewed, 31 additional apps were discarded because exercise prescriptive programs were not provided, and therefore, did not meet the study inclusion criteria. The final set of 30 apps was scored for quality of content against the guidelines of exercise prescription of the ACSM.

Figure 1. Flow diagram of iPhone coaching app selection.

Principles of Exercise Prescription

The ACSM defines best practices in exercise prescription based on the known health benefits of exercise and physical activity. Optimal exercise programs include elements of cardiovascular fitness, endurance, strength, and flexibility, which collectively promote healthy body composition and neuromuscular fitness [21]. Exercise prescription consists of 3 main components, namely, aerobic exercise, strength and resistance exercise, and flexibility. Each component contains safety, programming (the FITT principle) and single-session principles. These components and principles are summarized in [Multimedia Appendix 1](#).

Additional recommendations for safe exercise participation, particularly for beginners, include the following: reduce sitting time and sedentary behaviors, spread physical activity bouts throughout the day, no pain in joint, modify exercise in extreme environments (hot/humid), and be safe outdoors at night.

App Quality Scoring Strategy

We developed our scoring strategy based on the recommendations set forth by the ACSM and our experience in assessing the quality of online weight loss information search results [23]. Therefore, each app was scored across the components of aerobic exercise, strength/resistance, and flexibility, with aerobic exercise and strength divided along the section of safety, program principles, and single training session principles, whereas flexibility was divided across safety and program principles only. There is no clear evidence that one of the 3 main components should be emphasized more than the other. Thus, we weighed the 3 individual component scores (endurance, strength, and flexibility) based on the time allocated by the ACSM within a standard exercise program for health and fitness. In addition, each section (ie, safety, program components, and single-training session components) of the 3 components was allocated the same weight due to the lack of evidence of one specific part being more important. For the same reason, each atomic criterion (FITT) was weighed

identically. To allow further discrimination in the scoring, and to consider criteria that may be partially met, each criterion was scored as 0 (criterion not met), 1 (criterion somewhat met), and 2 (criterion met). Finally, the guidelines of the ACSM were operationalized in the following manner.

According to the ACSM guidelines, aerobic exercise safety is to be assessed with respect to 2 main criteria: the recommendation for physical examination before starting a program for populations at risk, and the recommendation for choosing an activity or activities that match a new exerciser's skill levels. Therefore, safety was scored as "meets criterion" if both recommendations were made by the app's designers, "somewhat met" if only 1 recommendation was made, and "not met" if neither was recommended. The safety of the strength/resistance component was assessed as "met" if the app did emphasize proper form and full range of motion when possible, with controlled breathing, "somewhat met" if controlled breathing or proper form/full range of motion was not emphasized, and "not met" if neither controlled breathing nor proper form was recommended. Finally, the safety component of flexibility was assessed in a similar manner with its 2 criteria being "no bouncing" and "light warm up prior to stretching." Program principles and single-training session principles were scored in the same manner as safety, across all their atomic criteria, following the recommendations described in [Multimedia Appendix 1](#). [Table 1](#) provides the summary of the app quality scoring system developed and used by the study team. The range of possible points was 0-14.

While the evaluation of each criterion was relatively straightforward, each coaching app was scored independently by 3 team members using iPhone devices. Notes on the features of each app, limitations, and any unique features were collected from each team member for qualitative analysis. In the case of a discrepant finding, where one of the evaluators scored differently from the remaining 2, a fourth team member served as the arbitrator and scored the app to determine the score.

Table 1. Scoring system for the quality of the apps for exercise prescription and programming for beginners. The point value for each item is in parentheses.

App components	Aerobic exercise (score weight in points)	Strength/resistance (score weight in points)	Flexibility (score weight in points)
Safety	Safety (1)	Safety (1)	Safety (1)
Program principles	Frequency (0.1667)	Frequency (0.1428)	Frequency (0.1428)
	Intensity (0.1667)	Intensity (0.1428)	Intensity (0.1428)
	Time (0.1667)	Type (0.1428)	Time (0.1428)
	Type (0.1667)	Repetitions (0.1428)	Type (0.1428)
	Volume (0.1667)	Sets (0.1428)	Volume (0.1428)
	Progression (0.1667)	Rest (0.1428)	Pattern (0.1428)
Single training session principles	Warm up (0.25)	Warm up (0.25)	
	Conditioning (0.25)	Conditioning (0.25)	
	Cool down (0.25)	Cool down (0.25)	
	Stretching (0.25)	Stretching (0.25)	
Possible points	6	6	2
		Total possible score (points)	14

Statistical Analysis

Three reviewers evaluated the 30 apps during the last week of April 2015 and scored the apps using the scoring system shown in [Table 1](#). An overall quality score and subscores for the 3 components of aerobic exercise, strength/resistance training, and flexibility were generated. Basic statistics were computed (arithmetic mean, SD, maximum for the set of the final 30 apps). A threshold quality score was established to indicate whether each app provided at least half of the content of the ACSM guidelines for the overall app score and the component subscores (3/6 points for aerobic exercise or strength/resistance components, and 1/2 points for flexibility). Inter-rater reliability was assessed using the Krippendorff alpha coefficient [24]. The

results were visualized using box-plot mapping. Statistical analysis was performed using R software (version 3.1.2).

Results

Binary Evaluation

We initially looked at apps that met any of the recommendations of the ACSM guidelines to perform a first filtering of the results. Pertaining to the aerobic components, a bit more than half did include some of the recommendations. On the strength/resistance component, apps performed a bit better in the initial filtering phase with 90% (n=27) of them meeting at least one criterion. By contrast, they underperformed significantly on the flexibility component with two thirds of apps not meeting any criteria at all. These results are summarized in [Table 2](#).

Table 2. Prevalence of apps that provided any information about the key components and principles of the ACSM guidelines, 9th edition.

Program component	Met "any" of the key components of the ACSM	Met "none" of the key components of the ACSM
Aerobic	17 (56.6%)	13 (43.4%)
Strength/resistance	27 (90%)	3 (10%)
Flexibility	10 (33.3%)	20 (66.7%)

App Quality Score

The final 30 apps included in this review are listed in [Table 3](#), where apps are presented in order from the highest to lowest

average app quality score. The maximal points for the overall quality score was 14 points; the maximal aerobic and resistance component quality subscores were 6 points and the flexibility subscore was 2 points.

Table 3. Training and workout apps included in the study analysis.

App	Overall quality Score (points)	Quality subscores (points) ^a	App comments
Sworkit Lite Personal Trainer	9.01	3.92; 4.11; 0.98	Provides good variation for 30-minute workouts, all 3 workout components and programming are present
The 7 Minute Workout-Get fit	5.39	2.53; 2.86; 0.00	Provides aerobic and resistance workouts, but no fitness program elements and progression
StrongLifts 5x5	4.47	0.99; 3.48; 0.00	Provides workout plan and progression; mainly focused on strength training
Running for Weight Loss: Interval Training	4.16	4.16; 0.00; 0.00	Provides a running training plan with all aerobic program elements, but no resistance training/flexibility instruction
JEFIT Workout	4.08	0.47; 3.51; 0.10	Provides workouts and video examples. Program elements are present, but must be set by the user
FitnessBuilder	4.04	0.99; 2.88; 0.17	Provides exercises for various body parts but no program elements; need upgrade to progress beyond beginner workouts
C25K-5K Trainer Free	3.67	3.67; 0.00; 0.00	Provides general progression plan to work up to running continuously for 4.8 km (3 mi)
Ultimate Fitness Free	3.53	0.00; 3.53; 0.00	Provides some workouts, payment required to access all features, but no fitness program components
Nike+ Training Club	3.11	1.14; 1.92; 0.05	Social network and workout log
BodySpace	2.56	0.00; 2.31; 0.25	Substantial index of exercises for workouts, workouts can come from different coaches, has pictures of exercises and demonstrations
Fitness Buddy Free	2.53	0.50; 2.03; 0.00	Provides workout videos and individual workout plans; fitness program elements and progression; targeted for women; 1 workout provided free
7-Minute Workout-Fitness for Women	2.54	1.13; 1.41; 0.00	Provides aerobic and resistance workouts, but no fitness program elements and progression; targeted for women; 1 workout provided
The Johnson and Johnson Official 7-Minute Workout	2.44	1.22; 1.22; 0.00	Provides aerobic and resistance workouts, but no fitness program and progression elements
Fitness Point-Workout Exercise	2.05	0.00; 2.05; 0.00	Provides strength training sessions only
FitStar Personal Trainer	1.99	0.48; 1.47; 0.04	Provides log for workouts and workouts to do, provides a few workouts for free but all program features only available with subscription; good exercise demonstrations and videos
7 Minute Workout	1.72	0.00; 1.72; 0.00	Provides some workouts, payment required to access all features, but no fitness program components; good basic fitness program
Instant Abs Trainer	1.64	0.00; 1.64; 0.00	Provides exercises for all body parts, but contains no fitness program components
Daily Workouts Free	1.56	0.05; 1.44; 0.07	Provides workout exercises and video, but no fitness program components; a "a home-made video" presentation
Jillian Michaels Slim Down	1.43	0.11; 1.27; 0.05	Features exercises for all body parts, but access to program details must be purchased by consumer
Simply Yoga Free	1.38	0.33; 0.33; 0.72	Only focuses on yoga; 1 free workout-only reduction; different workouts based on experience, track progress with pictures
Belly Fat Workout Free	1.38	0.00; 1.38; 0.00	Workouts geared to burning abdominal fat, "spot training"
Daily Yoga-Lose Weight, Get Relief	1.26	0.00; 0.33; 0.93	Provides exercises but no fitness program components

App	Overall quality Score (points)	Quality subscores (points) ^a	App comments
Cardio-Heart Rate Monitor + 7 Minute Workout	0.66	0.33; 0.33; 0.00	Heart rate monitor and tracker; has 7-minute aerobic and resistance workouts to improve fitness and endurance but no progressive fitness programming
Daily Butt Workout FREE	0.55	0.00; 0.55; 0.00	Provides exercises for all legs and glutes, but contains no program elements. Paid version includes more exercises for various body parts
Strava Running and Cycling	0.49	0.49; 0.00; 0.00	Provides workouts and log for workouts; only tracks when premium is purchased by consumer
Workout Trainer	0.44	0.00; 0.44; 0.00	Provides exercises for multiple body parts and logging tools. No fitness program components provided
8Fit Fitness at Home: Personal Trainer	0.33	0.00; 0.33; 0.00	Provides workouts and workout programs, but program components and progression features are only available after payment
Daily Ab Workout Free	0.33	0.00; 0.33; 0.00	Only an abs workout trainer, not other components
Abs Workout: Get Your Six Pack	0.33	0.00; 0.33; 0.00	Only an abs workout trainer, not other components
Runtastic Six Pack Abs Trainer	0.33	0.00; 0.33; 0.00	Only an abs workout trainer, not other components

^aQuality subscores are for aerobic; resistance; flexibility.

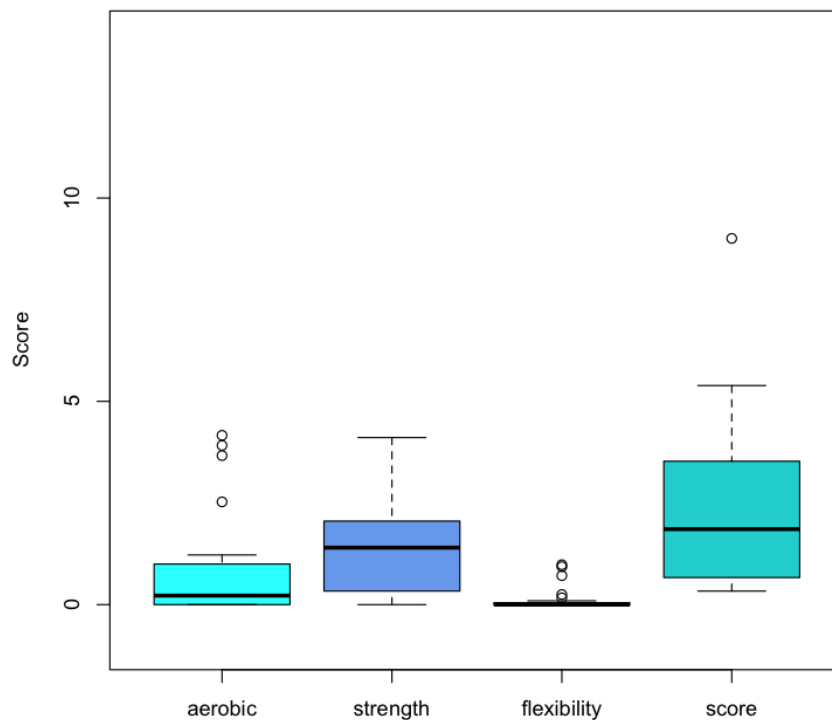
Among the 30 apps, only 3 apps (SworKit Lite Personal Trainer, C25K-5K Trainer Free, Running for Weight Loss: Interval Training) scored above 50% on the aerobic component on a 0-6 scale (mean 0.7514, SD 1.2150, maximum 4.1636). Four apps (SworKit Lite Personal Trainer, Ultimate Fitness Free, JEFIT Workout, and StrongLifts 5x5) scored above 50% on the resistance/strength component on a 0-6 scale (mean 1.4525, SD 1.2101, maximum 4.1094). Finally, none of the apps scored above 50% on the flexibility component on a 0-2 scale (mean 0.1118, SD 0.2679, maximum 0.9816). Finally, only 1 app (SworKit Lite Personal Trainer) had an overall score (64.3%)

above 50% on a 0-14 scale (mean 2.3158, SD 1.911, maximum 9.0072). The results are summarized in Table 4 and in the box plot of app quality scores and subscores with respect to the ACSM recommendations (Figure 2). The inter-rater reliability statistics on the overall app score broken down by component (aerobic, strength, and fitness) is .636 (Krippendorff alpha). The alpha is rather low (<.800), which indicates a low agreement among the 3 reviewers on the exact score. However, the 3 reviewers did agree on the fact that none of fitness and workout apps on the market meet all of the ACSM exercise prescription guidelines.

Table 4. Basic statistics of app quality scores based on the American College of Sports Medicine exercise prescription guidelines.

	Aerobic component	Strength component	Flexibility component	Overall quality score
Mean	0.7514933	1.452537	0.1118478	2.315878
SD	1.215081	1.210152	0.267902	1.911409
Maximal score	4.1636	4.109467	0.9816	9.0072

Figure 2. Box plot of app quality scores and subscores relative to the American College of Sports Medicine recommendations of exercise prescription and programming. Higher scores represent higher app quality.



Discussion

Principal Findings

Despite the relatively large number of fitness and workout apps, our findings indicate that very few of them are of sufficient quality to provide evidence-based exercise prescription, especially for beginners. The results are rather striking. Barely 20% (n=6) of the most popular free apps attained the quality threshold score of 50% for 1 subscore, and only 1 app scored above 7/14 points. During the scoring process, we collected comments from the study team on the apps. The most frequent criticism reported by the study team in 23 of 30 apps was that the apps did not provide an actual training plan, explaining how to choose the workouts and how to organize them in a week, although specific training sessions were provided. Only 4 provided training plans followed a safe and physiologically sound progression. Thus, a significant gap exists in available mobile coaching app technology, especially for novice exercisers. As such, there is the risk for users to participate in exercise programs without the appropriate level of physical preparedness, technique, and awareness of safety concerns.

Key features of the 2 highest quality apps include components of the training programs, exercise instruction, and a variety of activity within exercise sessions. The 2 top scoring apps were “Sworkit Lite Personal Trainer” and “7 Minute Workout.” “Sworkit Lite Personal Trainer” was the most comprehensive app that scored 9 points out of a possible 14 points and covered all 3 ACSM components of a well-designed training program. However, some of the exercises described may be technically difficult for beginners, such as plyometrics, which are associated with higher rates of injuries compared with nonstretch and activation movement [25,26]. A strength of this app was a good

variation of exercises for different 30-minute workout sessions (Figure 3).

The “7 Minute Workout” app from Get fit had an overall quality score of 5.38 points of a possible 14 points (Figure 4 shows a screenshot of this app). The exercises were well structured and well explained, even for novice exercisers. Useful video demonstrations were helpful for skill development and safe exercise execution. However, the app lacked the key elements of a fitness program, such as frequency, duration, intensity, and training progression

Several other apps had relatively high-quality content in 1 component, but not all. For example, “StrongLifts 5x5” and “Running for Weight Loss: Interval Training” had high-quality subscores for resistance exercise (3.48 points) and aerobic exercise (4.16 points), respectively. The other subscores for these apps were low or 0.00 points. Six apps were designed specifically to target 1 body part or area, such as the buttocks or abdomen, and did not address overall musculoskeletal, aerobic, or flexibility fitness (Runtastic Six Pack Abs Trainer, Abs Workout: Get Your Six Pack, Daily Ab Workout Free, Daily Butt Workout FREE, Belly Fat Workout Free, and Instant Abs Trainer). While each of these apps possesses certain value for guiding users on specific types of exercise or to meet targeted goals, these are not effective coaching apps for improving overall fitness in a manner endorsed by the ACSM. Most of the apps provided in Table 3 were aesthetically pleasing and interesting to view. However, several key considerations of the user were not typically taken into account including the initial fitness level, age, skill level, or familiarity with the exercise type (yoga, heavy lift maneuvers, or running technique) and exercise preferences. Most of these apps did not provide a live social element that could boost exercise participation rates, such as social messaging. Importantly, many apps are not free, which

is a barrier to users. Even among the free apps provided here, some provided partial content, and the full benefits of the app could only be attained after payment or subscription, such as “Jillian Michaels Slim Down” and “FitStar Personal Trainer.”

Figure 3. Sworkit app screenshots.

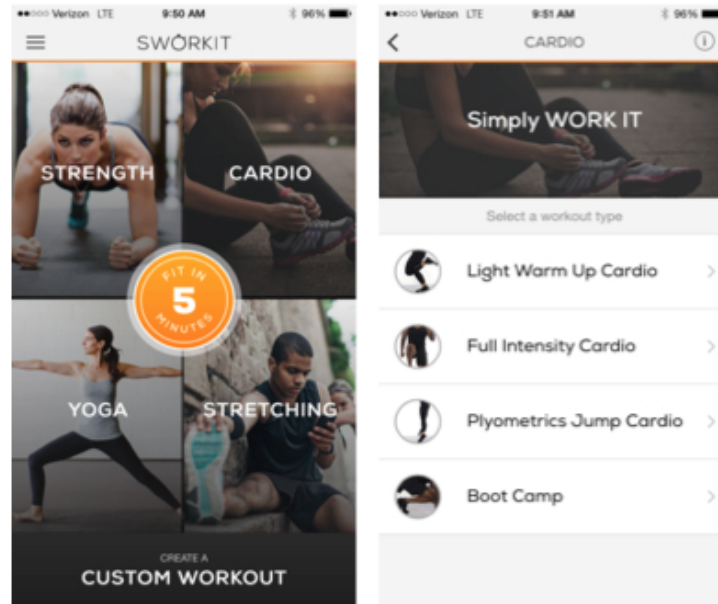
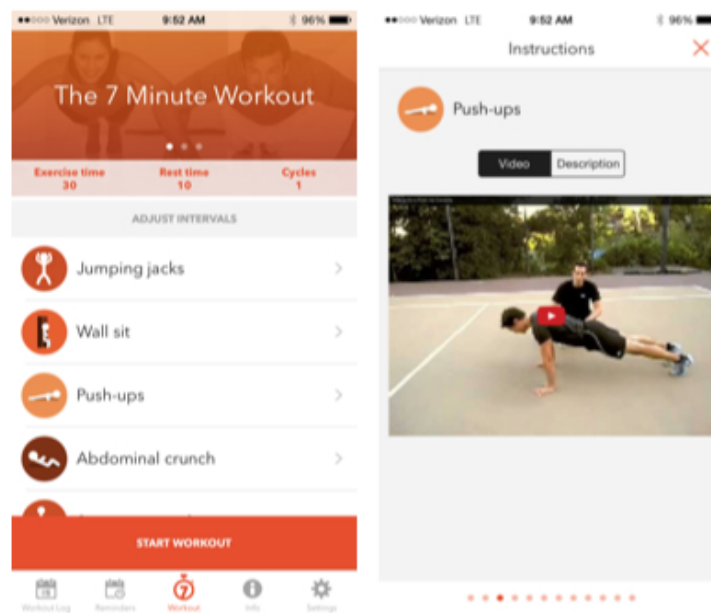


Figure 4. 7 Minute Workout app screenshots.



Limitations

There are some limitations to this work that deserve comment. As we noted, our scoring process is derived directly from the time recommendations of the ACSM on aerobic exercise, strength/resistance, and flexibility. The quality scores are based on the assumption that all the atomic elements of each component contribute equally to an athletic training program. This may not be the case. However, this is the most rational choice in the absence of evidence. There is the potential that an automatic query program over time may have yielded some

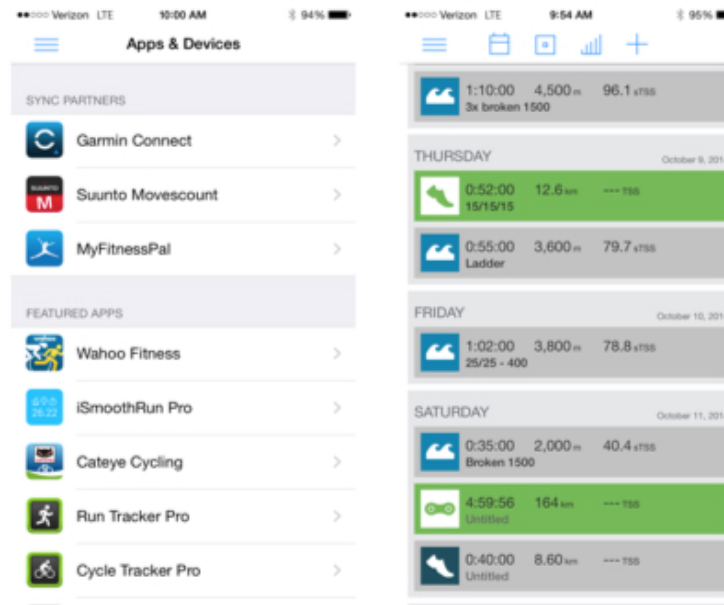
The challenge for the general user is to sift through the hundreds of “free” available apps to determine what would be most useful, instructive, and safe to follow.

additional apps that might have fit our inclusion criteria. However, we consider this a small possibility given that the content and complexity of the training and workout apps have been steadily improving over the last year. Additional queries over time would provide important insight into the evolution of these training and workout apps and how users value specific content. In addition, popular apps remain rather stable over relatively short periods. Another limitation of our study is that we restricted ourselves to free apps. However, an informal browsing of paying apps suggested that they do not score much better overall, with the inclusion of coaching features, personal

adjustments to the training program, and additional variations of workout sessions. A few exceptions exist. For instance, TrainingPeaks was developed primarily by coaches and exercise physiologists. It provides desktop and mobile platforms for logging workouts (running, cycling, triathlons, and strength workouts), training articles, a variety of metrics to track performance, ways to upload training data, and also training plans, for a varying fee. However, it is probably too complex for beginners, and its fees may be intimidating, and a barrier for many users (Figure 5). Last, the inter-rater reliability

statistics (computed using Krippendorff alpha) is rather low ($\alpha=.636$) in this study, which renders the necessity of a future study to refine the instrument and evaluate its test-retest reliability. One potential reason for a lower-than-expected agreement coefficient is reviewers' interpretations of the ACSM guidelines. However, our study is the very first that aimed to evaluate fitness and workout apps with respect to ACSM exercise prescription guidelines. In addition, all reviewers do agree on the fact that none of the apps we reviewed met all 3 components of the ACSM guidelines.

Figure 5. TrainingPeaks app screenshots.



Comparison With Prior Work

To the best of our knowledge, no work has previously evaluated the quality of mobile apps that are exercise prescriptive in nature. Some work [27-30] has been performed on the characterization of health and fitness-related apps, presenting the app functionalities, and studying health behavior theory constructs in these apps. These previous works have not assessed the app quality with respect to well-established guidelines of exercise prescription.

Need for Evidence-Based, Accessible Mobile Coaching for Public Use

These data strongly support the needs of developing new mobile fitness apps that adhere to the ACSM guidelines for exercise prescription for use in the general public. Scientifically sound fitness programs are needed to increase physical activity among Americans, and more generally for public health.

Free mobile coaching apps may be a technology vehicle for directly translating ACSM guidelines into changing the activity behavior of public in a safe, scientifically sound manner. The popularity of mobile apps may make exercise and physical activity more appealing to different age groups. Moreover, the use of apps may remove disparities of access to free resources for health improvement. If effective, these apps may become

an important component of primary care and disease prevention plans.

The results indicate that developers of mobile coaching apps have a unique opportunity to make a considerable impact in the field of health and fitness. Incorporation of the ACSM guidelines and FITT principles into app platforms using easy-to-understand language, pictures and videos, and progress trackers for exercise progression is critical to help users participate in regular activity. Moreover, platforms that contain educational pearls and answer questions (“Should I feel this burning ache in my muscle after I perform a set of chest press exercise?” or “Is it normal for me to breathe really hard and feel my heart pumping very fast when I run hard?”) can guide the exerciser about what to expect. Engagement of the user in the exercise process with the app may help improve adherence, reduce anxiety about the exercise experience, and empower the exerciser to progress further in his/her program by improving self-efficacy. Given the lack of safety considerations provided in current apps, app developers can immediately improve app quality by including key information such as contraindications to exercise, when to see a doctor before starting an exercise program, what pain is normal and what is not, and what precautions should be taken when exercising in hot weather or outside in the dark. Finally, coaching apps should be flexible with respect to individual preferences and availability to exercise equipment. Accounting

for user exercise-type preferences is essential for exercise consistency and adherence over the long term.

Conclusions

The study team analyzed the content of 30 apps that met the inclusion criteria and were considered exercise prescriptive. These apps were scored with respect to the quality of information provided relevant to the current guidelines of the ACSM. Nearly all the apps, although technically well designed,

did not meet the basic recommendations of the ACSM for exercise prescription, and therefore, would not be suitable for beginning exercisers. Free apps designed with the 3 key components of ACSM exercise programming following the FITT principle, safety, and individual session structure are desperately needed for public use. These apps can be the basis for setting and safely achieving fitness, body weight, and health goals.

Authors' Contributions

FM, lead author, was responsible for the study design, the data analysis, and the writing and editing of the manuscript. HV was responsible for the study design, the data collection, and the writing and editing of the manuscript. JB was responsible for the study design, and the writing and editing of the manuscript. TL, JB, and CH were responsible for the data collection.

Conflicts of Interest

None declared.

Multimedia Appendix 1

American College of Sports Medicine exercise program guideline summary for health and fitness.

[[PDF File \(Adobe PDF File\), 34KB - mhealth_v3i3e77_app1.pdf](#)]

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Abbreviations

ACSM: American College of Sports Medicine
FITT: frequency, intensity, time, and type

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Review

Expert Involvement and Adherence to Medical Evidence in Medical Mobile Phone Apps: A Systematic Review

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Abstract

Background: Both clinicians and patients use medical mobile phone apps. Anyone can publish medical apps, which leads to contents with variable quality that may have a serious impact on human lives. We herein provide an overview of the prevalence of expert involvement in app development and whether or not app contents adhere to current medical evidence.

Objective: To systematically review studies evaluating expert involvement or adherence of app content to medical evidence in medical mobile phone apps.

Methods: We systematically searched 3 databases (PubMed, The Cochrane Library, and EMBASE), and included studies evaluating expert involvement or adherence of app content to medical evidence in medical mobile phone apps. Two authors performed data extraction independently. Qualitative analysis of the included studies was performed.

Results: Based on inclusion criteria, 52 studies were included in this review. These studies assessed a total of 6520 apps. Studies dealt with a variety of medical specialties and topics. As much as 28 studies assessed expert involvement, which was found in 9-67% of the assessed apps. Thirty studies (including 6 studies that also assessed expert involvement) assessed adherence of app content to current medical evidence. Thirteen studies found that 10-87% of the assessed apps adhered fully to the compared evidence (published studies, recommendations, and guidelines). Seventeen studies found that none of the assessed apps (n=2237) adhered fully to the compared evidence.

Conclusions: Most medical mobile phone apps lack expert involvement and do not adhere to relevant medical evidence.

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KEYWORDS

mHealth; mobile apps; technology

Introduction

Background

Mobile health is growing [1]. Mobile apps are frequently used in daily clinical practice and enable immediate on-the-go access to key clinical information that supports clinical decision making

[2-5]. Patients use apps for disease information, screening, self-treatment, and management [6-9]. One may rightly ask, "Who provides us our app content?" Currently, anyone can publish medical apps. Although some app stores check for fulfillment of a number of technical criteria (eg, whether the app crashes upon launch), no one validates the medical content and no expert approval or peer-review systems exist.

Consequently, there are apps with variable quality: opioid-conversion apps suggest medication doses that may threaten patient safety [10], asthma self-treatment apps contain potentially life-threatening information [11], and very few apps on cardiopulmonary resuscitation are actually designed according to existing basic life-support guidelines [12].

Objective

From the aforementioned discussion, it is obvious that we need an overview of the literature to understand the extent of this problem. In this paper, we review studies that evaluate quality of medical apps by evaluating expert involvement or adherence of app content to medical evidence. We relate our findings to current initiatives that seek to encounter this problem.

Methods

Eligibility Criteria

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for reporting systematic reviews [13]. We included studies evaluating expert involvement or adherence of app content to medical evidence in medical mobile phone apps. The following studies were considered eligible: (1) investigating medical mobile phone apps within a predefined topic using a search strategy, and (2) assessing expert involvement or adherence to relevant medical evidence. Given that the definition of an expert and acceptable credentials may vary widely, we did not restrict the inclusion of studies to our own definitions of these concepts. Similarly, the degree of adherence to relevant medical evidence was not defined in advance; instead, we noted the included studies' own definitions and judgments. Language was restricted to only English. Case studies and reviews of a single app were excluded, because they did not include a search strategy to systematically review available apps.

Search Strategy and Study Selection

We searched existing literature through the bibliographic databases PubMed, The Cochrane Library, and EMBASE using the following search terms: ("smartphone" OR "iPhone" OR "Android") AND ("app" OR "application"). This broad search string was used to identify as many relevant studies as possible. The last search was performed March 17, 2015. One researcher (YS) removed all duplicates and screened all abstracts. All potentially eligible studies were read in full by 2 independent

researchers (YS and SRB). Disagreements were resolved by discussion. References of all included studies were read to find additional eligible studies. We only included studies with original data.

Data Collection and Synthesis of Results

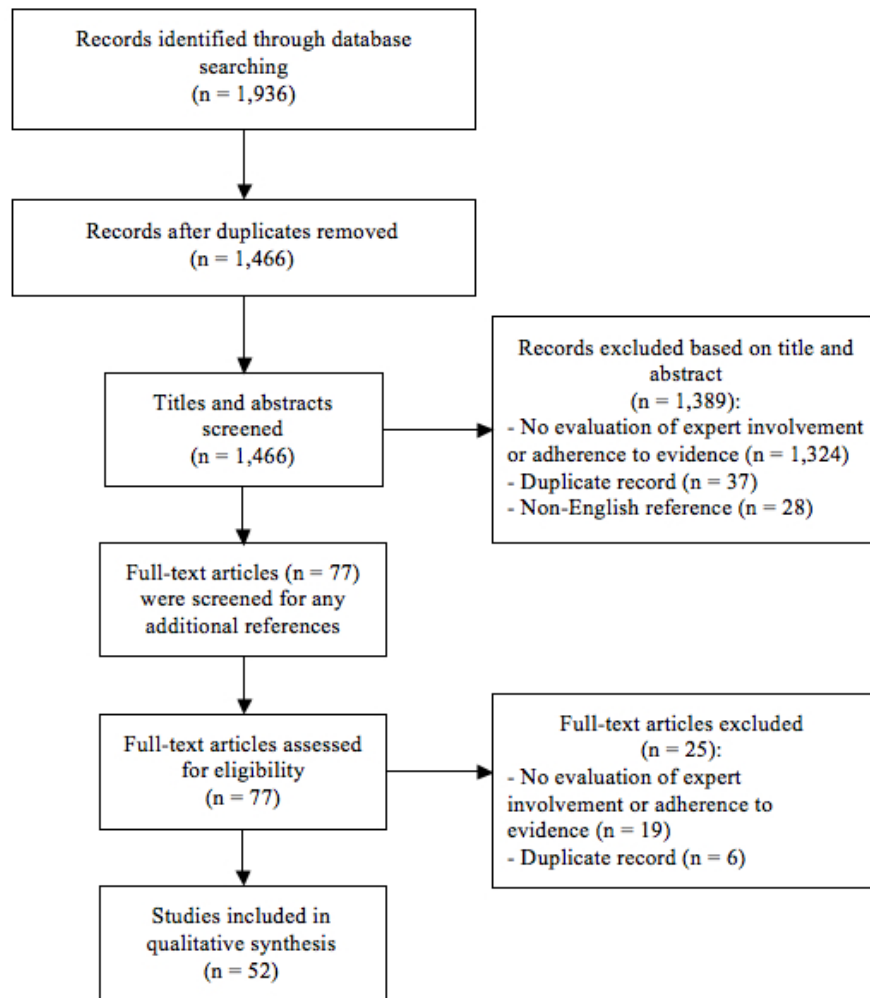
The research group piloted a data-extraction form. We extracted information on topic, app stores searched, methods used for assessment of expert involvement/adherence to medical evidence, and study results. Two researchers (YS and SHB) extracted data independently. Disagreements were solved through discussion and consensus. Microsoft Excel (Redmond, WA, USA) was used for data collection and management. The heterogeneity of the studies did not permit pooling of study results to conduct a meta-analysis. All studies were included in a qualitative analysis.

Results

Studies Identified

The broad search strategy yielded 1936 records, of which a great number were duplicates or irrelevant (eg, mobile-phone-assisted data collection in biomedical research). Fifty-two studies were identified as relevant, and included in this review. These studies assessed 6520 apps. Details on search and study selection are presented in [Figure 1](#).

Included studies are presented in [Tables 1](#) and [2](#). Topics tended to be broader for studies of expert involvement (eg, dermatology [14], ophthalmology [15], or pain management [16-18]), whereas studies on adherence to medical evidence tended to be more specific (eg, asthma self-management [11], prostate cancer [19], pediatric obesity [20,21]). Studies included a median of 71 apps (interquartile range 41-148), and studies of expert involvement tended to have slightly higher number of included apps with a median of 85 apps (interquartile range 39-192 apps), compared with studies of adherence to medical evidence having a median of 63 apps (interquartile range 40-104 apps). Studies reviewed mostly included apps from the Apple App Store (n=49, 98%) and Google Android Market (n=36, 71%). Fewer studies included apps from less popular app stores such as BlackBerry Market (n=19, 38%), Windows Market (n=16, 32%), Nokia Ovi (n=11, 22%), and Samsung Market (n=9, 18%). Studies that included a search in these less popular app stores were often unable to find any relevant apps for inclusion [10,16,22-26].

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of search results and study selection.

Studies on Expert Involvement

Twenty-eight studies assessed 3852 apps for expert involvement (Table 1). These studies dealt with topics within a variety of medical specialties and topics. The following 2 topics were assessed more than once: pain management (n=3) [16-18] and bariatric surgery (n=2) [22,23]. Studies mostly used the app

stores' app description (n=28, 100%) and the developers' website (n=15, 54%) to determine whether an app had expert involvement. Nine studies (32%) also downloaded the apps. All studies found that at least some of the assessed apps had expert involvement and none found expert involvement in all assessed apps. Overall, expert involvement was found in 9-67% of assessed apps.

Table 1. Included studies with assessment of expert involvement.^{a,b,c,d}

Reference	Topic	App stores in study ^e						Assessment based on			Apps in study N	Expert involvement n (%)
		Apple	Google Play	Black-Berry World	Windows Phone Store	Nokia Ovi	Samsung	D ^f	W ^g	C ^h		
[27]	Addiction recovery	-	+/+	-	-	-	-	+	+	-	87	11 (12.6)
[22]	Bariatric surgery	+/+	+/+	+/-	+/-	-	+/-	+	+	-	83	32 (38.6)
[23]	Bariatric surgery	+/+	+/+	+/-	-	-	-	+	-	+	28	12 (42.9)
[28]	Breast diseases	+/+	+/+	+/+	+/+	-	-	+	+	-	148	19 (12.8)
[29]	Cardiothoracic surgery	+/+	+/+	-	-	-	-	+	+	-	379	78 (20.6)
[30]	Colorectal diseases	+/+	+/+	+/+	+/+	+/+	+/-	+	-	-	63	21 (33.3)
[31]	Contraceptive reminder	+/+	+/+	-	-	-	-	+	-	+	32	3 (9.4)
[32]	Depression	+/+	+/+	+/+	+/+	+/+	-	+	-	-	243	30 (12.3)
[14]	Dermatology	?	?	?	?	?	?	+	+	-	61	39 (63.9)
[33]	Headache	+/+	+/+	-	-	-	-	+	-	+	38	7 (18.4)
[34]	Hepatitis	+/+	+/+	-	-	-	-	+	-	+	23	13 (57.5)
[35]	Hernia	+/?	+/?	+/?	+/?	+/?	+/?	+	+	-	26	9 (34.6)
[36]	Human immunodeficiency virus/acquired immune deficiency syndrome	+/+	+/+	-	-	-	-	+	-	+	41	20 (48.8)
[37]	Medical hypnosis	+/+	-	-	-	-	-	+	+	-	407	141 (34.6)
[38]	Melanoma detection	+/+	+/+	-	-	-	-	+	-	-	39	4 (10.3)
[24]	Microbiology	+/+	+/+	+/+	+/+	+/-	+/-	+	+	-	94	32 (34.0)
[39]	Neurosurgery	+/+	+/+	-	-	-	-	+	+	-	111	73 (65.8)
[15]	Ophthalmology	+/+	-	-	-	-	-	+	-	-	182	68 (37.4)
[10]	Opioid conversion	+/+	+/+	+/+	+/+	+/-	+/-	+	+	+	23	11 (47.8)
[16]	Pain management	+/+	+/+	+/+	+/-	+/-	-	+	-	-	104	15 (14.4)
[17]	Pain management	+/+	+/+	-	-	-	-	+	+	+	12	2 (16.7)
[18]	Pain management	+/+	+/+	+/+	-	-	-	+	+	+	220	77 (35.0)
[40]	Pharmacology and drug prescription	+/+	+/+	+/+	+/+	+/+	+/+	+	+	-	306	206 (67.3)
[25]	Radiology	+/+	+/+	+/+	+/+	+/+	+/-	+	+	-	321	185 (57.6)
[41]	Stroke	+/+	+/+	-	-	-	-	+	-	-	93	44 (47.3)
[42]	Surgery	+/+	+/+	-	-	-	-	+	-	-	597	72 (12.1)
[43]	Urolithiasis	+/+	+/+	+/+	+/+	-	-	+	-	+	42	15 (35.7)
[26]	Vascular diseases	+/+	+/+	+/-	+/-	+/-	+/-	+	+	-	49	13 (26.5)

^a+/+ indicates that the app store was searched and that apps were found.

^b+/- indicates that the app store was searched, but no apps were found.

^c- indicates that the app store was not searched.

^d? indicates that whether or not the app store was searched was unclear.

^e We have included both the app stores searched and the app stores in which included apps were found.

^f App description from the app store

^g Developer's website

^h Downloaded app content

Studies on Adherence to Medical Evidence

Thirty studies assessed 3051 apps for adherence to medical evidence (Table 2). Six topics were investigated in more than 1 study: weight loss (n=4) [44-47], smoking cessation (n=3) [48-50], disease self-management (n=3) [11,51,52], pediatric obesity (n=2) [20,21], physical activity (n=2) [53,54], and sports injury (n=2) [55,56]. Remaining studies investigated apps on a diverse range of topics. Assessment was mostly based on downloaded app content (n=24, 86%). In 2 studies, it was unclear whether the assessment was based on downloaded app content [52,57]. Three studies only used the app stores' app description for the assessment [38,44,58]. Studies compared the apps with a variety of forms of medical evidence. For example, smoking cessation apps were compared with US Public Health Service's clinical practice guidelines for treating tobacco use and dependence [48,49]. Several studies correlated the app contents with available Cochrane reviews, other systematic

reviews, or other published evidence [10,11,28,38,41,55,58-60]. In 6 studies, the assessment relied on criteria for ideal app contents as defined by the authors [33,61] or whether the app contents adhered to the general knowledge of the authors [19,43,46,62]. In 17 studies, none of the assessed apps (n=2237) adhered fully to the compared evidence [11,20,21,33,38,44-49,51-54,58,61]. In the remaining 13 studies, 10-87% of the assessed apps showed complete adherence to medical evidence [10,12,19,28,41,43,50,55-57,59,60,62]. Of these, only 5 studies found that more than half of the assessed apps showed complete adherence to medical evidence [19,41,56,60,62]; of note, 2 of these were based on the authors' own self-stated expertise [19,62]. In most studies, a number of apps adhered partly to the assessed evidence. No topic was clearly associated with a higher or lower prevalence of adherence to available evidence—lack of adherence was highly prevalent in all studied topics.

Table 2. Included studies with assessment of adherence to available evidence.^{a-d}

Reference	Topic	App stores in study ^e						Assessment based on			Adherence to evidence based on	Apps in study N	Complete adherence ^f n (%)
		Apple	Google Play	Black-Berry World	Win-dows Phone Store	Nokia Ovi	Sam-sung	D ^g	W ^h	C ⁱ			
[58]	Alcohol use	+/+	-	-	-	-	-	+	-	-	Evidence-based principles from published reviews, from the website of the National Institute on Alcohol Abuse and Alcoholism and the American Psychological Association	767	0 (0.0)
[11]	Asthma self-management	+/+	+/+	+/+	+/+	-	-	-	-	+	Correlation with international guidelines, systematic reviews, and best practices	103	0 (0.0)
[28]	Breast diseases	+/+	+/+	+/+	+/+	-	-	+	+	-	Correlation with international guidelines, systematic reviews, and best practices	148	21 (14.2)
[62]	Cancer	+/+	-	-	-	-	-	-	-	+	The authors' general knowledge on the area	77	42 (54.5)
[51]	Diabetes self-management	+/+	-	-	-	-	-	+	-	+	Inclusion of behaviors recommended by the American Association of Diabetes Educators	227	0 (0.0)
[59]	Eating disorders	+/+	+/+	+/+	+/+	+/+	-	+	-	+	Correlation with international guidelines, systematic reviews, and best practices	13	2 (15.4)
[33]	Headache	+/+	+/+	-	-	-	-	+	-	+	Criteria for an ideal app as defined by the authors	38	0 (0.0)
[57]	Hypertension	+/+	-	-	-	-	-	-	-	?	Conformity to guidelines	96	15 (15.6)
[52]	Hypertension self-management	+/+	-	-	-	-	-	+	-	?	Adherence to the Canadian Hypertension recommendations	58	0 (0.0)
[61]	Medication adherence	+/+	+/+	+/+	-	-	-	+	-	+	Ranking by authors' consensus on desirable app content	147	0 (0.0)
[38]	Melanoma detection	+/+	+/+	-	-	-	-	+	-	-	Correlation with international guidelines, systematic reviews, and best practices	39	0 (0.0)
[60]	Oncology	+/+	+/+	+/+	+/+	-	-	-	-	+	Correlation with international guidelines, systematic reviews, and best practices	50	33 (66.0)
[10]	Opioid conversion	+/+	+/+	+/+	+/+	+/-	+/-	+	+	+	Assessment of whether the apps refer to any publication or source to the algorithms used	23	11 (47.8)

Reference	Topic	App stores in study ^e						Assessment based on			Adherence to evidence based on	Apps in study N	Complete adherence ^f n (%)
		Apple	Google Play	Black-Berry World	Windows Phone Store	Nokia Ovi	Sam-sung	D ^g	W ^h	C ⁱ			
[20]	Pediatric obesity	+/+	-	-	-	-	-	+	-	+	Inclusion of recommended strategies and behavioral targets of the Expert Committee for Pediatric Obesity Prevention	57	0 (0.0)
[21]	Pediatric obesity	+/+	-	-	-	-	-	+	-	+	Adherence to American Academy of Pediatrics' guidelines for the prevention of pediatric obesity	62	0 (0.0)
[53]	Physical activity	+/+	-	-	-	-	-	-	-	+	Rating on a scale from 0 to 100 based on inclusion of instruments from evidence-based behavior change theories	127	0 (0.0)
[54]	Physical activity	+/+	+/+	-	-	-	-	+	-	+	Rating based on the taxonomy of behavior change techniques used in interventions	64	0 (0.0)
[19]	Prostate cancer	+/+	-	-	-	-	-	-	-	+	The authors' general knowledge on the area	15	13 (86.7)
[12]	Resuscitation	+/+	+/+	-	-	-	-	-	-	+	Adherence to the resuscitation guidelines from the European Resuscitation Council and American Heart Association	46	16 (34.8)
[48]	Smoking cessation	+/+	-	-	-	-	-	+	-	+	Coding according to items in the US Public Health Service's clinical practice guidelines for treating tobacco use and dependence	47	0 (0.0)
[49]	Smoking cessation	+/+	+/+	-	-	-	-	-	-	+	Coding according to items in the US Public Health Service's clinical practice guidelines for treating tobacco use and dependence	98	0 (0.0)
[50]	Smoking cessation	+/+	+/+	-	-	-	-	+	-	+	Inclusion of features that are in accordance with the self-determination theory	175	18 (10.3)
[55]	Sports injury	+/+	-	-	-	-	-	+	-	+	Correlation with available Cochrane reviews, other systematic reviews, or otherwise available evidence	18	5 (27.8)
[56]	Sports injury	+/+	+/+	+/+	+/+	+/+	+/+	+	-	+	Adherence to items in the Sports Concussion Assessment Tool 2	18	12 (66.7)

Reference	Topic	App stores in study ^e							Assessment based on			Adherence to evidence based on	Apps in study N	Complete adherence ^f n (%)
		Apple	Google Play	Black-Berry World	Win-dows Phone Store	Nokia Ovi	Sam-sung	D ^g	W ^h	C ⁱ				
[41]	Stroke	+/+	+/+	-	-	-	-	+	-	+	Correlation with international guidelines, systematic reviews, and best practices	93	55 (59.1)	
[43]	Urolithiasis	+/+	+/+	+/+	+/+	-	-	+	-	+	The authors' general knowledge on the area	42	6 (14.3)	
[44]	Weight loss	+/+	-	-	-	-	-	+	-	-	13 evidence-informed practices as defined by the Centers for Disease Control and Prevention, National Institutes of Health, the Food and Drug Administration, and the US Department of Agriculture	204	0 (0.0)	
[45]	Weight loss	+/+	+/+	-	-	-	-	-	-	+	Inclusion of behavioral strategies from evidence-based weight loss interventions	30	0 (0.0)	
[46]	Weight loss	?	+/+	?	?	?	?	-	-	+	The authors' general knowledge on the area	65	0 (0.0)	
[47]	Weight loss	+/+	-	-	-	-	-	+	-	+	Evaluation of the quality of health information using the Silberg scale	104	0 (0.0)	

^a+/+ indicates that the app store was searched and that apps were found.

^b+/- indicates that the app store was searched, but no apps were found.

^c- indicates that the app store was not searched.

^d Studies in which this is unclear is noted with "?"

^e We have included both the app stores searched and the app stores in which included apps were found.

^f Complete adherence is present for an assessed app when it meets the individual study's definition of complete adherence to the relevant guidelines, recommendations or scientific content. As such, a "0" in this column means that no single app assessed met the criteria for complete adherence.

^g App description from the app store

^h Developer's website

ⁱ Downloaded app content

Discussion

Principal Findings

Medical apps may save lives; with no regulation of the content, however, we fear that they may also do harm. Studies in this review focused on a wide range of medical topics, app platforms, and assessment methods and all reached one general conclusion: medical mobile phone apps generally lack expert involvement and do not adhere to relevant medical evidence. Expert involvement was found in 9-67% of assessed apps. Adherence to medical evidence was found in 10-87% of the assessed apps in 13 studies, and in none of the assessed apps in 17 studies. Medical professionals and patients should be aware of this, as mobile phones increasingly play a role in medical education

[5], clinical decision making [2], and patient empowerment [6-9].

For the common user, it may be practically impossible to assess whether or not an app adheres to current evidence and guidelines. In some cases, the app descriptions include references to publications from which the content is based. Levels of evidence as defined by the Oxford Centre for Evidence-Based Medicine state that systematic reviews and individual studies rank higher than opinions of an expert, but an expert opinion ranks better than nothing [63]. Hence, although expert involvement does not guarantee adherence to relevant medical evidence, it may be safer to have an expert involved than none.

Cheap and technically simple methods enable experts and clinicians to develop medical apps on their own [64-67]. These methods are based on Web apps developed using tools with a simple interface, hosted online, and distributed by the experts and clinicians [64-67]. Published examples include 1 Web app with clinical instructional videos for joint examination and 1 Web app with videos on psychiatric assessments and psychopathology lessons [65,67]. These works demonstrate that it is possible for experts to develop Web apps on their own with useful results [64,66]. However, 1 study in our review assessed both expert involvement and adherence of content to published evidence among opioid-conversion apps, and found that expert involvement per se does not necessarily lead to medical correctness of the content [10].

Apps can be considered an interactive way of communicating knowledge. We already use peer-review systems for such purposes—at least in scholarly journals—and one way of ensuring medically correct apps could be through peer reviews, which due to the unregulated nature of app stores would arrive after app publication. There are examples of short publications in medical journals of a review of 1 or more apps [68,69], and app developers are able to get an independent app review by submitting a request to Journal of Medical Internet Research mHealth and uHealth [70]. In addition, dedicated Web pages for app reviews exist [71,72]. One example of this is the Health Apps Library, which is developed and supported by the National Health Service in the United Kingdom [72]. The Health Apps Library enables developers to submit their app for review by clinicians that assesses whether the app is relevant to people in the United Kingdom, provide information from trusted sources, and comply with relevant data protection regulations [72]. The clinician then decides whether the app can be approved and published on the Health Apps Library [72]. However, even if a review exists, the user may not be aware of this. If the review is undesirable, the app developer may omit from referring to the review, which creates a bias. Previous studies on health information on the Internet reported similar results—some sources provide medically correct information, and some do not [73]—therefore, the problem highlighted in our systematic review is not new. However, some differences do exist when dealing with apps, which may allow to address this problem in the future. Apps are already reviewed by app stores before publication and app stores provide a streamlined access to content. Therefore, one possible way of addressing this problem could involve the collaboration between app stores and a

regulatory third party such as the Health Apps Library when publishing apps with medical content.

Limitations

Limitations of our approach should be noted. Apps can have expert involvement without stating it to the user, and app content may be accurate without referring to medical publications. In addition, apps with expert involvement can also contain inaccurate information, and referring to medical publications does not prevent out-of-date or inaccurate content. None of the studies included assessment of the actual use of the apps, which would provide an interesting dimension to our research question, as owning an app does not necessarily mean that the app is used. These dimensions may be enlightened by future studies. Our review found that different methods were used for the assessment of expert involvement and medical adherence. Some studies assessed expert involvement or adherence to medical evidence only by reviewing the app descriptions in the app stores and by visiting the app developers' website (Tables 1 and 2). For example, 1 study reviewed apps dealing with alcohol abuse and categorized each app's approach using the app description [58]. We acknowledge that in some cases, this approach may provide sufficient results. However, one should note that app descriptions do not necessarily reflect the actual app content. Therefore, future studies are encouraged to download and review actual app content. A clear consensus on a methodological golden standard does not exist, but we are currently seeing inspiring studies that explore different methods that evaluate authorship and content [47,74]. One recent example is the Mobile App Rating Scale (MARS), a 23-item assessment tool that provides quality scores for an app within 5 dimensions (engagement, functionality, aesthetics, information quality, and subjective quality), which demonstrated a high level of internal consistency and inter-rater reliability [74]. Reliable tools such as the MARS are important for the future direction of how and what to review, and may help future research in providing more comparable results.

In conclusion, most medical mobile phone apps lack expert involvement and do not adhere to relevant medical evidence. Because mobile phones are highly prevalent among medical professionals and patients, this poses a significant problem. Review services do exist, but additional effort is needed, and attention to the problem may help the community to figure out the solutions of the future.

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Conflicts of Interest

None declared.

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Abbreviations**MARS:** Mobile App Rating Scale

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Original Paper

Cannabis Mobile Apps: A Content Analysis

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Abstract

Background: Mobile technology is pervasive and widely used to obtain information about drugs such as cannabis, especially in a climate of rapidly changing cannabis policy; yet the content of available cannabis apps is largely unknown. Understanding the resources available to those searching for cannabis apps will clarify how this technology is being used to reflect and influence cannabis use behavior.

Objective: We investigated the content of 59 cannabis-related mobile apps for Apple and Android devices as of November 26, 2014.

Methods: The Apple and Google Play app stores were searched using the terms “cannabis” and “marijuana.” Three trained coders classified the top 20 apps for each term and each store, using a coding guide. Apps were examined for the presence of 20 content codes derived by the researchers.

Results: Total apps available for each search term were 124 for cannabis and 218 for marijuana in the Apple App Store, and 250 each for cannabis and marijuana on Google Play. The top 20 apps in each category in each store were coded for 59 independent apps (30 Apple, 29 Google Play). The three most common content areas were cannabis strain classification (33.9%), facts about cannabis (20.3%), and games (20.3%). In the Apple App Store, most apps were free (77%), all were rated “17+” years, and the average user rating was 3.9/5 stars. The most popular apps provided cannabis strain classifications (50%), dispensary information (27%), or general facts about cannabis (27%). Only one app (3%) provided information or resources related to cannabis abuse, addiction, or treatment. On Google Play, most apps were free (93%), rated “high maturity” (79%), and the average user rating was 4.1/5. The most popular app types offered games (28%), phone utilities (eg, wallpaper, clock; 21%) and cannabis food recipes (21%); no apps addressed abuse, addiction, or treatment.

Conclusions: Cannabis apps are generally free and highly rated. Apps were most often informational (facts, strain classification), or recreational (games), likely reflecting and influencing the growing acceptance of cannabis for medical and recreational purposes. Apps addressing addiction or cessation were underrepresented in the most popular cannabis mobile apps. Differences among apps for Apple and Android platforms likely reflect differences in the population of users, developer choice, and platform regulations.

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KEYWORDS

cell phones; mobile apps; cannabis

Introduction

Cannabis is the most widely used illicit substance in the United States, with 19.8 million US residents (7.5% age 12 or older reporting past-month use in 2013 [1]. In 2012, the prevalence of cannabis use surpassed that of cigarette smoking among youth age 12 to 17, and this continued into 2013 and 2014 [1,2]. Cannabis use and its legalization are contested issues, as policy changes have led to increases in the availability of cannabis for medical and recreational use in the United States, and problems associated with using cannabis (eg, diagnoses of cannabis use disorder) [3]. Cannabis remains a Schedule I substance under US federal law; however, two US states have legalized retail cannabis, two additional states and the District of Columbia have passed legislation to legalize use, and 33 states and Guam have legalized medical cannabis use. These state-level policy changes in the United States and the continued tension between federal and state laws have led to a proliferation of cannabis-related information in the United States and across the world.

Mobile technology, including the mobile phone, has been a vehicle for cannabis-related news and information. With a global audience totaling up to 1.75 billion in 2014, mobile phone technology is pervasive and widely used [4]. Mobile phones have revolutionized mobile communication technology through the availability of Internet access. Mobile phones also allow users to download apps, which are programs designed specifically for mobile phone operating systems. In June 2014, Apple announced that 75 billion apps had been downloaded from its App Store for the iPhone/iPad [5], and a June 2014 report showed that downloads from Google Play for Android devices had reached roughly 80 billion [6]. Market research firms have estimated that in 2015, there will be nearly 3 billion devices running the Android operating system and 500 million running the Apple operating system (iOS) worldwide [6].

People are increasingly turning to mobile phones to get information about potential health risk behaviors such as cannabis use. A majority of users (52% of Americans) use their mobile phones to gather health-related information [7]. However, it is unclear what is available to them when they do seek out this information.

Some previous work has characterized the content of mobile apps related to substance use. A review of 384 alcohol-related apps available on Apple's App Store and Google Play found that the majority of apps were primarily for entertainment (50%) or claimed to provide a blood alcohol concentration (39%), and the latter apps were highly unreliable. Only 11% of apps supported the safety of reduction/cessation of drinking [8]. A review of 87 addiction apps on Google Play in 2012 found that apps typically provided information on recovery, content to enhance motivation and promote social support, and tools to monitor progress [9]. Abrams and colleagues conducted two reviews of mobile apps for tobacco cessation, and concluded that these apps generally do not adhere to US Clinical Practice Guidelines for smoking cessation [10,11]. Jacobs and colleagues [12] classified Facebook apps for smoking cessation, similarly concluding that the few available apps had low adherence to

recommended guidelines. There has not been a content analysis of mobile apps related to cannabis use, and it is unclear whether available apps address addiction or cessation at all.

Other content analyses have evaluated the scientific rigor of health-related mobile apps. Cowan et al [13] found that iPhone apps targeting physical activity were generally lacking in theoretical content, and higher-priced apps and those that addressed a broader activity spectrum incorporated more theoretical content. In an evaluation of iPhone diet apps, West et al [14] found most apps to be theory deficient and provide only general information or assistance. Breton and colleagues similarly concluded that only a small fraction (15%) of apps for weight control adhered to 5 or more of 13 practices recommended by government agencies for the control of weight [15]. Content analysis of apps for pediatric obesity prevention (weight loss, healthy eating, physical activity) found that most apps (62%) lacked any expert recommendations, and those that did were limited in the number of recommendations made (mean 3.6, SD 2.7 out of 15 defined guidelines). More than half (56%) of the apps were games, consistent with strategies appealing to young people [16]. Other reviews showed a similar lack of comprehensive, scientific information for asthma management [17], and variance in adherence to established guidelines for first aid by source [18] and for cancer information by target audience (health care professionals vs the public) [19]. Results of these studies highlight that, although the material is vast, there is a lack of information with scientific grounding or theory-based interventions available to users.

A report of young adults' perspectives on apps for health behavior change showed that young adults have an interest in using such apps, and that accuracy, legitimacy, security, effort required, and immediate effects on mood were important influences on app usage [20]. It is unclear whether mobile apps for cannabis use address health behavior change in any way. Given widespread cannabis use, political controversy surrounding its legalization, and the potential for mobile technology to deliver information about cannabis to a large body of users worldwide, there is a need to understand the nature of available cannabis information on mobile phones. This study analyzed the top cannabis-related mobile apps on Apple's App Store and Google Play in terms of app characteristics (price, rating, download range) and content codes (strain classification, laws, games, social media, medicinal use, etc). Findings will inform how cannabis is portrayed in the context of mobile apps, describe what (if any) health information is conveyed in cannabis apps, and highlight gaps in available information.

Methods

Identifying Cannabis Apps

We used several strategies to identify apps that would be most likely encountered by users seeking cannabis-related information. First, a search for the most commonly used words for "cannabis" was performed at the website UrbanDictionary.com in January 2014. A total of 110 commonly used and slang terms were listed, and used as search terms on Apple's App Store and Google Play. At the time of searching, Google Play reported up to 250 apps for each term and all terms

had 250 results. On Apple's App Store, the number of results differed widely by search term. Terms with meanings other than strictly cannabis (eg, "bomb," "zombie," "pot") had more results than those referring primarily to cannabis (eg, "marijuana"). The first, second, and third authors made a decision not to use terms that could refer to something other than cannabis, and used the frequency of search results for all remaining terms to inform the final choice to use the terms "cannabis" and "marijuana" for the content analysis.

A search for apps using the keywords "marijuana" and "cannabis" was then performed on Apple's App Store and Google Play on November 26, 2014. The first 20 results for either search term in both stores were considered for coding. Any app that did not duplicate a previous result was coded for content. Only the first 20 results were chosen for analysis based on consensus among investigators that users rarely go beyond the first 1-2 screens in app stores, a rationale similar to that used in a content analysis of electronic cigarette websites [21]. The total number of apps analyzed in this exploratory project was comparable to previous reviews of tobacco smoking cessation apps that included 47 [10] and 98 apps [11], and a review of 12 Facebook apps for smoking cessation [22].

Coding Guide Development

In January 2014, a research staff member, supervised by the first author, searched the Apple App Store and Google Play store using the term "marijuana" and selected the top 10 apps in each store (20 apps total) to develop a coding guide, similar to the procedure used by Grana and Ling [21] for electronic cigarette websites. The staff first drafted a guide relevant to cannabis apps, including prompting for all features included on the Apple App Store and Google Play, and content codes. In March 2014, a coder who did not participate in the final coding process for the analysis again selected a sample of top 10 apps from each store using the search term "marijuana" (for a total of 20 apps), coded them and further revised the coding guide. The top apps listed for searches change quickly; therefore, the apps that were in the top search results during the coding guide development may not have been in the top results at the time of the final content analysis.

Throughout the coding guide development process, the guide was reviewed iteratively by the first three authors, refined, and retested to generate consistent definitions and examples.

In March 2014, 2 coders were trained by the first author and a sample of apps were coded and evaluated for reliability. Twenty apps (10 Apple's App Store, 10 Google Play, not necessarily included in the final sample) resulting from the search term "marijuana" were used for training, and reliability with Kappa ranged from .62 (medicinal use) to .89 (news). Any discrepancies in coding were discussed with the first author and a consensus was reached. After reliability was established, apps meeting search criteria for the main analysis (search terms "cannabis" and "marijuana") were divided and given to the same 2 coders. Coders downloaded all free and paid apps to examine features. In November 2014, a third coder downloaded and coded all 59 apps reported in this analysis. Reliability for the 8 apps that were the same on Apple's App Store under the search term "cannabis" in March and November 2014 ranged

from .71 (facts) to 1.00 (all other categories), indicating strong reliability.

Coding Guide

The final guide included coding for basic information about app compatibility (eg, type of mobile phone, version of operating system required for use), and basic description of the app based on information reported by Apple's App Store or Google Play (name of the app, URL, age restriction based on Apple's App Store or Google Play categories, average user ratings based on Apple's App Store or Google Play ratings, total app installs [Google Play only], and any exact fees for app use). Categories of apps as specified by Apple's App Store or Google Play were also coded. Explanations of Apple App Store categories were available online [23]. No description of categories was available for Google Play.

Each mobile app was coded for the presence of each of the following content codes: (1) *Utilities* (including phone wallpaper, battery widget, backgrounds, clock widget, weather widget, brightness widget, toggle widgets [wifi, sound, auto-rotate, data], unit converter weight scale); (2) *News* (cannabis-related); (3) *Social Media* (apps allowing for connection with other users); (4) *Medicinal Use* (connection with doctors who prescribe medicinal cannabis); (5) *Recipes* for cooking with cannabis; (6) *Games* (cannabis-themed); (7) *Cannabis Strain Classification* (pictures, videos, information about the effects of each strain, ability to upload pictures of cannabis); (8) Information on *Growing Cannabis* (eg, information on seed fermentation or ideal growing conditions); (9) *Dispensaries* (medical or recreational, global vs specific region, contacting a dispensary, offer of discounts for dispensary products); (10) *Laws* pertaining to cannabis (including in any US state or another geographic region); (11) *Cannabis Social Gatherings* (descriptions, directions to cannabis events); (12) *Cannabis Cup* results; (13) *Cannabis Smoking Etiquette* (eg, "how" to smoke, things not to do); (14) *Cannabis Dictionary*; (15) *Facts* about cannabis; (16) *Cannabis Abuse, Addiction or Treatment*; (17) *Virtual Simulation* (eg, smoking a virtual joint, realistic joint rolling); (18) *Log* of cannabis use (record of previously tried marijuana/cannabis strains and/or flavors, daily use of joints/blunts, and/or daily growth of marijuana/cannabis plants); (19) *Cannabis Jokes*; and (20) *Cannabis Quotes*. A single app could include any number of categories. Examples of each content code are listed in Table 2, and screenshots of sample apps are in Multimedia Appendix 1.

Data Analysis

We calculated the frequency of results from each search term related to cannabis and determined the best search terms for content coding. Once coding was completed, we calculated frequencies and used descriptive statistics to characterize apps. Microsoft Excel was used for all analyses.

Results

Content Analysis

Total apps available for each search term were 124 for "cannabis" and 218 for "marijuana" on Apple's App Store, and 250 each for "cannabis" and "marijuana" on Google Play.

Within the top 20 apps for each search term (“cannabis” and “marijuana”) in each store, there were 10 duplicates on Apple’s App Store and 11 duplicates on Google Play. Thus, 59 independent apps (30 on Apple’s App Store, 29 on Google Play) were coded (see [Appendix 2](#) for a complete list).

On Apple’s App Store, most apps were free (77%), all were rated for users aged “17+” years, and the average rating was 3.9/5 stars. On Google Play, most apps were free (93%), rated “high maturity” (79%), and the average rating was 4.1/5 stars. The modal range of downloads was 100,000-500,000 (34%; [Table 1](#)).

Table 1. Overview of mobile cannabis/marijuana apps (N=59).

Category	All (N=59)	Apple App Store (n=30)	Google Play (n=29)
Free, n (%)	50 (85)	23 (77)	27 (93)
Average price ^a (SD)	\$2.43 (0.88)	\$2.56 (0.79)	\$1.99 (1.41)
Average user rating (SD)	4.0 stars (0.64)	3.9 stars (0.94)	4.1 stars (0.31)
Type of app^b, n (%)			
Lifestyle	17 (29)	12 (40)	5 (17)
Medical	11 (19)	9 (30)	2 (7)
News (App Store)/ news & magazines (Google Play)	3 (5)	2 (7)	1 (3)
Games	11 (19)	4 (13)	7 (24)
Reference (App Store)/books & refer- ence (Google Play)	5 (9)	2 (7)	3 (10)
Health & fitness	3 (5)	1 (3)	2 (7)
Personalization ^c	N/A	N/A	6 (21)
Education ^c	N/A	N/A	1 (3)
Entertainment ^c	N/A	N/A	2 (7)
Age restriction/maturity level, n (%)			
17+	N/A	30 (100)	N/A
High maturity	N/A	N/A	23 (79)
Medium maturity	N/A	N/A	6 (21)
Total installs^d, n (%)			
1000-5000	N/A	N/A	2 (7)
5000-10,000	N/A	N/A	2 (7)
10,000-50,000	N/A	N/A	6 (21)
50,000-100,000	N/A	N/A	2 (7)
100,000-500,000	N/A	N/A	10 (34)
500,000-1,000,000	N/A	N/A	5 (17)
1,000,000-5,000,000	N/A	N/A	2 (7)

^aAverage price calculated for only those apps with any cost.

^bType of app as specified by Apple’s App Store or Google Play.

^cCategory only present on Google Play.

^d Installs information only present on Google Play.

Based on our coding, the three most common content codes across all apps were cannabis strain classification (33.9%), facts about cannabis (20.3%), and games (20.3%). On Apple’s App Store, the top 20 apps provided cannabis strain classifications (50%), dispensary information (27%), or general facts about cannabis (27%; [Table 2](#)). Only one app (3%) provided any

information or resources related to cannabis abuse, addiction, or treatment. On Google Play, the most popular apps offered games (28%), phone utilities (eg, wallpaper, clock; 21%) and cannabis food recipes (21%); no apps addressed abuse, addiction, or treatment.

Table 2. Content codes of mobile cannabis apps (N=59).

	Example	All, n (%) (N=59)	Apple App Store, n (%) (n=30)	Google Play, n (%) (n=29)
Strain classification	<i>Leafly Marijuana Strain and Dispensary Reviews</i> (App Store and Google Play)—contains a database of hundreds of marijuana strains and their effects, flavors, medical treatment, and availability nearby	20 (34)	15 (50)	5 (17)
Facts	<i>Marijuana Facts</i> (Google Play)—a collection of marijuana-related facts pertaining to consumption, cultivation, production, history, and sustainability	12 (20)	8 (27)	4 (13)
Game	<i>Pot Farm - Grass Roots</i> (Google Play)—grow and sell virtual weed	12 (20)	4 (13)	8 (28)
Dispensaries	<i>Weedmaps</i> (App Store and Google Play)—helps users connect to local dispensaries and access menus, strain reviews, and exclusive offers	10 (17)	8 (27)	2 (7)
Recipes	<i>Weed Cookbook - Medical Marijuana Recipes & Cooking</i> (App Store)—a collection of recipes that include cannabis as an ingredient	10 (17)	4 (13)	6 (21)
News	<i>Cannabis News Pro</i> (App Store)—a collection of cannabis-related news from multiple sources	9 (15)	6 (20)	3 (10)
Utilities	<i>Cannabis Joint Battery Widget</i> (Google Play)—shows phone's battery level as a burning joint	9 (15)	3 (10)	6 (21)
Growing cannabis	<i>Cannabis Pocket Reference</i> (Google Play)—contains a Grow Guide with growing information, pest/disease control tips, grow diary, and nutrient charts	8 (14)	4 (13)	4 (14)
Social media	<i>Rate My Weed - The First Ever Marijuana Recognition Software</i> (App Store)—allows users to share marijuana recognition results on Facebook and Twitter	8 (14)	6 (20)	2 (7)
Laws	<i>WeedLaws: Marijuana Law Guide</i> (Google Play)—provides state-specific legal information regarding use, possession, cultivation, and sale of cannabis	7 (12)	4 (13)	3 (10)
Medicinal use	<i>Marijuana - MyGreenz Locator</i> (App Store)—connects users to medical marijuana doctors and dispensaries	7 (12)	5 (17)	2 (7)
Cannabis cup	<i>Cannabis Cups</i> (App Store)—allows users to view and judge featured strains, gives directions to Cannabis Cup events, and includes Cannabis Cup results from previous years	5 (9)	4 (13)	1 (3)
Log	<i>Medical Marijuana Log</i> (App Store)—allows users to record daily cannabis use via blunts, joints, vapes, bowls, or dabs	5 (9)	4 (13)	1 (3)
Dictionary	<i>Marijuana 420</i> (App Store)—dictionary of marijuana-related terms, street names, and slang	3 (5)	3 (10)	0
Quotes	<i>Marijuana Quotes</i> (Google Play)—collection of marijuana-related quotes	3 (5)	0	3 (10)
Smoking etiquette	<i>Joint 4 Dummies</i> (Google Play)—teaches users several ways to roll a joint	3 (5)	2 (7)	1 (3)
Social gatherings	<i>Cannabis Culture</i> (Google Play)—Canadian-based magazine that covers cannabis cultural events such as the Global Marijuana March and 420	3 (5)	2 (7)	1 (3)

	Example	All, n (%) (N=59)	Apple App Store, n (%) (n=30)	Google Play, n (%) (n=29)
Virtual simulation	<i>iSmoke: Weed HD - Free</i> (Google Play)—a simulation of rolling and lighting a joint while listening to a soundtrack	2 (3)	0	2 (7)
Abuse, addiction, or treatment	<i>Marijuana Anonymous Mobile</i> (App Store)—12-step guide to recovering from marijuana addiction, includes addiction-related literature and a meeting search function to connect users	1 (2)	1 (3)	0
Jokes	<i>Marijuana Jokes</i> (Google Play)—collection of marijuana-related jokes	1 (2)	0	1 (3)

On Apple's App Store, the app that appeared as the top result for both search terms ("cannabis" and "marijuana") was *Leafly Marijuana Strain and Dispensary Reviews*. It featured a large database of strain reviews (with pictures, flavors, effects, etc), a "Finder" function to locate and review nearby dispensaries (medical or recreational), and an information section with cannabis-related news and content. The app was free and had an average user rating of 5 stars. This app was given 5 content codes: *News, Medicinal Use, Strain Classification, Dispensaries, and Facts*.

The app that appeared as the second result for both search terms in Apple's App Store was *Marijuana Handbook Lite - The Ultimate Medical Cannabis Guide With The Best of Edible, Ganja Strains, Weed Facts, Bud Slang and More!* The app featured a wide range of cannabis-related resources, including a strain library, a maps section to locate medical or recreational dispensaries, a marijuana dictionary, a facts section, and a cookbook. The app was free and the average user rating was unknown. This app was given 6 content codes: *Recipes, Strain Classification, Dispensaries, Smoking Etiquette, Dictionary, and Facts*.

On Google Play, the app that appeared as the top result for both search terms was *Pot Farm - Grass Roots*, a game that allowed players to grow and harvest virtual marijuana. Users could run their own dispensaries to sell weed and connect with other gamers to trade weed. The app was free, had an average user rating of 4.4 stars, and had 500,000-1,000,000 downloads. This app was given 2 content codes: *Social Media* and *Games*.

The Google Play app that appeared as the second result for the search term "cannabis" was *BudTrimmer - Weed and Cannabis*, a game in which a player swiped across the screen to slash buds and collect points. The app was free, had an average user rating of 4.3 stars, and had 100,000-500,000 downloads. This app was coded as a *Game*.

The Google Play app that appeared as the second result for the search term "marijuana" was *Weedmaps*. This app functioned as a dispensary finder that helped users connect to local medical or recreational dispensaries, medical marijuana doctors, and delivery services. Users could also access dispensary menus, strain reviews, and "exclusive offers." The app was free, had an average user rating of 4.2 stars, and had 1,000,000-5,000,000 downloads. Coders gave this app 4 content codes: *Medicinal Use, Strain Classification, Dispensaries, and Facts*.

Only one app addressed cannabis abuse, addiction, or treatment in any way. On Apple's App store, *Marijuana Anonymous Mobile* employed a 12-step recovery program, analogous to the 12-Step Recovery Program of Alcoholics Anonymous, to help users stop cannabis use. The app contained information regarding addiction and recovery, including a monthly newsletter and an interactive 12-Step Workbook. It offered a chat feature and a meeting search function that allowed users to find in-person, phone, and online meetings. It also included a Sobriety Date Counter that allowed users to record the number of days of abstinence. The app was listed as the 17th result under the search term "marijuana," was free, and had an unknown user rating. This app was given 2 content codes: *Abuse, Addiction, or Treatment* and *Facts*.

Discussion

Principal Findings

This study examined 59 mobile apps related to cannabis. Over half (58%) of the top apps on Google Play had been downloaded at least 100,000 times, showing that mobile users are generally interested in this category of apps. Overall, the most popular mobile app content was primarily focused on information (strain classification, facts) and recreation (games), with cannabis recipes demonstrating popularity as well. In contrast, only one app in our sample focused on cannabis addiction or treatment. The popularity of informational and recreational apps likely reflects a growing societal acceptance of cannabis, which is also reflected in state laws that have become more favorable toward medical and recreational use in recent years. Indeed, Apple recently relaxed a policy in its App Store prohibiting cannabis-related social media apps, likely both reflective of and influencing the increasing acceptance of cannabis use as something that connects a growing number of people [24]. To our knowledge, this study is the first to describe the content of cannabis-related mobile apps. Updates are likely to show a larger number of apps and a continued focus on information and recreation if state laws and public attitudes toward cannabis continue to move in a favorable direction.

Apps addressing addiction or cannabis cessation were underrepresented in the most popular cannabis mobile apps. This could in part reflect the low level of motivation among non-treatment-seeking marijuana users to cut down or quit use [25]. It also could reflect a lack of interest among mobile phone users to seek out health-related or cessation apps pertaining to

cannabis. Although there is some evidence that a majority (57%) of clients in drug treatment have mobile phones [26], there is limited evidence about the desire of persons in treatment to use apps for therapeutic purposes and about the effectiveness of mobile apps for cannabis treatment. We found two published studies that showed promise in the use of mobile technology to treat cannabis use disorders: one using an ecological momentary intervention to monitor substance use among youth after a treatment episode [27]; and another testing the usability of an app to monitor and reduce cannabis use (Assess Plan Track Tips) [28]. As apps are developed, if evidence mounts as to their success in aiding behavior change, it is possible that these apps could become a reliable source of cannabis education or cessation interventions. Health departments and other prominent health organizations should consider creating or endorsing accurate and evidence-based cannabis mobile apps to give them credibility in the ever-expanding app marketplace.

The top apps for iPhone tend to provide information (eg, strains of cannabis) or have some educational purpose, while top Android apps tend to be primarily for entertainment (games, phone utilities). These differences likely reflect differences between iPhone and Android developers, who often program an app for only one platform, and the platforms themselves dictate app content based on rules/approval. For example, the Android market is perceived to be easier to enter than the Apple market because of fewer restrictions [6]; scrutiny may be particularly strong for approving cannabis apps in the Apple App Store [29].

Although we could not link user data to app characteristics in this analysis, market research has suggested that while Android has a larger user base, iPhone users in the United States are younger and more affluent, engage with a larger amount of mobile phone content, and are more likely to engage in mobile commerce [30]. Future investigations should directly survey mobile users about their use of cannabis apps on both Apple and Android operating systems to determine potential implications for user activity. Of the 59 apps coded for this project, 8 were available on both platforms (Apple and Android). Of those 8, 6 were in the top 20 apps under either “marijuana”

or “cannabis” search terms on the Apple App Store, but not in the top 20 on Google Play. *Leafly Marijuana Strain and Dispensary Reviews* and *Weedmaps* were in the top 20 in both stores using all 4 search terms, indicating popularity among users of both types of devices. Both apps provide a resource for those looking to classify different types of cannabis and locate dispensaries.

Limitations

It was not possible to link app content to user data. Further, search criteria were generated by using common words related to cannabis (ie, “cannabis” and “marijuana”); however, users who are seeking a particular type of app may search directly for that app type (eg, “cannabis treatment”), which would not have been captured by this analysis and would likely yield different results. Surveys of cannabis app seekers would be useful to clarify this further. The decision to rate the top 20 app results for each search term was based on the authors’ judgment that this would encompass apps seen by a user during most searches. The logic was that most users would not go beyond approximately 1-2 screens on a desktop computer and even fewer results on a mobile device, for which fewer results are available on a single screen. A different method, incorporating more apps, would likely have yielded different results. The content analysis is based on search results found in November 2014. The app marketplace is changing rapidly; therefore, apps that appeared at the top of search at the time of the study may no longer be top apps in the future.

Conclusions

Cannabis mobile apps are numerous and the most popular apps focus on information, classification, and recreation (eg, games), consistent with the expanding business of growing and selling cannabis in the United States. Notably absent from the most popular apps were those addressing the important public health concern of cannabis addiction or negative health effects, for which mobile apps could be useful. Finally, there are notable differences among apps on Apple’s App Store and Google Play, likely reflecting the population of users, developer choice, and platform regulations.

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Authors' Contributions

Dr Ramo designed the study with consultation from Drs Popova and Grana and Ms Chavez. Dr Ramo supervised the coding, and Dr Ramo and Ms Zhao conducted the analysis and drafted the manuscript. Drs Popova and Grana reviewed and revised subsequent drafts of the manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Screenshots of apps representing each content area coded.

[[PDF File \(Adobe PDF File\), 727KB - mhealth_v3i3e81_app1.pdf](#)]

Multimedia Appendix 2

List of mobile apps analyzed (N=59) in order of popularity.

[[PDF File \(Adobe PDF File\), 32KB - mhealth_v3i3e81_app2.pdf](#)]

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Original Paper

Review and Evaluation of Mindfulness-Based iPhone Apps

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Abstract

Background: There is growing evidence for the positive impact of mindfulness on wellbeing. Mindfulness-based mobile apps may have potential as an alternative delivery medium for training. While there are hundreds of such apps, there is little information on their quality.

Objective: This study aimed to conduct a systematic review of mindfulness-based iPhone mobile apps and to evaluate their quality using a recently-developed expert rating scale, the Mobile Application Rating Scale (MARS). It also aimed to describe features of selected high-quality mindfulness apps.

Methods: A search for “mindfulness” was conducted in iTunes and Google Apps Marketplace. Apps that provided mindfulness training and education were included. Those containing only reminders, timers or guided meditation tracks were excluded. An expert rater reviewed and rated app quality using the MARS engagement, functionality, visual aesthetics, information quality and subjective quality subscales. A second rater provided MARS ratings on 30% of the apps for inter-rater reliability purposes.

Results: The “mindfulness” search identified 700 apps. However, 94 were duplicates, 6 were not accessible and 40 were not in English. Of the remaining 560, 23 apps met inclusion criteria and were reviewed. The median MARS score was 3.2 (out of 5.0), which exceeded the minimum acceptable score (3.0). The Headspace app had the highest average score (4.0), followed by Smiling Mind (3.7), iMindfulness (3.5) and Mindfulness Daily (3.5). There was a high level of inter-rater reliability between the two MARS raters.

Conclusions: Though many apps claim to be mindfulness-related, most were guided meditation apps, timers, or reminders. Very few had high ratings on the MARS subscales of visual aesthetics, engagement, functionality or information quality. Little evidence is available on the efficacy of the apps in developing mindfulness.

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KEYWORDS

mindfulness; mindfulness-based mobile apps; mobile health (mHealth); mental health

Introduction

Background

Mindfulness has grown in popularity in the last two decades, and there is growing evidence for its positive impact on well-being [1,2]. Many different perspectives of mindfulness have evolved over this period. An influential definition by Jon Kabat-Zinn is that mindfulness is “paying attention on purpose,

in the present moment, and non-judgmentally to the unfolding of experience moment by moment” (p 145 [3]). Mindfulness is seen as a skill that can be developed through practice. The benefits of present-centered attention and acceptance of experience that can be achieved through mindfulness include enhanced awareness, greater self-regulation, greater openness and acceptance to experiences, and the development of new perspectives on the context and content of information [4]. This

contrasts with mindlessness, where an individual's attention is focused on past experiences and concerns about the future rather than on the present moment [5].

Accordingly, mindfulness has been found to have beneficial psychological, somatic, behavioral, and interpersonal effects [6], developing tolerance, acceptance, patience, trust, openness, gentleness, generosity, empathy, gratitude, and loving-kindness, each of which is relevant to the personal recovery of people with mental disorders, as well as to positive well-being in general [2]. Mindfulness has also been found to reduce psychological distress and optimize psychological functioning in young people [7]. There is growing evidence for the efficacy of mindfulness-based programs in promoting well-being [8], reducing depression [9], and preventing relapse in depression [10].

While mindfulness can be an effective tool for improving health and psychological well-being, finding an effective mindfulness delivery medium that can reach a wider audience remains a challenge.

Apps for Mental Health

The global prevalence and burden of mental disorders is substantial, and delivering mental health services effectively to millions in need remains a challenge [11]. While Web-based interventions are gaining empirical support [12], mobile interventions are still in their infancy [13]. Mobile health (mHealth) is an emerging field that uses wireless technologies such as mobile phones and other devices in health practice. The advent of apps has created new opportunities. Smartphones can keep the user connected to the Internet at all times. Smartphones and apps provide computing facility comparable to personal computers and software with the advantage of mobility.

Smartphone use is growing rapidly [14], and smartphones now account for 25% of total Web usage. A recent Australian study [15] reported that 88% of its survey respondents use websites or apps on their mobile phone and predicted that 92% of respondents would own a smartphone by October 2015. Global mobile app downloads are expected to reach 269 billion by 2017 [16]. Smartphone usage by young people is particularly high: The Australian Communications and Media Authority reported that in May 2013, 89% of people aged 18-24 years had a smartphone and 83% of this age group downloaded an app in the previous 6 months [17]. E-technologies are also well-accepted by young people as sources of health information. In a recent survey, 39% of young people reported using the Internet to seek information about a mental health problem [18]. An implication of this wide acceptance of e-technologies is that they may offer a medium to improve the well-being of young people by supporting the development of mindfulness [18,19].

The Apple Store now has a staggering 1.4 million apps, more than 35,000 of which are health-related [20]. However, little information is available on the quality or efficacy of these apps beyond user reviews and star ratings [21]. It is imperative that health apps contain high-quality information and have positive effects for users [22].

In particular, while there is growing evidence for the positive effects of face-to-face mindfulness-based training programs, it

is unclear if mindfulness apps can provide the same benefits. A search for studies in various databases (ERIC, MEDLINE, PsycINFO, Web of Science, ProQuest) only identified one randomized controlled trial [23] examining the efficacy of a mindfulness training app (Headspace).

The present study conducted a systematic review of mindfulness-based mobile apps, evaluated the quality of these apps using an expert rating scale, and described features of the highest-scoring apps.

Methods

Systematic Search

A systematic search of mindfulness-based mobile apps accessible from Australia was conducted in June 2014. The search was conducted using the Google app search function as well as the search feature in the iTunes app store. The Google app search included mindfulness, vipassana, mindful, meditation, and present moment, and excluded hypnosis, hypnotize, weight, magazine, mindmap, mind map, mind-map, and binaural. "Mindfulness" was the only search term used in iTunes, as the search feature was more limited.

Preliminary screening removed irrelevant apps (music/relaxation, happiness, inspirational cards, games, clocks, etc), apps not in English, and those that were not readily accessible. Mindfulness apps that were secular, explicated mindfulness practice, and also had guided mindfulness training were included. Apps that only gave reminders, timers, or guided meditation tracks were excluded, as were apps that cost more than \$10 (on the grounds that they were unlikely to be purchased by a large number of users). While guided meditation tracks are a part of mindfulness training, that by itself cannot be justified as mindfulness training as they lack education about mindfulness.

The apps were rated and reviewed in iOS 7 with an iPhone 5s. Each app was tested by at least one author for a minimum of 30 minutes in a real-world setting. The authors were involved in the development of the MARS [24] and had undertaken mindfulness training. Two of the authors had delivered mindfulness training as part of their clinical psychology practice.

Measures/Rating Tool

The MARS [24] was used to rate app quality. It contains 23 items in 3 sections: classification, app quality, and satisfaction. Each MARS item uses a 5-point scale (1-Inadequate, 2-Poor, 3-Acceptable, 4-Good, 5-Excellent). The classification section is only for descriptive purposes. The 19-item app quality section rates apps on four subscales: engagement, functionality, aesthetics, and information quality. The subjective quality section contains 4 items evaluating the user's overall satisfaction. The MARS is scored by calculating the mean scores of the app quality subscales and the total mean score. The subjective quality items are scored separately as individual items. The MARS has demonstrated excellent internal consistency ($\alpha=0.92$) and interrater reliability (ICC=.85) [24]. A second rater reviewed and rated 30% of the apps on the MARS for interrater reliability purposes.

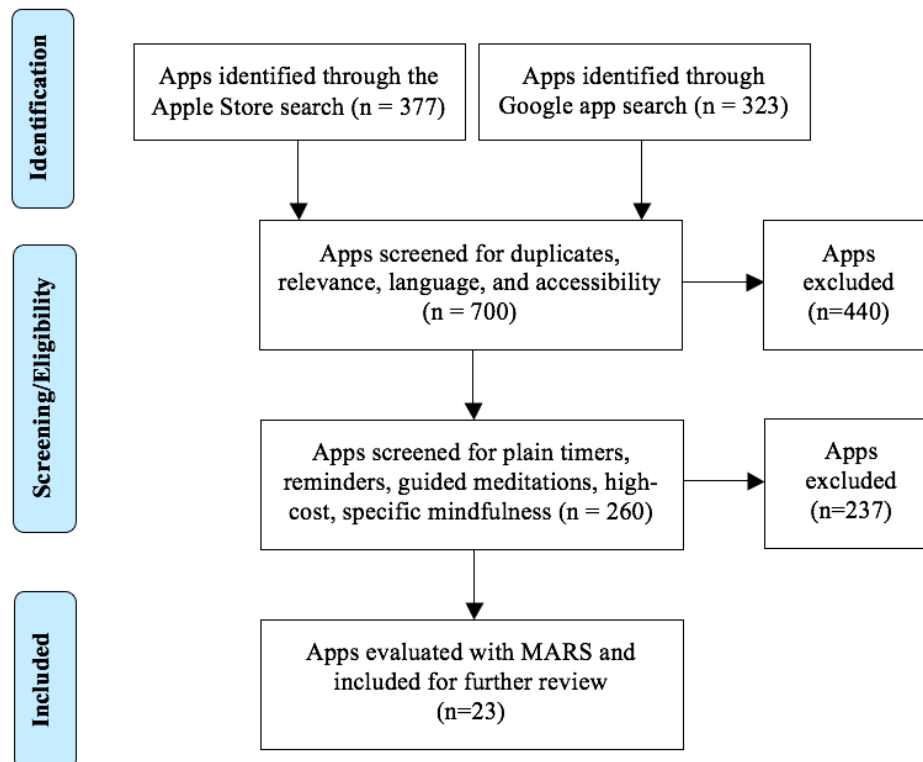
Results

Systematic Search

The Google and iTunes searches identified 323 and 377 apps, respectively (Figure 1). Excluding duplicates, there were 606 apps. However, 10 were not accessible, 40 were in languages other than English, and 296 were not relevant (ie

music/relaxation, happiness, inspirational cards, games, clocks, etc). Of the remaining 260 apps, 23 met the inclusion criteria. Excluded apps comprised those containing timers or reminders (74), guided meditation tracks for common practice or special occasions (129; religious practice/pregnancy/eating/exercise), or information only (37; eBooks/audiobooks/guidelines, without any tools to practice). Nine of the included apps were free and the rest cost between \$2.49 and \$5.99.

Figure 1. Systematic search for mindfulness apps in Apple store.



App Quality

Table 1 shows the subscale and overall scores of apps rated with MARS. It was not possible to rate item 19, which provides a measure of the evidence base for the apps, as a Google Scholar search only identified one efficacy study [23] on one of the included apps (Headspace). Seven apps (30%) were evaluated by two expert MARS raters, and there was an excellent level of interrater reliability (two-way mixed ICC=.84; 95% CI 0.79-0.87).

The Headspace app had the highest average MARS total (4.0) and subscale scores. The next highest were Smiling Mind (3.7), iMindfulness (3.5) and Mindfulness Daily (3.5). Mindfulness Trainer scored the lowest (2.6). The median MARS was 3.2, and all but three of the apps met or beat the minimum acceptability score of 3.0. Satisfaction (the only totally subjective subscale) was not included in the overall score.

Features of High-Quality Mindfulness Apps

Features of the reviewed apps are summarized in Tables 2 and 3. All contained guided meditations and mindfulness education. They also had at least 2 of the following 9 most common types of guided meditations [25]:

1. Breathing — deep breathing with awareness of the in and out breathes
2. Body scan — awareness of the body focusing on each of the body parts, usually starting from the toes and progressively moving towards the head
3. Sitting meditation — breathing meditation in a sitting posture, with awareness of the body
4. Walking meditation — practicing mindful walking, raising awareness of each movement as we walk slowly
5. Loving kindness meditation — a meditation practice to accept, love and show kindness to oneself and others
6. Thoughts and emotions — acknowledging thoughts and emotions non-judgmentally, as they come and go
7. Mountain meditation — a guided imagery practice, imagining oneself as a mountain and feeling stronger
8. Lake meditation — a guided imagery practice, imagining oneself as a lake, experiencing stillness and peace
9. Three-minute breathing space — a 3-minute guided meditation, with becoming aware in the first minute, gathering and focusing attention in the second minute, and expanding the attention in the third minute.

Almost all apps provided mindful breathing and body-scan exercises. Only one contained all 9 types of guided meditations (Mindfulness Trainer) and few contained loving kindness, lake,

and mountain meditations. Buddhify 2 differed from the rest by providing guided meditations to practice in different situations, including exercising, working online, sleeping, and

on your work break. The recording quality, voice used, and pace of the delivery of guided meditations varied from app to app.

Table 1. MARS Rating.

App ^a	Engagement	Functionality	Aesthetics	Information ^b	Satisfaction	Overall
1 Headspace ^c	3.8	4.8	4.7	4.0	4.0	4.0
2 Smiling Mind ^c	3.4	4.5	4.3	3.8	4.0	3.7
3 iMindfulness ^c	3.0	4.8	3.7	3.7	2.5	3.5
4 Mindfulness Daily	3.2	4.0	4.0	3.7	3.3	3.5
5 Buddhify 2	3.6	3.8	3.7	3.5	3.8	3.4
6 Complete Mindfulness ^c	3.0	4.0	4.0	3.7	2.8	3.4
7 Mindfulise	3.6	3.5	4.0	3.3	2.5	3.4
8 ACT Coach	3.0	4.0	3.0	3.8	3.5	3.3
9 Rhythm Free	3.4	3.5	4.0	3.2	3.0	3.3
10 Simply8	2.8	3.8	4.0	3.5	2.8	3.3
11 Stop, Breathe & Think	3.2	4.0	3.3	3.3	3.0	3.3
12 Mindfully Me	3.0	4.0	3.3	3.3	2.5	3.2
13 The Meditation App with Michael Stone	3.0	4.0	3.0	3.5	2.5	3.2
14 Meditation without borders ^c	2.6	4.0	3.3	3.5	2.8	3.2
15 Mindfulness Coach	2.8	3.8	3.0	3.7	2.8	3.2
16 The Mindfulness App ^a	3.0	3.8	3.0	3.5	2.5	3.2
17 Take a Chill ^c	3.2	3.5	2.7	3.5	2.5	3.1
18 iMindfulness - On The Go	3.0	3.8	3.0	3.2	2.5	3.1
19 Personal Coach - Mindfulness	3.0	4.0	2.7	3.2	2.5	3.1
20 The Breathing Anchor - Andries J Kroese	2.8	3.8	2.7	3.3	2.5	3.0
21 Mindfulness by Potential Project	2.8	3.5	2.7	3.0	2.0	2.8
22 Cleveland Clinic - Stress Free Now	2.4	3.8	2.7	3.0	2.5	2.8
23 Mindfulness Trainer	2.2	3.3	2.3	3.0	1.8	2.6

^a The rated versions ([Multimedia appendix 1](#)) of the apps may not be available in the App Store at the time of publication, as they may be replaced by newer versions.

^b The information quality score excluded Item 19 of the MARS.

^c Rated by two raters for interrater reliability purposes.

Table 2. Summary of mindfulness-based apps features.

#	App	Timer	Reminders	Mood assessments	Tracking	PB Practice ^a
1	Headspace	✓	✓		✓	✓
2	Smiling Mind	✓	✓	✓	✓	✓
3	iMindfulness	✓	✓		✓	
4	Mindfulness Daily	✓	✓	✓	✓	✓
5	Buddhify 2	✓			✓	
6	Complete Mindfulness					
7	Mindfulise	✓			✓	
8	ACT Coach				✓	
9	Rhythm Free	✓	✓		✓	
10	Simply8	✓	✓			✓
11	Stop, Breathe & Think			✓	✓	
12	Mindfully Me	✓	✓		✓	
13	The Meditation App with Michael Stone	✓	✓		✓	
14	Meditation without borders					✓
15	Mindfulness Coach	✓	✓		✓	
16	The Mindfulness App	✓	✓		✓	
17	Take a Chill	✓	✓		✓	
18	iMindfulness On The Go	✓	✓		✓	
19	Personal Coach - Mindfulness	✓	✓			
20	The Breathing Anchor - Andries J Kroese	✓	✓		✓	
21	Mindfulness by Potential Project	✓	✓		✓	
22	Cleveland Clinic - Stress Free Now					
23	Mindfulness Trainer					

^aProgram-based practice

Table 3. Summary of mindfulness-based app features.

#	App	App community	Social Media	In-app Purchase	Cost
1	Headspace	✓	✓	✓	Free
2	Smiling Mind		✓		Free
3	iMindfulness			✓	\$2.49
4	Mindfulness Daily		✓	✓	Free
5	Buddhify 2			✓	\$3.79
6	Complete Mindfulness				\$2.49
7	Mindfulise				\$3.79
8	ACT Coach				Free
9	Rhythm Free		✓	✓	Free
10	Simply8		✓		\$3.79
11	Stop, Breathe & Think		✓		Free
12	Mindfully Me		✓		Free
13	The Meditation App with Michael Stone		✓		\$3.79
14	Meditation without borders		✓		\$5.99
15	Mindfulness Coach				Free
16	The Mindfulness App		✓	✓	\$2.49
17	Take a Chill		✓	✓	\$2.49
18	iMindfulness On The Go			✓	\$2.49
19	Personal Coach - Mindfulness				\$2.49
20	The Breathing Anchor - Andries J Kroese				\$2.49
21	Mindfulness by Potential Project				\$2.49
22	Cleveland Clinic - Stress Free Now				Free
23	Mindfulness Trainer				\$3.79

The majority of apps contained timers and provided reminders. Seven did not have a timer (ACT Coach, Complete Mindfulness, Stop, Breathe & Think, Meditation without Borders, MindKind Now, Cleveland Clinic - Stress Free Now, Mindfulness Trainer) and nine did not have reminders (ACT Coach, Buddhify 2, Cleveland Clinic - Stress Free Now, Complete Mindfulness, Meditation without Borders, Mindfulise, Mindfulness Trainer, MindKind Now, Stop, Breathe & Think).

Five apps provided progressive/program-based mindfulness training (Headspace, Smiling Mind, Mindfulness Daily, Simply8 and Meditation without Borders). Headspace provided free access to a 10-day program, Take 10, which has 10 guided meditation sessions of approximately 10 minutes each. Completing a session unlocked the next meditation track. Smiling Mind had a 10-week program for different age groups. The introductory session at the start of each week explored breath, sounds, tastes, etc. The user was advised to practice mindfulness and relevant take-home activities with the assistance of the app. Simply8 was a 3-week program with 8 minutes of guided meditation every day under the themes of calm, clear, and aware (focusing on one theme each week). Mindfulness Daily provided short mindfulness exercises for 21 days. The

user can also access guided meditations such as body scan, kindness, and awareness any time. Meditation without Borders was a 4-week program advising the users to practice guided meditations for at least 20 minutes per day.

While most apps provided exclusive texts and videos explaining the concepts of mindfulness, some apps relied on guided meditation tracks to educate the user. Take A Chill referred to relevant websites and did not provide much mindfulness education within the app. Few apps (eg ACT Coach, Complete Mindfulness) provided comprehensive text-based education. Headspace used video infographics to explain the concepts. Two of the apps (Mindfulness by Potential Project and iMindfulness) mentioned the 7 attitudes for mindfulness training, otherwise known as the essential pillars of Mindfulness-Based Stress Reduction (MBSR) practice [25].

Twelve apps provided an option to share the user's experience in social networks such as Facebook and Twitter (Headspace, Meditacious, Meditation without Borders, Mindfully Me, Mindfulness Daily, Rhythm Free, Simply8, Smiling Mind, Stop, Breathe & Think, Take A Chill, The Meditation App with Michael Stone, The Mindfulness App). Headspace and

Meditacious also had an app community. Eight apps provided in-app purchase that included additional guided meditation tracks (Take a Chill, iMindfulness On The Go, Headspace, Mindfulness Daily, The Mindfulness App, iMindfulness, Buddhify 2, and Rhythm Free, which also provided reminders)

Discussion

Principal Findings

Though the search for mindfulness apps identified 606 apps, excluding duplicates, only 23 provided mindfulness training. Timers, reminders, meditation, relaxation, or reference apps can assist in mindfulness practice, but categorizing them as mindfulness apps is inappropriate [26].

Mindfulness is much more than meditation, a breathing exercise, or a relaxation technique. Meditation is a practice that aids development of mindfulness [27,28]. Breathing is used as an exercise in the practice of mindfulness and relaxation can be an outcome. Contemplative practices (breathing, sitting, walking meditations), understanding emergent bodily and mental experiences, and withdrawing from habitual experiential avoidance form part of mindfulness training in mindfulness-based interventions such as MBSR and Mindfulness-Based Cognitive Therapy [29]. A mindfulness app should clearly explain the philosophy and practice of mindfulness and address common misconceptions. An app without mindfulness education may be beneficial if this information has been provided as part of face-to-face mindfulness training. However, a stand-alone mindfulness app should educate the user on mindfulness. All of the apps included in the review explain the concept of mindfulness at varying levels. Some (eg Headspace, Smiling Mind) employed interesting visual modes of explanation.

Mindfulness is a habit and a mind-training skill that requires regular practice and sustained effort to be effective [3,30-32]. This is a challenge for both face-to-face and app-based mindfulness training. Mindfulness apps provide 24/7 access to mindfulness-based practice. Interactive mobile applications and aesthetically pleasing and well-designed apps are likely to be more effective in engaging the user in regular mindfulness practice [33,34]. Headspace, Mindfulise, Buddhify 2 and Smiling Mind exceeded the minimum acceptable level score (3.0) on the MARS engagement subscale. These apps had high-quality graphics, simple and easy-to-use interfaces, and soothing voices for the guided meditation tracks. Headspace used short video infographics that complemented the guided meditation tracks. Unlike most apps that used a linear menu style, Buddhify 2 used an interesting collapsible circular menu to choose the meditation tracks. The low median score of the reviewed apps on the MARS engagement subscale, highlights the need to focus on engagement and motivation during the design process.

Participation in an app community can help motivate users to engage in healthy activities [35]. A supportive app community can help users share and discuss their mindfulness experiences and the challenges of regular practice. This could potentially

complement or substitute for the support provided in face-to-face mindfulness training. While nearly 50% of the reviewed apps provided social network sharing, only Headspace and Meditacious incorporated app community support. Research is required to determine the impact of sharing in social media and participating in a supportive app community on the frequency of mindfulness-based practice.

Assessing the quality of an app, especially a health intervention app, is an essential step before evaluating its efficacy [36]. The 23 mindfulness apps reviewed in this study had a median objective quality MARS score of 3.2. This suggests the apps had an overall acceptable level of quality. However, the low median engagement and moderate median aesthetics and information subscale scores highlight potential target areas for improvement.

Strengths and Limitations

This study is one of the first to review mindfulness-based mobile apps and evaluate their quality using a new multidimensional expert rating scale. The MARS provides a reliable measure of app quality on four objective subscales (engagement, functionality, visual aesthetics, information quality) and one subjective scale. Only the objective quality scales are included in the total app quality score. Expert ratings on 30% of the reviewed apps had a high level interrater reliability in the current study. However, while the MARS can be used to provide an evaluation of the quality of existing apps, this cannot replace the use of rigorous user-centered design and evidence-based practice in the design of health behavior apps.

The current review was limited to iPhone iOS apps, indicating future research is required to review and rate the quality of mindfulness apps developed for Android and other app platforms. Future research is also required to assess the quality of mindfulness training and individual guided meditation tracks contained in the apps, as there is currently no gold standard for how mindfulness is best conceptualized or practiced.

Future Research

mHealth is fast becoming an essential component of global health care [37]. The majority of mHealth apps developed to date have focused on physical health and lifestyle domains rather than mental health [38,39]. While an increasing number of mindfulness apps are being developed, the current evidence base is limited to one trial examining the efficacy of the Headspace app [23]. Future research is needed to determine and compare the efficacy of mindfulness apps in randomized controlled trials.

Conclusions

Only 4% of the 700 apps identified in our search provided mindfulness training and education. Though many apps claimed to be mindfulness apps, most of them were not. While the reviewed apps scored an acceptable median MARS score, very few scored high, indicating that the quality of the apps can be improved. The lack of evidence for the effectiveness of mindfulness apps needs to be addressed.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Mindfulness-based iPhone apps.

[[XLSX File \(Microsoft Excel File\), 80KB - mhealth_v3i3e82_app1.xlsx](#)]

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Review

Popular Glucose Tracking Apps and Use of mHealth by Latinos With Diabetes: Review

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Abstract

Background: Diabetes mellitus in the United States is an increasingly common chronic disease, costing hundreds of billions of dollars and contributing to hundreds of thousands of deaths each year. The prevalence of diabetes is over 50% higher in Latinos than in the general population, and this group also suffers from higher rates of complications and diabetes-related mortality than NHWs. mHealth is a promising new treatment modality for diabetes, though few smartphone apps have been designed specifically for Latinos.

Objective: The objectives of our study were: (1) to identify the most common features of the most popular diabetes apps and consider how such features may be improved to meet the needs of Latinos; (2) to determine the use of diabetes apps among a sample of online Hispanics in the US.

Methods: Our study consisted of two parts. First, 20 of the most popular diabetes apps were reviewed in order to ascertain the most prevalent features and functionalities. Second, an online survey was fielded through a popular health website for Latinos (HolaDoctor) inquiring about respondents' use of diabetes apps.

Results: Approximately one-third of apps reviewed were available in Spanish. The most common features were blood glucose recording/annotation and activity logs. The majority of apps permitted exportation of data via e-mail but only a third enabled uploading to an online account. Twenty percent of apps reviewed could connect directly with a glucometer, and 30% had reminder functionalities prompting patients to take medications or check blood glucose levels. Over 1600 online surveys were completed during the second half of April 2014. More than 90% of respondents were from the United States, including Puerto Rico. The majority of respondents used a device running on an Android platform while only a quarter used an iPhone. Use of diabetes apps was approximately 3% among diabetic respondents and 3.6% among diabetic respondents who also had a smartphone. Among app users, blood glucose and medication diaries were the most frequently used functionalities while hemoglobin A1c and insulin diaries were the least used. A significant majority of app users did not share their progress on social media though many of these were willing to share it with their doctor.

Conclusions: Latino diabetics have unique needs and this should be reflected in diabetes apps designed for this population. Existing research as well as our survey results suggest that many Latinos do not possess the prerequisite diabetes knowledge or self-awareness to fully benefit from the most prevalent functionalities offered by the most popular diabetes apps. We recommend developers incorporate more basic features such as diabetes education, reminders to check blood glucose levels or take medications, Spanish language interfaces, and glucometer connectivities, which are relatively underrepresented in the most popular diabetes apps currently available in Spanish.

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KEYWORDS

diabetes mellitus; mobile health; mobile applications; systematic review; Hispanic

Introduction

Diabetes Mellitus in the United States

Diabetes affects almost 26 million Americans—over 8% of the US population—and is the seventh leading cause of death in the United States [1]. Among Latinos, the proportion affected is approximately 11.8%, an almost 70% greater prevalence than in the general population [2]. According to the American Diabetes Association, the total cost of diabetes-related expenditures in 2012 was almost a quarter of a trillion dollars, translating to an average medical expenditure of almost \$14,000 per patient [3]. A major source of these expenditures is hospitalizations, which have been shown to cost more for patients who have diabetes [4]. According to 2011 data from California where over a third of the population is Hispanic [5], the average cost of a hospitalization for a patient with diabetes exceeded that of a nondiabetic patient by over \$2,000 [4]. Almost a third of all hospitalizations in California that year were for diabetic patients, a proportion which rose to over 40% among Latinos and was higher than that of African- or Asian-Americans [4].

Contributing to the problem is a lack of health literacy among Hispanics [6] which increases the risk of poor glycemic control [6]. Latinos have been shown to lag behind African-Americans and Whites in important health behaviors such as checking blood glucose levels, performing diabetic foot exams, and getting recommended vaccinations [7]. These findings are compounded by the feelings of many Latino patients that the care they receive from providers is frequently substandard [8] and problematic [9]. The number of Latino healthcare providers relative to the population is also small [10], and the resulting language challenges can lead to decreased patient compliance and worse outcomes [8]. Altogether, Latinos have worse glycemic control than the general diabetic population [11], are 60% more likely to start dialysis, and 50% more likely to die from diabetes than NHWs in the United States [12].

The Potential for mHealth

mHealth is a promising new treatment modality for diabetic patients that has been shown in studies to improve glycemic control [2,13,14]. It has also been found to be a potential source for cost savings and reduced burden on the health care system [15]. Though mHealth is broadly defined by the World Health Organization as “medical and public health practice supported by mobile devices” [16], the arrival of the smartphone in 2007 has caused an exponential proliferation of apps which have garnered increased attention among clinicians, researchers, and the federal government [17,18]. To date, there are few apps targeted specifically at Latinos with diabetes. This represents a missed opportunity, as over 90% of Latinos use a cell phone regularly - almost half of which are smartphones [19] - and they are just as likely as Whites to own a smartphone [20]. Given the challenges facing Latino diabetics with respect to health literacy and performance of health behaviors in the face of limited access to quality care, increased use of glucose tracking

apps could facilitate reductions in poor outcomes in this population.

Technology and the Latino Community

Evidence suggests that Latinos already have the capacity to use mobile technology to increase healthy behaviors. The Text4Baby Program, for example, involved the dissemination of text messages to pregnant women and mothers of newborns. A study by the National Latino Research Center revealed improvements in participants' health knowledge, appointment attendance, and immunization adherence. Satisfaction with this program was also found to be higher among Spanish speakers [21]. The TExT-MED (Trial to Examine Text Messaging for Emergency Department patient with Diabetes) study in Los Angeles involved a similar intervention in which text messages were sent to low income inner-city patients with diabetes, almost 75% of whom were Latino. Results included improvements in healthy eating, increased physical activity, and higher medication adherence [22]. These studies suggest that simple interventions can be accepted and lead to improvements in healthy behaviors in Latinos, including those with diabetes.

Despite these encouraging findings, there is little research into the use of glucose tracking apps by Latinos or on which app functionalities are the most pertinent to this population. Recommendations endorsing specific apps for Latinos have been put forth by various organizations [23,24] though these are not research-based. There is therefore an unmet need for scholarly research into how mobile phone technology can best benefit Latinos suffering from diabetes.

Goals of the Study

The goals of our study were twofold. First, we sought to identify the most prevalent functionalities of the most popular glucose tracking apps currently available. Second, we aimed to survey the usage of glucose tracking apps among Latinos visiting a popular Spanish language health website. In light of the challenges facing Latino diabetics, we attempted to set forth some basic guidelines for apps ideally suited to this population.

Methods

Overview

A systematic search strategy was used to select and review the most popular glucose tracking apps from official mobile phone stores. Each app was then examined and functionalities common to multiple apps were compiled into [Table 1](#). A survey inquiring into glucose tracking app usage was then posted on the HolaDoctor website for a total of three weeks, during which time 1601 surveys were completed.

Review of Glucose Tracking Apps

Overview

Searches for eligible apps on the iPhone and Android platforms were conducted on January 4th (Apple) and 5th (Android), 2014. A total of ten apps were selected from each platform (five free

and five paid). iPhone apps were selected by navigating to the Medical section of Apple's App Store and clicking the link "View Medical in iTunes" in the upper right hand corner. This required previous installation of iTunes on the computer's hard drive [25]. Android apps were selected in a similar fashion by locating the list of the top free and paid medical apps on the Google Play website [26]. The first five apps in each section meeting eligibility criteria were selected. Because some apps had versions available on both iPhone and Android platforms or had both free and paid versions listed in the search results, several of the selected apps had multiple versions reviewed. The authors felt this would not be redundant, however, as features of such apps were found to vary depending on platform and cost.

Eligibility Criteria

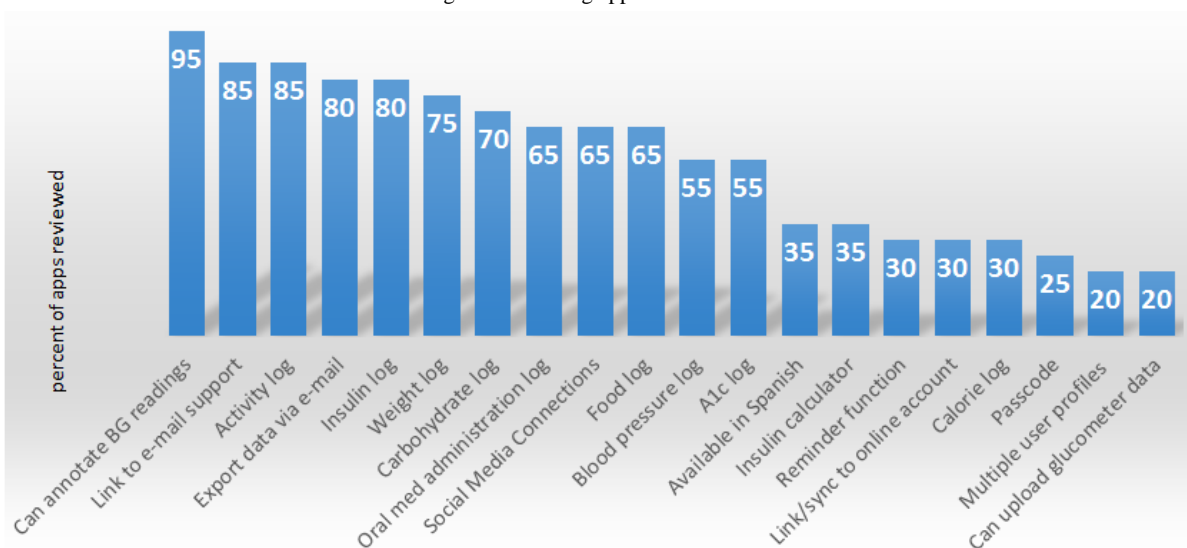
Apps were considered eligible if they could be found in the "medical" section of the Apple or Google Play stores and had the capacity to record and recall blood glucose measurements. All apps selected for review possessed additional functionalities (see [Multimedia Appendix 1](#)), though the quantity and

characteristics of these were not considered during the selection process.

Data Extraction

Reviews of all iPhone apps with the exception of Track3 by Coheso, Inc. were carried out on an iPod Touch running iOS version 6.1.5. Evaluation of the Track 3 app required a more recent version of iOS, thus an iPhone 4S running iOS version 7.0.4 was used. Reviews of Android apps were carried out with either a Nexus 4 running Android version 4.4.2 or a laptop running BlueStacks App Player for Windows (beta-1). App functionalities for all apps were investigated by author JW (see [Figure 3](#)). Product descriptions from the Apple App Store, Google Play website, or app developer websites were referenced as needed to clarify uncertainties. Apps were classified as being available in Spanish if either a change in the language setting of the mobile phone device from English to Spanish resulted in a meaningful change in the language of the app display or if the app itself had a language setting that included Spanish. Prices listed for each app were current as of January 4 (Apple App Store) or January 5 (Google Play website), 2014.

Figure 3. Prevalence of functionalities found in selected glucose tracking apps.



Online Survey

An online survey was posted on the HolaDoctor website [1] from April 15 to May 1, 2014 (see [Multimedia Appendix 1](#)). HolaDoctor's website, also available through Univision.com as *Univision Salud con HolaDoctor*, is the most frequently visited Spanish language health website on the Internet, with over 3.5 million monthly unique visitors, of which over 1 million reside in the US. Over half of HolaDoctor's traffic access the website through mobile devices. The survey was available only in Spanish. Questions explored respondents' diabetes status as well as use of mobile phones and glucose tracking apps. A total of 1161 surveys were completed over an initial 17 day period. After several user comments reported unfamiliarity with the term "app," a second survey using clarifying language was posted from May 12 to May 19, 2014. This resulted in the completion of an additional 440 surveys for a total of 1601 surveys. Summary data can be found in [Table 1](#).

Results

Review of Glucose Tracking Apps

Overview

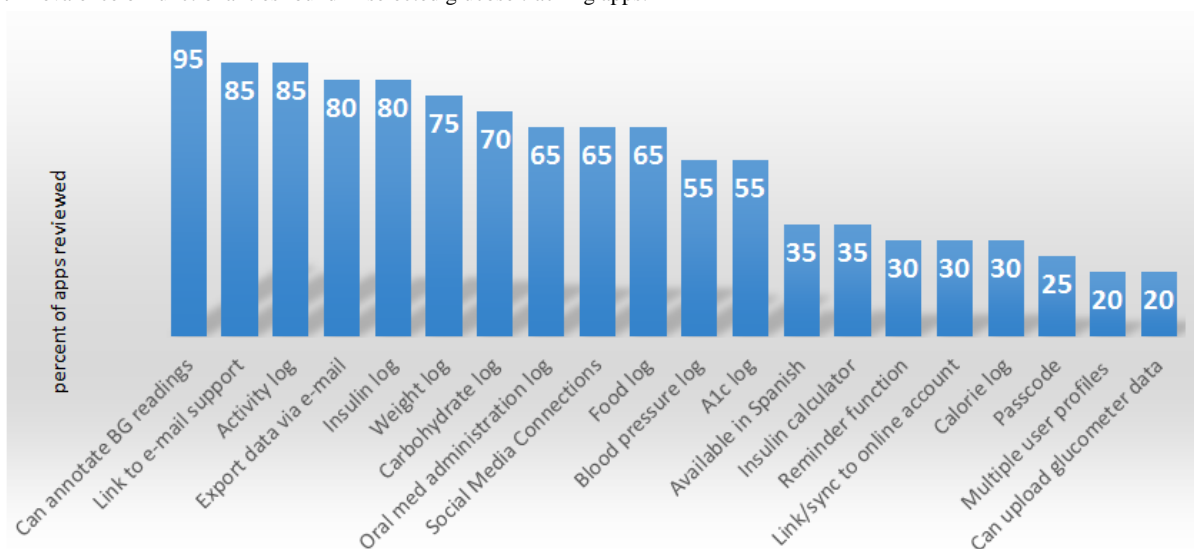
Samples of the results of the app review can be found in [Figure 1](#), [Figure 2](#), and in [Multimedia Appendix 1](#). A total of 20 apps were reviewed, though some apps were reviewed multiple times as described in the Methods section. It should be noted that while the ability to record and recall blood glucose measurements was the primary selection criterion, analytical capabilities such as calculations of averages and creations of figures including graphs and flow sheets invariably accompanied this functionality. Thirty five percent of all apps reviewed were available in Spanish (20% of iPhone apps and 50% of Android apps). The ability to annotate blood glucose readings was the most common feature, while pass codes and the capacity for

multiple user profiles were the least common. Only 20% of apps could download data directly from glucometers.

Figure 1. Screenshot of Diabetes App Lite by BHI Technologies, Inc. <https://itunes.apple.com/us/app/diabetes-app-lite-blood-sugar/id387337850?mt=8>.



Figure 2. Prevalence of functionalities found in selected glucose tracking apps.



Price

The price of apps ranged from free up to ten dollars with the average price of paid apps being approximately \$5.03. The average price for iPhone apps (\$6.39) was higher than that for Android apps (\$3.66).

Documentation Functionalities

Activity logs (85%) were the most prevalent documentation functionality followed by insulin logs (80%), weight logs (75%), and carbohydrate logs (70%). While 80% of the apps reviewed included insulin administration logs, only 65% included logs for oral or injectable noninsulin medications. Carbohydrate and

food logs (70% and 65%, respectively) were featured more often than calorie logs (30%).

Information Sharing

Data export via e-mail was present on 80% of apps while social media connections were featured on 65%. Fewer than a third of apps allowed users to upload their data to online app-sponsored accounts.

Glucometer Connectivity

Twenty percent of apps permitted download of blood glucose measurements from a glucometer. The prevalence of this functionality was equal for both Apple and Android apps.

Online Survey

Diabetes Demographics

Table 1 shows the results of the online survey. A total of 1601 surveys were completed. 68.9% (1103/1601) of responses came from the continental United States and 22.0% (353/1601) came from Puerto Rico. 2.9% (46/1601) were from Mexico, while 3.4% of respondents (54/1601) marked “unknown.” 36.7% of respondents (588/1601) reported a history of diabetes, and 17.2% (276/1601) reported caring for a family member with the disease. Among those who reported a personal history of diabetes, nearly 13% (74/588) reported having type I, while 69% (408/588) reported having type II, and 18% did not know which type of diabetes they had. Among those reporting type I diabetes, fewer than half (29/74) reported taking insulin.

Table 1. Survey results, all respondents (n=1601).

General characteristics	Number (%)
Country	
United States	1103 (68.89)
Puerto Rico	353 (22.05)
Mexico	46 (2.87)
Other ^a	45 (2.81)
Unknown	54 (3.37)
Do you have diabetes?	
Yes	588 (36.73)
No	491 (30.67)
I don't know	246 (15.37)
I take care of a family member with diabetes	276 (17.24)
Mobile phone platform	
Android	815 (50.91)
iOS	415 (25.92)
Blackberry	17 (1.06)
Do not have mobile phone	354 (22.11)

^aCountries in this category included Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Nicaragua, Panama, Peru, Spain, Switzerland, and Venezuela

Mobile Phone Usage and Glucose Tracking App Usage

77.8% of respondents (1,247/1601) reported using a mobile phone. Approximately 65% (815/1247) of these used Android devices while 33.3% (415/1247) used an iPhone; seventeen respondents used a Blackberry. Roughly 2% (33/1601) of all respondents reported using a glucose tracking app; this increased to 3% (18/588) among diabetics and 3.6% (16/449) among respondents with both a history of diabetes and mobile phone use. Among diabetics who used apps, about half (n=10) used them in Spanish while about a quarter (n=4) used them in

English. Almost a quarter of respondents reported not knowing in which language they used the app.

Cost

Nearly half of glucose tracking app users downloaded free apps. This proportion increased to 61.5% (8/13) when excluding respondents unable to recall the price of their app. Conversely, 38.4% of respondents (5/13) able to recall the price of the app paid money for it. Of these five respondents, three of them paid three dollars or more.

Table 2. Survey results among patients reporting a history of diabetes (n=588).

General characteristics	Number (%)
Country	
United States	415 (70.6)
Puerto Rico	133 (22.6)
Mexico	15 (2.6)
Other ^a	8 (1.4)
Unknown	17 (2.9)
Diabetes type	
Type I	74 (12.6)
Type II	408 (69.4)
Don't know	106 (18.0)
Do you use insulin?	
Yes	161 (27.4)
No	427 (72.6)
Do you use insulin? (type I only, n=74)	
Yes	29 (39.2)
No	45 (60.8)
Do you use insulin? (type II only, n=408)	
Yes	111 (27.2)
No	297 (72.8)
Do you use a diabetes app?	
Yes	18 (3.1)
No	570 (96.9)

^aCountries in this category included Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Nicaragua, Panama, Peru, Spain, Switzerland, and Venezuela

Documentation and Reminder Functionalities

Tracking of oral medications was the most popular documentation functionality, with 50% of respondents expressing approval (9/18), followed by 44% endorsing blood glucose monitoring (8/18). Exercise tracking, with 22% endorsement (4/18) was featured less often than dietary monitoring of carbohydrates or calories consumed, at 33% (6/18). Insulin and A1c tracking were the least commonly utilized documentation functionalities, at 17% each (3/18). 50%

and 44% of respondents (9/19 and 8/18 respectively) reported frequent use of reminders to check blood glucose or take medications.

Information Sharing

The majority of respondents (83%) either kept their data private or shared it only with their doctor. The remaining 17% shared information about their diabetes on social media outlets such as Facebook, Twitter, or diabetes forums.

Table 3. Characteristics of app usage among diabetic respondents reporting use of diabetes apps (n=18).

General characteristics	Number (%)
Language in which app is used	
English	4 (22)
Spanish	10 (56)
I don't know	4 (22)
How much did you pay for the app?	
Free	8 (44)
\$0.99	1 (6)
\$2.99	1 (6)
More than \$3.00	3 (17)
I don't remember	5 (28)
Proportion of respondents reporting frequent use of the following documentation functionalities	
Oral medications	9 (50)
Blood glucose	8 (44)
Blood pressure	6 (33)
Diet-related	6 (33)
Weight	5 (28)
Exercise	4 (22)
A1c	3 (17)
Insulin	3 (17)
None of these	4 (22)
Proportion of respondents reporting frequent use of the following reminder features	
Reminder to check blood glucose	9 (50)
Reminder to take medications	8 (44)
None	4 (22)
Information sharing	
Shares with physician only	10 (56)
Does not share with anyone	5 (28)
Diabetes forums	2 (11)
Facebook	1 (6)
Twitter	1 (6)

Discussion

Summary of Study

In this study, we set out to characterize the most prevalent functionalities for popular glucose tracking apps and survey Latinos on their use of these apps. We went about this task by selecting and reviewing 20 of the most popular glucose tracking apps on the market as of January, 2014 and posting an online survey on one of the most popular Spanish language health websites on the Internet. In our app review we found blood glucose analytical instruments (eg graphs, flow sheets, statistics) to be the most prevalent functionalities. These were frequently accompanied by documentation of dietary and biometric data as well as functionalities enabling users to share data on social

media. In contrast, a minority of apps were available in Spanish, contained reminder functionalities encouraging adherence to blood glucose monitoring and medication regimens, or allowed download of data directly from glucometers.

Our online survey found that approximately three percent of respondents with diabetes used a glucose tracking app, a proportion that is higher than the estimated global average of 1.2% [27]. Of these, the number of respondents running their apps on Android products was nearly double the number of those running their apps on Apple products. Most of the apps used were free to download. Fifteen percent of respondents reported not knowing their diabetes status and fewer than half of self-reported type I diabetics reported using insulin. These findings support the findings from other studies [6,28-30] that

there is a lack of diabetes knowledge and awareness among Latinos.

Comparison With the Literature

At least three studies have been completed on the prevalence of various glucose tracking app functionalities using systematic search strategies [31-33]. Two of the studies reviewed apps limited to one platform. The 2011 article by Chomutare et al [31] is the only study of the three to consider both major platforms, reviewing 49 iPhone apps and 33 Android apps. In comparison with this 2011 review, we found a significantly greater prevalence of multiple functionalities including medication management, diet management, physical activity monitoring, and disease-related reminders. The starkest contrast between the earlier review and ours was the prevalence of social media. Only 15% of apps had social media functionalities in the 2011 review versus 65% of apps in our review. This contrast most likely reflects the growing role of social media in daily life [34].

A limited number of studies have evaluated glucose tracking app use in a specific segment of the population. An article by Arnhold et al [35] studied the usability of glucose tracking apps among patients ages 50 years and older. Our study, while not providing empirical evidence as to which app functionalities work best for a specific subgroup, agrees with Arnhold et al's finding that there is a need for further investigation into how mobile phone apps can be tailored to specific target audiences.

How Glucose Tracking Apps Designed for Latinos Should be Different

Overview

Latinos lag behind NHWs in levels of health literacy, which in turn has been shown to affect glycemic control [6]. This population also tends to have worse self-management practices [36], including lower levels of physical activity and inconsistent self-monitoring of blood glucose [37]. Glucose tracking apps should address these disparities in knowledge and practice using carefully selected functionalities tailored to this population.

Education

Education has been shown to be an underrepresented feature of most glucose tracking apps [31] but should be included in apps for Latinos considering both the lower overall levels of educational attainment of Latinos relative to NHWs [38] as well as the findings of our survey. Content should be provided at a basic reading level and available in both English and Spanish. In addition, audio or video-based educational materials could complement text, as they may help bypass literacy barriers and would likely be well accepted among Latinos who are already major consumers of online multimedia [19].

Self-Management Functionalities

Self-management functionalities focusing on blood glucose monitoring, diet, and exercise should be easy to use and motivational. The number of functionalities on a single app should be kept to the minimum necessary to encourage consistency without decreasing usability [32]. Self-management practices can be encouraged by minimizing the burden of data

entry and by employing reminders (eg to check blood glucose or take medication) to minimize unintentional nonadherence [39,40].

Data Entry Burden

Data entry burden can be reduced through the use of simplified graphic interfaces with adjustable text and icon sizes for elderly or visually impaired users [41] as well as glucometer connectivity. Glucometer connectivity is currently lacking in most popular apps according to our study which found that only 20% of the apps reviewed had this capacity.

Reminders

Reminder functionalities were available in fewer than third of the apps reviewed, though our survey found that the majority of app users surveyed used reminders regularly. Automated reminders can serve several functions, not the least of which could include boosting medication adherence and self-monitoring of blood glucose. Periodic reminders for feet exams, physician visits, and yearly flu vaccines can also be incorporated. Besides conveying instructions, reminders can be educational and/or motivational in a manner similar to the text message interventions used in the Text4Baby and TExT-MED programs. App content should always be culturally appropriate [42] and mindful of social determinants of health as well as the social and cultural heterogeneity within the Latino population itself [43].

Limitations of the Study

Our app review included only a small fraction of the glucose tracking apps available for download on the iTunes app store and Google Play. Methods used to select apps were subject to proprietary ranking algorithms by Apple and Google and thus the apps reviewed may not represent those of the highest quality as judged by more impartial measures such as third party ratings. To these authors' knowledge, however, no such rating system exists for glucose tracking apps. Nevertheless, there may have been apps of high quality that were not reviewed.

For the survey portion of the study, respondents on the HolaDoctor website constituted a convenience sample which may not reflect the entire Hispanic population. With its very large visitor base of over 1 million monthly unique users, the HolaDoctor website does, however, fairly represent the *online* Hispanics in the United States. Furthermore, evidence suggests that the majority of Latinos in the United States already use the internet in some fashion [44]. Nevertheless, this does largely exclude the elderly, those with less than a high school education, and those who are predominantly Spanish speaking [44], groups who shoulder a significant proportion of the diabetes burden within the Latino population as a whole. Given that 17% of the respondents in our survey reported providing care for a family member with diabetes, however, it is possible that the benefits of diabetes apps may extend beyond the immediate user to family members, specifically the elderly. Respondents living in countries other than the United States were also permitted to complete surveys, and this may affect the generalizability of the study's conclusions given the inherent variation in social, cultural, and economic conditions between countries. The effect of this variation is likely to be minor, however, as the vast

majority of responses (93%) came from the continental United States or Puerto Rico.

Finally, a number of the online surveys contained internally inconsistent responses. In particular, fewer than half of type I diabetics reported using insulin. Such incongruous responses may be due to respondents' confusion with the survey questions, though the authors suspect it stems more from a lack of knowledge and awareness regarding what type of diabetes they have, if any.

Conclusion

There is a significant need for diabetes apps targeted at Latinos. Given the high prevalence of diabetes in the Latino population and the CDC estimating a 50% lifetime diabetes risk for Latino children born in the year 2000 [45], apps designed specifically for this population will be needed to realize the full potential of mHealth to improve the lives of those affected by this disease.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Review of selected glucose tracking apps.

[[PNG File, 79KB - mhealth_v3i3e84_app1.png](#)]

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Abbreviations

A1c: glycosylated hemoglobin

iOS: iPhone operating system

mHealth: mobile health

NHW: non-Hispanic White

TEXT-MED: trial to examine text messaging for emergency department patient with diabetes

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Original Paper

A Framework to Assist Health Professionals in Recommending High-Quality Apps for Supporting Chronic Disease Self-Management: Illustrative Assessment of Type 2 Diabetes Apps

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Abstract

Background: This paper presents an approach to assist health professionals in recommending high quality apps for supporting chronic disease self-management. Most app reviews focus on popularity, aesthetics, functionality, usability, and information quality. There is no doubt these factors are important in selecting trustworthy apps which are appealing to users, but behavioral theory may be also be useful in matching the apps to user needs.

Objective: The framework developed aims to be methodologically sound, capable of selecting popular apps which include content covered by evidence-based programs, consistent with behavioral theory, as well as a patient-centered approach for matching apps to patients' individual needs.

Methods: A single disease—type 2 diabetes—was selected to illustrate how the framework can be applied as this was deemed to represent the types of strategies used in many chronic diseases. A systematic approach based on behavioral theory and recommendations from best practice guidelines was developed for matching apps to patients' needs. In March 2014, a series of search strategies was used to identify top-rated iPhone and Android health apps, representing 29 topics from five categories of type 2 diabetes self-management strategies. The topics were chosen from published international guidelines for the management of diabetes. The senior author (KH) assessed the most popular apps found that addressed these topics using the Behavioral Theory Content Survey (BTS), which is based on traditional behavioral theory. A tool to assist decision making when using apps was developed and trialed with health professionals for ease of use and understanding.

Results: A total of 14 apps were assessed representing all five topic categories of self-management. Total theoretical scores (BTS scores) were less than 50 on a 100-point scale for all apps. Each app scored less than 50% of the total possible BTS score for all four behavioral theories and for most of the 20 behavioral strategies; however, apps scored higher than 50% of the total possible BTS score for specific strategies related to their primary focus. Our findings suggest that the apps studied would be more effective when used in conjunction with therapy than as stand-alone apps. Apps were categorized according to topic and core intervention strategies. A framework for matching apps to identified patient needs was developed based on app categorization and principles of patient-centered care. The approach was well accepted and understood by a convenience sample of health practitioners.

Conclusions: The framework presented can be used by health practitioners to better match apps with client needs. Some apps incorporate highly interactive strategies of behavioral theory, and when used as an adjunct may increase patient participation and the effectiveness of therapy.

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KEYWORDS

mobile apps; chronic disease; patient-centered care; technology

Introduction

Chronic disease is Australia's biggest health challenge, accounting for 90% of all deaths in 2011 [1]. These diseases are prolonged in duration, do not often resolve spontaneously, and are rarely cured completely [1]. They are typically associated with lifestyle choices; therefore, for treatment to be effective, patients need to be willing and able to manage their own condition on a daily basis.

Self-management is now considered the appropriate strategy for chronic diseases where lifestyle is critical to management. Traditionally, health professionals have delivered chronic disease self-management (CDSM) interventions to individuals in one-on-one or group situations. Studies have found conventional interventions are most effective when delivered using a patient-centered approach, over long periods, with short follow-up, and regular reinforcement [2]. Unfortunately, these interventions are expensive to implement and difficult to sustain in the primary care setting. Less intensive interventions are needed, and mobile technologies may be helpful as they are affordable and practical. Furthermore, mobile technologies promote increased patient participation which is an essential component of CDSM.

Australians own more advanced-feature mobile phones and have downloaded more apps than many other developed countries. In 2013, 64% of the Australian population owned an advance-feature mobile phone and the average user has 33 apps installed [3]. App use will increase as it is predicted that 91% of the population will own an advanced-feature mobile phone by 2017 [3]. Although app research is limited, many studies have found significant improvements in chronic disease outcomes using mobile interventions [4,5]. Most of the interventions used simple technologies such as short message service (SMS) text messaging for self-monitoring and automated feedback; mobile apps are more sophisticated with real-time, graphic feedback and social functionality.

Due to their popularity, portability, connectivity, and increasing sophistication, apps are an ideal platform for influencing behavior. Despite this, users receive little guidance and support in selecting health apps. Health apps do not require approval from the Therapeutic Goods Administration (TGA) or any other body in Australia to our knowledge. There is a general lack of trust among health professionals in the quality of apps, as many are developed by businesses for commercial gain. A small

number of professional organizations recommend apps based on the authenticity of content, user engagement, and aesthetics. While there is no doubt these factors are important in selecting trustworthy apps which are appealing to users, they do not define what apps do or how they can be used to assist in changing behavior.

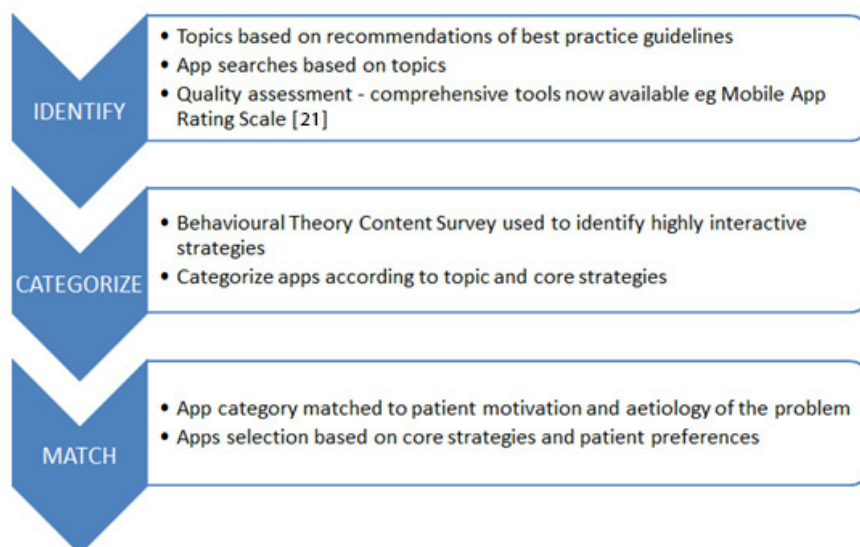
Current broad international diabetes guidelines recommend interventions be based on behavioral theory [6,7,8]. Behaviorally focused interventions that include interactive strategies have the greatest impact on metabolic and diabetes self-care outcomes [9]. Furthermore, behavioral theories provide a systematic way of explaining and predicting behavior. Social cognitive models have been used as a framework for assessing the behavioral theory content of lifestyle interventions [10,11]. The Behavioral Theory Content Survey (BTS) is a validated tool [10,12] which has been shown to have substantial interrater agreement in assessing mobile apps [12]. It assesses the inclusion and interactivity of 20 intervention strategies which are shared by four key models/theories: (1) Health Belief Model, (2) Theory of Planned Behavior, (3) Transtheoretical Model, and (4) Social Cognitive Theory. While studies have found mobile apps are not usually based on behavioral theory [10,12], many incorporate highly interactive strategies which may support therapy.

This paper presents an approach to assist health professionals in recommending high-quality apps for supporting chronic disease self-management. The framework developed aims to be methodologically sound, capable of selecting popular apps which include content covered by evidence-based programs and consistent with behavioral theory, and a patient-centered approach for matching apps to patients' individual needs. A single disease—type 2 diabetes—was selected to illustrate how the framework can be applied as this was deemed to represent the types of strategies used in most chronic diseases.

Methods

Framework

We used a three-step process for selecting, categorizing, and matching apps to patients' needs (see [Figure 1](#)): (1) identification of popular, high-quality apps which include content covered by evidence-based programs, (2) categorization of apps based on topics and core intervention strategies, and (3) a patient-centered approach for matching apps to patients' needs.

Figure 1. Framework for selecting, categorizing, and matching apps to patients' needs.

App Identification

Using type 2 diabetes as an example in adopting the framework, our aim was to identify popular, high-quality health apps which are consistent with type 2 diabetes evidence-based guidelines.

Apps were selected based on 29 topics identified from the following: (1) patient education topics recommended in the Canadian Diabetes Association 2013 Clinical Practice Guidelines for the Prevention and Management of Diabetes [6] and (2) the seven self-management behaviors identified by the American Association of Diabetes Educators [13]. The topics were grouped into five categories: (1) healthy eating, (2) physical activity, (3) self-monitoring, (4) problem solving, and (5) healthy coping.

A series of search strategies were used to identify eligible health apps available in the Apple App Store and Google Play in March 2014. The apps were first identified from extensive searches of the Apple App Store as it contains the largest number of health apps [14]. Availability was then cross-checked in Google Play. App descriptions and information provided by the Apple App Store were used in the initial screening process. Apps were downloaded to an iPhone and fully explored before selection.

First a search of "Top 200 Free" and "Top 200 Grossing" general and health apps in the Apple App Store was conducted to identify the most downloaded free health apps and the paid health apps generating the most revenue. This was followed by

a broad search using the keyword "diabetes." More refined keyword searches followed using keywords specific to topics where less than four apps had been identified in the broader searches including "GI" (glycemic index), "glycemic index," "relaxation," "confidence," and "CBT" (cognitive behavioral therapy). Each selected app was then individually searched in the Google Play Store. Only free and low-cost (ie, less than AUD \$5) apps were selected from refined searches as they dominate app purchases [15].

Apps were selected based on the following inclusion criteria: (1) consistent with the 29 app topics, (2) less than AUD \$5, and (3) written in English. Apps were excluded if they (1) did not support the International System of Units (SI) of measurements, (2) required extra components to function, (3) were designed specifically for children, (4) did not describe how food databases were compiled, (5) were designed specifically for type 1 diabetes, (6) marketed specific products, and/or (7) contained information that was assessed as inaccurate, biased, or unsafe.

App Categorization

The apps were grouped according to topic and core intervention strategies. The primary author (KH), having a special interest in health behavior theory, identified the core intervention strategies of each app using the Behaviour Theory Content Survey (see Table 1) [16]. A copy of the evaluation template can be obtained by request from Doshi et al [16].

Table 1. Behavioral Theory Content Survey^a: intervention strategies by behavior change model or theory.

Strategy No.	Intervention strategies ^b	Health Belief Model	Transtheoretical Model	Theory of Planned Behavior	Social Cognitive Theory
1	General information (K)	X	X	X	X
2	Perceived benefits (C)	X	X	X	X
3	Perceived barriers (C)	X	X		X
4	Perceived risks (C)	X		X	
5	Self-efficacy (C)		X	X	X
6	Self-talk (C)		X		X
7	Perceived social norms (C)		X	X	
8	Self-monitoring (B)		X		X
9	Realistic goal setting (B)				X
10	Time management (B)				X
11	Stimulus control (B)		X		X
12	Self-reward (B)		X		X
13	Social support (B)		X		X
14	Modeling/vicarious learning (B)				X
15	Relapse prevention (B)		X		X
16	Stress management (EF)				X
17	Negative affect management (EF)				X
18	Skill building/overview (T)		X		X
19	Increasing knowledge (T)	X	X	X	
20	Motivational readiness (T)		X		
	No. strategies per model/theory	5	14	6	16

^aWith kind permission from Springer Science+Business Media: < Ann Behav Med, Evaluation of physical activity web sites for use of behavior change theories, volume 25, 2003, p107, Doshi A, Patrick K, Sallis JF, et al, [Table 1](#)> [16].

^bKnowledge (K), cognitive (C), behavioral (B), emotion focused (EF), therapeutic (T).

The Behavior Theory Content Survey [16] assesses interventions for the use of 20 strategies (see [Table 1](#)) shared by four key behavioral models/theories: (1) Health Belief Model, (2) Theory of Planned Behavior, (3) Transtheoretical Model, and (4) Social Cognitive Theory. The strategies are listed individually as they are common to more than one theory. Each intervention strategy is scored out of 5 as it is rated dichotomously for the inclusion of the following five dimensions of user interaction: (1) provides general information or guidelines, (2) assesses current practices or use of strategies, (3) provides feedback on assessment, (4) offers general assistance on behavior change, and (5) offers individually tailored assistance in response to assessment and feedback. The levels are hierarchical as level 5 (individual advice) is thought to be more effective than level 1 (providing general information). The BTS is the sum of scores for all 20 intervention strategies; the maximum BTS score is 100, representing 20 strategies, each of which are scored out of 5 to indicate the level of interactivity.

Matching Apps to Patients' Needs

Health practitioners work with patients (within consultations) to identify core problems and root causes or etiology of problems. Using a patient-centered approach, conventional

interventions are usually selected based on problem etiology and patient motivation. We propose that in step 1 apps be selected using the same process, as they are simply another intervention and should complement other therapies. In step 2, the apps are grouped together according to topic and core intervention strategy. Presenting these categories in a table can aid health practitioners in matching apps to the patient's needs. The primary author (KH) tested the process within dietetic consultations in a primary care setting to determine its usefulness. Next, the tool was further developed based on feedback from a convenience sample of experienced health professionals teaching and examining nutrition therapy.

Results

App Identification

Only 4 health apps were recovered from the top 200 free and grossing app searches but they were not specific to diabetes; for example, 2 were exercise apps and 2 were diet-focused apps. Out of the 4 health apps, only 1—clean eating diet app—was ranked in the top 100, and only 2 health apps—exercise apps—met the inclusion criteria.

The most popular free health apps were diet and physical activity apps, and the paid apps generating the most revenue were physical activity and relaxation/meditation apps. The 53 apps which met the eligibility criteria were general diet, physical activity, and relaxation apps. There were no diabetes-specific apps identified in the top or grossing Apple App Store and health app searches.

The 919 apps recovered using the "diabetes" keyword search were a mixture of free and paid apps, including diabetes-specific and general apps. A total of 37 apps met the inclusion criteria and these included diabetes goal-setting, general diet, and general physical activity tracker apps. Fewer than 4 apps were identified from all searches for the topic areas relating to diabetes-specific healthy eating, problem solving, and healthy coping.

An additional 3 apps were recovered using the refined keyword searches, including 2 relaxation apps and 1 CBT app. The search strategies did not recover any eligible diabetes-specific diet apps.

A total of 68 apps were excluded as they were not available on Google Play. A total of 27 apps were available for both iPhone and Android platforms.

App Categorization

App Topics

Apps were identified for all five topics (see [Table 2](#)). General apps were relevant to, and could be grouped into, more than one topic. A wider variety of apps were identified for healthy eating and physical activity than for other topic areas.

Table 2. Categorization of app types by topic.

Topic categories	App types
Healthy eating	Diet tracker
	Food selection
	Menu planning
	Diabetes-specific goal trackers
	General goal tracker
	Coaching
	Cognitive behavioral therapy
Physical activity	Exercise trackers
	Resistance exercise
	Diabetes-specific goal trackers
	General goal tracker
	Cognitive behavioral therapy
Self-monitoring	Diabetes tracker
	Expert support
Problem solving	Coaching
	Peer support
Healthy coping	Cognitive behavioral therapy
	Peer support
	Relaxation

Behavioral Theory Content Analysis

Similar apps were grouped together, and only the results for the highest-scoring app for each of the 14 app types are reported in [Table 3](#).

Table 3. Total Behavioral Theory Survey score and individual component scores of those apps scoring best in type.

App type	Therapy/model scores ^a				Strategy category scores					Total BTS scores ^b
	HBM ^c	TTM ^d	TPB ^e	SCT ^f	K ^g	C ^h	B ⁱ	EF ^j	T ^k	
General goals	3	21	7	29	3	4	22	0	2	31
Exercise tracker	2	21	6	26	1	4	20	1	3	29
Diabetes goals	5	21	9	24	2	5	17	0	5	29
Diet tracker	7	19	9	19	3	5	10	2	5	25
Cognitive behavioral therapy	5	18	6	23	1	10	5	4	4	24
Resistance exercise	7	16	8	19	2	5	10	1	5	23
Mindfulness	4	14	5	21	1	5	7	6	3	22
Coaching	7	17	5	20	2	7	7	2	3	21
Menu planning	4	13	4	18	1	3	12	0	3	19
Peer support	2	9	5	12	0	4	9	2	1	16
Expert support	2	12	3	14	1	1	9	1	3	15
Food choice	7	11	8	9	4	2	1	0	4	11
Diabetes tracker	0	9	3	9	0	3	8	0	0	11
Relaxation	1	4	2	9	0	1	1	5	3	10
Mean score (SD)	4.0 (2.4)	14.6 (5.3)	5.7 (2.3)	18.0 (6.5)	1.5 (1.2)	4.2 (2.4)	9.9 (6.2)	1.7 (2.0)	3.1 (1.5)	20.4 (7.0)

^aScores do not add up to 100 as the 20 strategies can map to more than one model/theory.

^bThe Behavioral Theory Survey (BTS) score only counts each strategy once and therefore is the sum of the strategy categories; maximum BTS score is 100.

^cHealth Belief Model (HBM); maximum score is 25.

^dTranstheoretical Model (TTM); maximum score is 70.

^eTheory of Planned Behavior (TPB); maximum score is 30.

^fSocial Cognitive Theory (SCT); maximum score is 80.

^gKnowledge (K); maximum score is 5.

^hCognitive (C); maximum score is 30.

ⁱBehavioral (B); maximum score is 40.

^jEmotion focused (EF); maximum score is 10.

^kTherapeutic (T); maximum score is 15.

App Scores

The total BTS scores are shown in the last column of [Table 3](#). The mean total BTS score was 20.4 (SD 7.0) out of 100. Apps more often included behavioral (mean 9.9/40, SD 6.2) and knowledge strategies (mean 1.5/5, SD 1.2), and less often used cognitive (mean 4.2/30, SD 2.4) and emotion-focused strategies (mean 1.7/10, SD 2.0). Mean scores for all behavioral models/theories were less than 25% of the total possible scores;

scores were highest for Social Cognitive Theory (mean 18.0/80, SD 6.5).

Most apps (11/14, 79%) incorporated more than 50% of the different intervention strategies, but within each strategy, scores were generally less than 2 out of 5. However, all apps included at least one strategy (mean 2.3, SD 1.1) that scored higher than 2 out of 5. Highly interactive intervention strategies, including self-monitoring, social support, modelling/vicarious learning, and stimulus control, were those most commonly included (see [Table 4](#)).

Table 4. Intervention strategy distribution by all apps.

Intervention strategy	Intervention category	Apps using strategy, n	Apps with BTS ^a >2/5 ^b , n
Self-monitoring	Behavioral	12	6
Skill building/overview	Therapeutic	12	2
Social support	Behavioral	10	4
Modeling/vicarious learning	Behavioral	10	5
General information	Knowledge	11	3
Stimulus control	Behavioral	11	5
Realistic goal setting	Behavioral	10	2
Self-efficacy	Cognitive	14	0
Increasing knowledge	Therapeutic	11	1
Negative affect management	Emotion focused	9	2
Perceived social norms	Cognitive	7	0
Perceived barriers	Cognitive	6	1
Time management	Behavioral	6	1
Stress management	Emotion focused	5	2
Self-talk	Cognitive	2	1
Perceived benefits	Cognitive	6	1
Perceived risks	Cognitive	5	0
Self-reward	Behavioral	3	0
Relapse prevention	Behavioral	2	0
Motivational readiness	Therapeutic	1	0

^aBehavioral Theory Survey (BTS).

^bNumber of apps that scored >2 out of 5 for the intervention strategy. A score above 2 indicates tailored advice or assistance.

Matching Apps to Patients' Needs

Table 5 shows how app categorization can be used to assist practitioners in matching apps to patients' needs.

Table 5. Matching apps using type 2 diabetes as an example.

Topic and intervention category: selection based on problem etiology and patient motivation identified during usual practice		App type and core intervention strategies: selection based on patient preference identified during usual practice	
Topic category	Intervention category	App type	Core intervention strategies ^a
Healthy eating	Knowledge	Diet tracker	General knowledge
		Food selection	General knowledge
	Cognitive	Coaching	Perceived barriers
		Cognitive behavioral therapy	Self-talk
	Behavioral	Diet tracker	Self-monitoring
		General goal tracker	Self-monitoring
			Realistic goal setting
			Social support
			Modeling/vicarious learning
			Menu planning
Physical activity		Diabetes-specific goal tracker	Self-monitoring
			Realistic goal setting
			Social support
			Modeling/vicarious learning
		Coaching	Stimulus control
	Emotion focused	Cognitive behavioral therapy	Negative affect management
	Cognitive	Cognitive behavioral therapy	Self-talk
	Behavioral	Exercise tracker	Self-monitoring
			Social support
			Modeling/vicarious learning
		Resistance exercise	Self-monitoring
			Modelling/vicarious learning
		Diabetes-specific goal tracker	Self-monitoring
Self-monitoring			Realistic goal setting
			Social support
			Modeling/vicarious learning
		General goal tracker	Self-monitoring
			Realistic goal setting
			Social support
Problem solving	Emotion focused	Cognitive behavioral therapy	Negative affect management
	Therapeutic	Resistance exercise	Skill building/overview
	Behavioral	Diabetes tracker	Self-monitoring
Healthy coping		Expert support	Stimulus control
	Cognitive	Coaching	Perceived barriers
	Behavioral	Peer support	Social support
			Modeling/vicarious learning
		Coaching	Stimulus control
	Cognitive	Cognitive behavioral therapy	Self-talk
	Behavioral	Peer support	Social support
			Modeling/vicarious learning
		Mindfulness	Stimulus control

Topic and intervention category: selection based on problem etiology and patient motivation identified during usual practice		App type and core intervention strategies: selection based on patient preference identified during usual practice	
Topic category	Intervention category	App type	Core intervention strategies ^a
	Emotion focused	Cognitive behavioral therapy	Negative affect management
		Relaxation	Stress management Negative affect management
		Mindfulness	Stress management Negative affect management
	Therapeutic	Cognitive behavioral therapy	Skill building/overview
		Mindfulness	Skill building/overview

^aStrategies with Behavioral Theory Survey Scores of >2/5. A score above 2 indicates tailored advice or assistance.

Discussion

Principal Findings

In this paper we proposed a framework to assist health professionals in recommending high-quality apps for supporting chronic disease self-management. We used type 2 diabetes to illustrate the processes used in (1) creating the app library, (2) identifying core intervention strategies incorporated into apps, and (3) a patient-centered approach to match apps to patient needs.

Our library included apps that incorporated highly interactive strategies from all of the intervention categories. This is different from other studies where the primary focus of the mobile interventions was self-monitoring [4,10,17]. For example, Azar et al [10] found that weight-management apps incorporated mostly behavioral and knowledge strategies and did not use emotion-focused strategies. We selected the most popular apps for topics based on the recommendations from published international guidelines for the management of diabetes, whereas Azar et al [10] searched for a specific type of app (tracker) and included the most popular. Using our search strategy we were able to recover apps that specifically focused on emotion-focused and cognitive strategies.

The behavioral content analysis revealed that most of the apps (11/14, 78%) included more than 50% of theoretical strategies, but total BTS scores were low as few of the highly personalized interactive strategies were included. Apps mostly provided general information and general assistance to users with limited assessment, feedback, or tailored assistance. While apps scored poorly overall, they tended to score high for specific strategies related to their primary focus. Higher-scoring strategies, such as self-monitoring, goal setting, and social support, are associated with healthy eating, higher dietary self-efficacy [18], and Social Cognitive Theory which has been used extensively to explain dietary behavior.

Behavioral theories such as SCT indicate that stand-alone apps would need to use specific combinations of high-scoring strategies to be effective. Table 3 illustrates that all of the apps scored less than 50% of the total possible BTS scores for all four of the behavioral models/theories. The results suggest that even when apps incorporate highly interactive intervention

strategies, they cannot replace human factors such as empathy and understanding as they seem not to incorporate sufficient emotion-focused and cognitive strategies. It is as yet unclear if apps that incorporate many strategies would be effective. The general apps would be relevant for a range of chronic diseases. The low scores indicate that a mixture of apps using complementary strategies or apps used in conjunction with more highly interactive interventions would be more effective than solitary apps. Other studies have found mobile interventions are most effective when used as an adjunct to therapy [17,19].

Mobile apps may support and reinforce many aspects of therapy. Tracker apps track symptoms and behavior and are useful to both the health practitioner and the patient. Patients become more aware of their symptoms and behaviors when using assessment apps and this may increase their participation in decision making. Newer technologies objectively estimate food intake and physical activity, reducing demands on users and reliance on self-report. Strategies and goals for behavior change identified in therapy can be programmed into goal-tracking apps which patients can use to prompt new behaviors and monitor progress between visits. Many apps guide patients when practicing new skills and have functions including reminders and social connectivity, which can be used to stimulate desired behavior. App reminders can shape behavior by prompting new behaviors and reminding the patients of motivations for change at predetermined times. Patients can receive encouragement and emotional support from peers via social connectivity. Mobile apps may allow health practitioners to spend less time on assessment and providing general information, and more time on supporting behavior change.

Practical Application

When used as an adjunct, high-quality health apps may increase the effectiveness of therapy [17,19]. However, patients need guidance from health practitioners for matching apps to their health needs and goals. Table 5 outlines a patient-centered approach for matching apps to patients' needs, preferences, and motivations identified during usual practice. The topic and app category could be based primarily on patient motivation and the etiology of the problem, and the core theoretical strategies of the app could be selected based on patient preference. For example, the diet tracker and/or the food selection app may be the best option(s) for a patient who is motivated to lose weight,

wants to focus on diet, and has a food and nutrition knowledge deficit. The diet tracker app will increase the patient's awareness of how their diet compares to their nutritional goals and will support them in pinpointing less desirable food choices in their diet; the food selection app could be used to identify healthier alternatives.

High-quality apps that are customized to patients' needs will deliver appropriate guidance, feedback, and triggers for new behaviors, thereby providing intensive support between appointments. It is important that health practitioners provide guidance on how to customize app goals and interpret automated feedback, and provide patients with tailored assistance in further modifying behavior in response to app feedback at follow-up appointments. Empowering patients to use apps should increase their active participation in managing their health. The framework could be used as a basis for future research evaluating the effectiveness of behaviorally based, mobile interventions.

Strengths and Limitations

The framework presented here is a systematic and methodological approach that was well accepted and understood by a convenience sample of health practitioners. App selection was based on topics recommended in published international guidelines for the management of diabetes, and general criteria focusing on the health practitioners' assessment of information quality and reliability. It uses behavioral theory to explain how apps may be used to support therapy. Studies show mobile text-messaging interventions based on behavioral theory are more effective than non-theory-based ones [20]. Best practice guidelines for chronic disease management of lifestyle-related problems in general recommend basing interventions on behavior change theory. Our framework can be adapted to other

conditions, as behavioral theory helps in identifying strategies which match patient needs.

Additionally, the framework can be flexibly delivered to meet practitioners' needs. For example, some practitioners may not have the time to build the library from scratch, and instead prefer to build it based on their patients' favorite apps. In this instance, they would skip step one and start by assessing the behavioral theory content of the apps using BTS. This would enable them to advise patients on the best use of preferred apps in supporting behavior change. Using this method, their library will most likely not contain the less popular emotion-focused and cognitive apps. Therefore, regardless of the method, we suggest that these apps be identified using the refined keyword searches described in step 1, for instance, the keywords "GI," "glycemic index," "relaxation," "confidence," and "CBT."

Limitations of the study include the adoption of a relatively general app selection approach that used popularity as a key criterion. Information quality was assessed through professional opinion rather than through a more stringent set of criteria which could not be located at the time. Recently, a comprehensive tool for assessing app quality has been published—the Mobile App Rating Scale [21]. Integration of this tool into the app selection step may increase the quality of the apps included in the library.

Conclusions

The potential for health apps to support the management of chronic disease is considerable. Health professionals are well positioned to guide patients in the most effective use of apps to meet their needs. Apps are rapidly evolving, so health professionals need to be vigilant and continuously assess apps and refine selection tools for matching apps with therapy. High-quality health apps may be handy instruments for the modern health practitioner's toolbox.

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Authors' Contributions

KH was the chief investigator primarily responsible for study conception and design, data analysis, and primary authorship on the manuscript. SC assisted with study design, data interpretation, and writing of the manuscript. JB assisted with study design. All authors critically reviewed the manuscript and approved the final version submitted for publication.

Conflicts of Interest

None declared.

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Abbreviations

- B:** behavioral
- BTS:** Behavioral Theory Content Survey
- C:** cognitive
- CBT:** cognitive behavioral therapy
- CDSM:** chronic disease self-management
- EF:** emotion focused
- GI:** glycemic index

HBM: Health Belief Model
K: knowledge
SCT: Social Cognitive Theory
SI: International System of Units
SMS: short message service
T: therapeutic
TGA: Therapeutic Goods Administration
TPB: Theory of Planned Behavior
TTM: Transtheoretical Model

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Original Paper

Comparison of a User-Centered Design, Self-Management App to Existing mHealth Apps for Persons Living With HIV

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Abstract

Background: There is preliminary evidence that mobile health (mHealth) apps are feasible, attractive, and an effective platform for the creation of self-management tools for persons living with HIV (PLWH). As a foundation for the current study, we conducted formative research using focus groups, participatory design sessions, and usability evaluation methods to inform the development of a health management app for PLWH. The formative research resulted in identification of the following functional requirements of a mHealth app for self-management: (1) communication between providers and peers, (2) medication reminders, (3) medication log, (4) lab reports, (5) pharmacy information, (6) nutrition and fitness, (7) resources (eg, social services, substance use, video testimonials), (8) settings, and (9) search function.

Objective: The purpose of this study was to conduct an ecological review of the existing apps for PLWH and to compare the functionality of existing apps with the app specifications identified in our formative work.

Methods: We searched two mobile app stores (Google Play and iTunes) and found a total of 5606 apps. We reviewed the apps, narrowed our search terms, and found a total of 112 apps. Of these, we excluded 97 (86.6%) apps that were either not in English (10/112, 8.9%), not HIV focused (32/112, 28.9%), or focused only on HIV prevention (2/112, 7.8%); targeted health care providers (26/112, 23.2%); provided information only on conference schedules and events (7/112, 6.3%), fundraisers (7/112, 6.3%), specific clinics (7/112, 6.3%), international or narrow local resources (3/112, 2.7%); or were identified in the first search but were no longer on the market at the next review (4/112, 3.6%). The 15 apps meeting inclusion criteria were then evaluated for inclusion of the nine functionalities identified in our earlier work.

Results: Of the 15 apps that we included in our final review, none had all of the functionalities that were identified in our formative work. The apps that we identified included the following functionalities: communication with providers and/or peers (4/15, 27%), medication reminders (6/15, 40%), medication logs (7/15, 47%), lab reports (5/15, 33%), pharmacy information (4/15, 27%), resources (7/15, 47%), settings (11/15, 73%), and search function (6/15, 40%). No apps included nutrition or fitness information.

Conclusions: Currently, there are only a small number of apps that have been designed for PLWH to manage their health. Of the apps that are currently available, none have all of the desired functionalities identified by PLWH and experts in our formative research. Findings from this work elucidate the need to develop and evaluate mobile apps that meet PLWH's desired functional specifications.

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KEYWORDS

mHealth; HIV; mobile apps; user-centered design

Introduction

Self-management is a dynamic, interactive, and regular process in which individuals manage their illness to promote health [1]. Through self-management an individual manages symptoms, treatments, lifestyle changes, and the consequences of health conditions [2] to maintain an adequate quality of life [3]. Self-management is increasingly important in chronic conditions, as the impact of these diseases continues to increase and affect over half of the US population [4]. Interventions that enable self-management and provide patients with information and skills that enhance their ability to participate in their health care are increasingly recognized as an essential component of the management of chronic conditions.

Chronic disease self-management is particularly relevant for persons living with HIV (PLWH) in the United States given that, as a result of advances in treatment regimens, HIV is now largely recognized as a chronic disease [5]. HIV requires lifelong therapy and is often characterized by multiple comorbidities that can present unique problems for the delivery of health care. A networked and well-resourced health care system is required to identify people with HIV, link them to care, provide services, and address comorbidities and other complications [6]. Improving PLWH's ability to self-manage their illness is key to achieving the aims of the National HIV/AIDS Strategy for the United States by increasing access to care, improving health outcomes for PLWH, and reducing HIV-related health disparities [7].

HIV has disproportionately affected persons from underserved communities, specifically racial and ethnic minorities and those from low-socioeconomic groups [8-10]. Findings from the National HIV Behavioral Surveillance survey indicated that HIV prevalence was 2.8% among blacks and 1.2% among Latinos. HIV prevalence was higher among those who reported less than a high school education, compared with those with a high school education. HIV prevalence was also higher for those with an annual household income less than US \$10,000, compared with those with an income of US \$20,000. Geographic differences were also noted with prevalence being highest among survey participants in the Northeast followed by the southern region of the United States [11].

The potential for information and communication technology, such as mobile health (mHealth) technology and specifically mobile apps, to enhance self-management through the provision of support (information, education, reminders, etc) for behavior change has been well documented over the last decade [12-19]. A growing body of research confirms the benefits of empowering consumers with information and decision-making support [20-22]. Patient participation in their health has been shown to lead to increased patient satisfaction and positive changes in adherence patterns that translates into improved clinical outcomes [23-25].

Health disparities can be narrowed through the use of mHealth technologies, which are being used for patient monitoring, data

collection, health information exchange, and real-time care management [26,27]. mHealth may be particularly relevant to low-socioeconomic PLWH since it has the potential to improve access to care by reducing challenges associated with geographic and economic disparities [28,29]. mHealth also provides unique possibilities for bridging the divide in health care delivery among underserved racial and ethnic minority groups [30]. The fact that African Americans and Hispanics download apps more frequently than non-Hispanic whites is a notable illustration [31].

Although mHealth tools for PLWH have been suggested as having potential to positively impact self-management, to date they have not been well developed or evaluated. Currently, there are only a small number of mHealth apps for PLWH [32], but little documentation exists showing that they have been developed in partnership with the target end users or health care providers to ensure that desired content and features are included in the app. Of the limited number of studies specifically focused on mobile apps for PLWH, only one study incorporated users' preferences into the mobile app among HIV-positive young mothers [33], *but did not* rigorously evaluate the app after its development. In another study, researchers developed a mobile app consisting of a music program to improve adherence to antiretroviral (ARV) medications for adult PLWH, but did not report engaging the intended end users in its development [34].

Mobile phone apps are increasingly being used for the care of persons living with HIV and other sexually transmitted diseases (STDs), however most have failed to attract user attention and positive reviews. For example, in a review of existing apps for the care of persons living with HIV and other STDs and the prevention of these diseases, researchers found that apps were infrequently downloaded (ie, median 100 to 500 downloads) and not highly rated (ie, an average customer rating of 3.7 out of 5 stars). Based on this 2013 review, less than 0.3% of the more than 29,000 health-related apps available for iPhone and Android consumers were dedicated to HIV/STD information and prevention [32].

In response to the dearth of HIV apps derived from end users' needs and design preferences, we conducted a multistage study to inform the design of a mobile app for PLWH to self-manage their illness. We then conducted an ecological review of existing apps with the same purpose—to support self-management for PLWH—to compare included functionalities. The goal of this paper is to report the design specifications of a mobile app that were derived from user-centered design methods and to compare the mobile app that we designed to the existing mobile apps that are currently available for PLWH to self-manage their disease.

Methods

App Design Process

Overview

The information systems research (ISR) framework [35] informed a three-stage process used to develop a design document outlining the blueprint of a mHealth self-management app for PLWH in the United States. The purpose of this project was to identify the desired features, user interface, and functionality of a mobile app for PLWH.

Focus groups, end-user design sessions, heuristic evaluation, and end-user usability testing were the methods applied to develop the design document. First, we conducted six focus group sessions with PLWH (n=50), ages 18 to 59 years, and three focus group sessions with HIV care providers (n=30) to identify the desired content, features, and function of the ideal mHealth app for PLWH to self-manage their health. Four group sessions with PLWH were conducted in English, and two group sessions with PLWH were conducted in Spanish. Among the six focus groups conducted with PLWH, over half of the participants reported their race as black/African American (26/50, 52%) and half reported their ethnicity as Latino/Hispanic (25/50, 50%). The methods for focus group data collection are published elsewhere [36].

Next, we conducted two participatory design sessions. In the first group, we had 5 participants out of 50 (10%); 3 of the 5 (60%) reported their race as African American and 2 (40%) reported their ethnicity as Latino. In the second design session, we had 6 participants out of 50 (12%), 3 (50%) of whom had participated in the first design session. Of the 6 participants, 3

(50%) were female and 3 (50%) were male; 4 (67%) participants self-identified as African American and 2 (33%) identified as Latino. Details of the methods and findings from the design sessions are published elsewhere [37].

Following these sessions, we created an initial low-fidelity prototype with a visual framework of the screen content and layout of the app in PowerPoint. To identify features that could increase technology acceptance, we conducted two types of usability assessments [38]: (1) a heuristic evaluation of the prototype using informaticians with experience in interface design and/or human computer interaction and (2) end-user usability testing systematically observing how well PLWH used the app. We had a total of five heuristic evaluators and 10 end-user usability testers. We used an iterative process revising the mock-up; after one heuristic evaluator and two subsequent end users evaluated the mock-up, we made changes to the app design in accordance with the recommendations. In total, we had five versions of our mock-ups. At the end of our usability testing, we finalized the design document which included the functional specifications and user interface design of a mHealth app for PLWH to self-manage their illness. Our end-users across groups and stages of the project had many similar ideas; there was a strong degree of agreement among all participants. We reached saturation of ideas before moving on to the next stage of app development.

Based on our user-centered iterative design process, our end users identified nine functionalities as being components of their ideal mobile app to support their health management needs. The functionalities included the following: communication, reminders, medication logs, lab reports, pharmacy information, nutrition and fitness, resources, settings, and search. The functionalities are listed in Table 1 and described in detail below.

Table 1. User-centered design self-management app for persons living with HIV: functionalities and sample details.

Functionality	Sample details
Communication	Provider-patient communication and peer communication
Reminders	Medication reminders for a time and date, setting medical appointment reminders, medical checklist (eg, flu vaccines, colonoscopy), and an audio recorder
Medication logs	Pill identification and summary of current and discontinued medications
Lab reports	CD4 ^a count, viral load, STD ^b , glucose, and CBC ^c results and trends
Pharmacy information	Current pharmacy information
Nutrition and fitness	Nutrition and exercise information, food, and weight-loss tracking
Resources	HIV medical care, social services, substance use, law/advocacy, and case management
Settings	Profile picture, password, and alerts
Search	Search within the app

^aCluster of differentiation 4 (CD4): glycoprotein found on surface of T helper immune cells.

^bSexually transmitted disease (STD).

^cComplete blood count (CBC).

Communication

Communication included both provider-patient communication and peer communication. Communication with medical providers included provider discussion forums, a 24/7 hotline,

and a chat with a provider or case manager. Communication with peers included peer forums and interactive blogs.

Reminders

There were a number of functionalities associated with setting reminders, including medication reminders for a time and date,

setting medical appointment reminders, medical checklist (eg, flu vaccines, colonoscopy), and an audio recorder.

Medication Logs

In our final design document, there is also a medication log which includes pill identification with the names and pictures of medications, a summary of current medications, medications discontinued, and specifically highlighting which medications had been discontinued in the past 3 months.

Lab Reports

Lab reports included CD4 count/viral load with a graph of the individual's trends, sexually transmitted disease results, glucose trends, and complete blood count results.

Pharmacy Information

Participants wanted to record their current pharmacy location and contact information.

Nutrition and Fitness

Formative research participants wanted nutrition information, weight-loss goals, and a food tracker with a food diary and calorie calculator. Participants wanted physical activity information related to aerobic and muscle-strengthening activities.

Resources

Participants identified a number of broad categories of resources including information on HIV medical care, social services, substance abuse, and law/advocacy, as well as a sexual risk calculator, instructions on how to use a condom, HIV video testimonials, and an HIV medical dictionary. HIV medical care resources included HIV medical providers and clinics, HIV organizations/adult day programs, case management, HIV/AIDS Services Administration (HASA), AIDS medication assistance, mental health providers, support groups, and Medicaid information. Social services included food pantries, realtors for HASA recipients, and homeless services. Participants identified types of substance abuse resources and organizations such as needle exchange programs and support groups. Participants also wanted specific legal information about HIV transmission for each state and legal information about domestic violence. They also wanted video testimonials specific to women, men, and lesbian, gay, bisexual, and transgender (LGBT) persons, as well as testimonials about disclosing one's status.

Settings

Participants wanted the app to have settings which allowed them to post a profile picture, set a password, and provide news, information, and medical alerts (eg, missed medications, appointments).

Search

Participants also specified that the app should have a search function to easily navigate through the app.

Review of Existing Apps and Comparison to our User-Centered Design App

App Search Strategy

To identify health management apps for PLWH available in the marketplace we searched two online mobile app stores in March 2015—Google Play and iTunes—using the following search terms: HIV, AIDS, medication tracker, medication reminder, medication alarm, medication information, antiretroviral therapy (ART), antiretroviral adherence, ARV, adherence, AIDS treatment, HIV test, and pill.

After initially using these broad search terms, we did a review of the apps and found that many were not relevant and that a large number of apps were games, non-English, and had to do with first aid or the provision of aid. As a result, we narrowed our search terms to the following: HIV treatment, HIV medication, HIV/AIDS treatment, HIV/AIDS care, HIV reminder, AIDS medication, antiretroviral, and living with HIV. Each term was searched separately in each store and a list of search results was compiled.

Selection Criteria

The apps were eligible for inclusion if they were targeted to PLWH. The apps were excluded if they were games, not in English, for health care professionals, for fundraising, not focused on HIV, a specific clinic, international (eg, Hong Kong medications), local resources (eg, only for the city of Philadelphia), or a conference itinerary. Two study team members (RS, JPM) independently reviewed the titles of each of the apps and excluded apps from further review that clearly did not meet eligibility criteria.

Data Extraction, App Selection, and Assessment

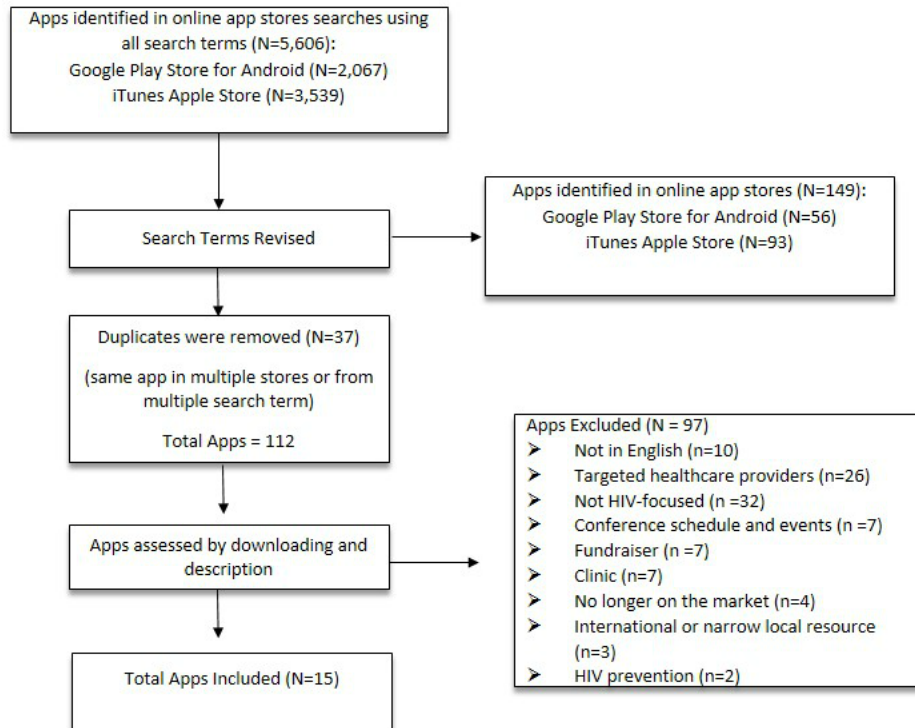
We identified a total 149 apps from both app stores using the terms listed above. We then assessed the list of apps to identify any duplicate apps (ie, same app available in Android and Apple platforms). We found 37 apps that were the same in both stores, narrowing our total number of apps to 112 (see [Figure 1](#)). Of these, we excluded 97 (86.6%) apps that either were not in English (10/112, 8.9%), not HIV focused (32/28.6%), or focused only on HIV prevention (2/112, 1.8%); targeted health care providers (26/112, 23.2%); provided information only on conference schedules and events (7/112, 6.3%), fundraisers (7/112, 6.3%), specific clinics (7/112, 6.3%), or international or narrow local resources (3/112, 2.7%); or were identified in the first search but were no longer on the market at the next review (4/112, 3.6%). At the end of our extraction process, we identified a total of 15 unique apps.

The apps meeting eligibility criteria were downloaded for full functionality evaluation by two of the study authors (JPM, SJI). A standardized form was created to extract app characteristics using Research Electronic Data Capture (REDCap). The REDCap Web-based application allows users to build and manage online surveys and databases quickly and securely [39]. Each app was assessed for platform (ie, Apple or Android), targeted population (ie, men who have sex with men [MSM], men, women, youth/adolescents, young adults, older adults, and homeless persons), user rating and number of people

contributing to the rating, range of the number of downloads where available, and the cost to download (see [Multimedia Appendix 1](#)). Finally, we coded each app to determine if it had the functionality identified in our formative work. Broader

functionalities included the following: communication (ie, peers and medical provider), setting medication reminders, medication logs, lab reports, pharmacy information, nutrition and fitness, resources, and settings.

Figure 1. Flowchart of the screening process of mobile apps for persons living with HIV to manage their health.



Results

Of the 15 apps included in our comparative assessment, 9 (60%) were available on both platforms, 5 (33%) were only available from iTunes, and 1 (7%) was only available from Google Play. All of the apps were available for free to download (see [Table 2](#)).

Of the 8 out of 15 (53%) apps with customer ratings, the weighted average rating was 4.42 (SD 2.10) stars. The mean number of reviews for rated apps was 36 (SD 41) (range 1-91). Only Google Play provides information on the number of downloads per app. Of the 10 apps with download information, 2 (20%) apps had 100 to 500 downloads, 2 (20%) apps had 500 to 1000, 2 (20%) apps had 1000 to 5000 downloads, and 2 (20%) apps had 5000 to 10,000 downloads. None of the apps were focused on any of the targeted populations listed above.

Most (10/15, 67%) of the apps were available in English only. Out of the 15 apps, 1 (7%) was available in English and Spanish, and 2 (13%) were available in English and French. Of the 15 apps, 1 (7%) was available in English, German, and Spanish and 1 (7%) was available in four languages: English, French, German, and Spanish.

None of the apps included all of the functions that were identified in our formative work as specified by end users. The following functionalities were included in the apps in our review: communication with providers and/or peers (4/15, 27%), medication reminders (6/15, 40%), medication log (7/15, 47%), lab reports (5/15, 33%), pharmacy information (4/15, 27%), resources (7/15, 47%), settings (11/15, 73%), and search function (6/15, 40%). No apps included functionality related to nutrition or fitness. Out of 15 apps, 5 (33%) included four or more functions, while the remainder had less than four.

Table 2. Overview of 15 apps for persons living with HIV.

App name	Author	Platform	Rating (# rating)	Downloads, n	Languages supported	User-centered design HIV app functionality
AIDSinfo HIV/AIDS Drug Database [40]	NLM ^a at NIH ^b	Google, Apple	4.2 [14]	500-1000	English	Settings, medication reminders, search
AIDSinfo HIV/AIDS Glossary [41]	NLM at NIH	Google, Apple	4.2 [42]	500-1000	English, Spanish	Resources (HIV medical dictionary), search
aidsmap news [43]	Thomas Paterson	Apple	N/A ^c	N/A	English	Settings (alerts: HIV news), search
Facing AIDS [44]	HHS ^d	Google, Apple	5 (Google-1 ^e)	100-500	English	Communication (peers), settings (profile picture)
HIV Answers [45]	Gilead Sciences	Google, Apple	4.4 (Google-18)	1000-5000	English	Medication log, pharmacy information, resources (HIV medical care, social services), settings (password), search
HIV Medication Guide [46]	Headcan	Apple	N/A	N/A	English, French	Search
HIV Testing Sites & Care Services Locator [47]	HHS	Apple, Google	3.7 (Google-3)	100-500	English	Resources (HIV medical care, social services, substance use), search
HIVPlus Treatment Guide [48]	Here Media	Apple, Google	3.5 (Apple-8) 4.6 (Google-29)	1000-5000	English	Medication reminders (date, recorder, medical appointments), medication log, lab reports, resources (HIV video testimonials, medical dictionary), settings (HIV info, HIV news, missed appointment alerts)
iStayHealthy [49]	Peter Schmidt	Apple, Google	4.6 (Google-91)	5000-10,000	English, French, German, Spanish	Medication reminders (date), medication log (pill ID, summary), lab reports (glucose, CBC ^f , CD4 ^g count/viral load) pharmacy information, resources (HIV medical care), settings (alerts)
My Health Matters [50]	Merck	Apple	N/A	N/A	English, German, Spanish	Medication reminders (date, recorder), medication log, lab reports (glucose, CBC, CD4 count/viral load), pharmacy information, resources, settings (password)
NV SelfCare [51]	The Center Las Vegas	Apple, Google	N/A	10-50	English	Communication (providers), medication log, settings (username, password)
Red Ribbon, Your HIV/AIDS Health Manager [52]	Communication Software, Inc	Android	3.7 (Google-6)	100-500	English	Medication reminders (date), medication log, lab reports, settings (username, password)
TalkPositive [53]	Pharmi-Web2002 Limited	Apple	N/A	N/A	English	Medication reminders (date, medical appointments), medication log, lab reports, pharmacy information, settings (username)
The Body [54]	Remedy Health Media	Apple, Google	4.4 (Google-87) 5 (Apple-9)	5000-10,000	English	Communication (peers), resources (HIV video testimonials), HIV news
YourDocTalk: HIV Treatment Talking Tool [55]	CATIE ^h	Apple	N/A	N/A	English, French	Communication (providers)

^aNational Library of Medicine (NLM).^bNational Institutes of Health (NIH).^cNot applicable (N/A).^dUS Department of Health and Human Services (HHS).^eThis number denotes the number of people who provided reviews.^fComplete blood count (CBC).

[§]Cluster of differentiation 4 (CD4).

^hCanadian AIDS Treatment Information Exchange (CATIE).

Discussion

Principal Findings

Wide gaps exist between user-desired functionality of apps and those which currently exist for PLWH. As described earlier, many of the desired functionalities, such as lab reports, communication tools, and nutrition and fitness components, did not exist in many of the existing apps for PLWH. It has been well documented in the technology acceptance literature that if technology is not perceived as useful then it is unlikely that end users will use it [56,57]. This points to the need to develop technology, and more specifically apps, which meet the desired functional specifications of the intended end users. Given these current gaps, it is not surprising that many apps leave the marketplace quickly and are not widely downloaded (see Table 2).

In addition to the gaps in functionality, most apps are only available in English. There is a dearth of apps available in Spanish (3/15, 20%). This is particularly relevant since Hispanics/Latinos accounted for over 20% of all new HIV infections in the United States despite representing only 16% of the total US population [8]. This points to the need for the development of existing apps in Spanish and is an especially important charge for the apps developed by the US government.

Rapidly Changing Landscape for mHealth Apps

By some estimates, there are as many as 97,000 health apps currently available in the app stores [58]. Of these, there are a limited number of apps available that are specifically tailored for PLWH to manage their health. The landscape for mHealth apps is also rapidly changing. For example, in a 2013 review of apps for HIV/STD-positive persons, Muessig et al identified 8 apps for PLWH. Of those apps identified in their review, only 5 are still available [32]. Similarly, in our review 4 of our originally identified apps were no longer available when the second reviewer went to download the app a few weeks later. The rapid turnover of available apps points to issues with regulation, sustainability, and maintenance. There is currently much debate as to which apps need to be regulated and by whom [59]. Of more relevance to our work, there is greater concern over sustainability since it is clear that apps rapidly leave the marketplace, which can be very problematic if patients successfully rely on an mHealth app to support the management of their illness. Lack of sustainability also presents challenges for rigorous evaluation of existing apps because of their rapid disappearance.

US Food and Drug Administration Regulation of Apps

The US Food and Drug Administration (FDA) has a growing interest in the regulation of certain types of medical apps in the United States. The most recent FDA guidance refers only to mobile medical apps. More specifically, the FDA will apply its regulatory oversight to mobile apps that are medical devices and whose functionality could pose a risk to a patient's safety if the mobile app were to function as intended [60]. Current

regulation of apps is important to consider in thinking about dissemination, oversight, cost to development, and use of mobile apps. Given the current guidelines, the app that we designed in our formative work would not be subject to FDA oversight. Moreover, the apps that we identified in our review also do not fall within the category of mobile medical apps.

Apps for Persons Living With HIV

While there is a dearth of apps available specifically for PLWH, there are a number of apps that are available for persons to self-manage their health that are not unique to HIV. For example, in a review of mobile apps for supporting medication self-management, 424 apps were identified, pointing to the broad availability of these apps, but findings from this review pointed to the same limitations as those found in our study: the quality, content, and functionality are highly variable [42,61]. Importantly, medication self-management apps may not need to be specifically designed for PLWH and, consequently, some of those 424 apps may be relevant to our study population. Even so, the review found that most apps were unable to support complex or varying regimens which may make them useless to PLWH who need to change their regimens in response to resistance, and who are also frequently being treated for opportunistic infections and/or comorbid conditions [62,63].

Findings from our formative work supported the design and creation of an app for PLWH which would provide an entire set of desirable functions. Our formative work focused on the creation of a "one-size-fits-all" app for PLWH. There are some users who may prefer simpler apps that only provide specific functions limited to what they want. In addition, large multifunction apps take up a lot of storage space on devices. Nonetheless, our formative work did not ask users to consider space limitations and instead asked them to focus on the components and user interface which would make the app most useful and easiest to use.

In our formative work, our study participants identified a number of functionalities beyond medication management that they considered key to the management of their disease. Findings from our work are further supported by the current demographics of the HIV epidemic in the United States. HIV in the United States has become largely a chronic illness [63]. PLWH are living longer, and as they live longer they are experiencing chronic diseases similar to their HIV-negative counterparts. They have even greater needs for self-managing their health [64], illustrating the need for the development of a self-management app for PLWH that we identified in our formative work.

In terms of functionality, more than half of the apps in our review included settings and nearly half included medication logs, reminders, resources, and a search function. Yet other features such as communication with providers and/or peers, pharmacy information, and lab reports were less available. This is unfortunate since the functionalities were described as desired by our targeted end users. Interestingly, PLWH and health care providers for PLWH identified nutrition and fitness as key

content necessary for maintenance of their health. Diet and fitness have been identified by end users as important health information needs in previous studies [65]. At the same time, none of the HIV apps that we identified in our review included this content.

Limitations

There are some important limitations to mention. First, the formative research phase that we conducted used relatively small samples in a single geographic area. Therefore, the views are not necessarily representative of all English- and Spanish-speaking PLWH. This is an important limitation to our formative research results and therefore also an important limitation to the existing app-feature assessment results presented in this paper. Nonetheless, we did include both English and Spanish speakers in our design process, as well as health care providers, to gather more generalizable information.

There are also limitations with our review of the existing apps. First, the search functions within the mobile app store are limited and a search term can return hundreds or thousands of unrelated apps. Second, other apps were identified as relevant and meeting inclusion criteria. However, at the stage of review some were found to be no longer available. Therefore, their features could not be assessed for inclusion in this study. Because user reviews

are not included for all apps we were only able to provide user review scores on a portion of the included apps.

Conclusions

Our formative work used an iterative design process incorporating end-user feedback and expert review to identify the functional specifications and user interface design of a design document for an mHealth app for PLWH to self-manage their health. Development of mHealth technologies is currently progressing at a rapid pace that is evident by the large number of apps that are currently available. Given the low uptake and rapid disappearance of apps, there is a strong need to integrate the needs of the end users in technology development. Findings from our review demonstrate the gap between what PLWH identified as the functional components of an app they desired versus the functionalities within apps that currently exist. Future work is needed to develop apps that meet end users' desired needs. Furthermore, there is a need for rigorous evaluation of these apps to determine their efficacy to improve health outcomes. Finally, if an app were found to be useful and usable from the end users' perspective, as well as effective at improving health outcomes, then a model for sustainability needs to be developed so that these apps can be appropriately disseminated and implemented in the lives of persons who suffer from chronic illnesses such as HIV.

Conflicts of Interest

This publication was supported by a cooperative agreement between Columbia University School of Nursing and the Centers for Disease Control and Prevention (CDC; 1U01PS00371501; PI: R Schnall). The findings and conclusions in this paper are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.

Multimedia Appendix 1

Standardized form to extract app characteristics.

[[PDF File \(Adobe PDF File\), 10KB - mhealth_v3i3e91_app1.pdf](#)]

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Abbreviations

ART: antiretroviral therapy
ARV: antiretroviral
CATIE: Canadian AIDS Treatment Information Exchange
CBC: complete blood count
CD4: cluster of differentiation 4
FDA: US Food and Drug Administration
HASA: HIV/AIDS Services Administration
HHS: US Department of Health and Human Services
ISR: information systems research
LGBT: lesbian, gay, bisexual, and transgender
MSM: men who have sex with men
N/A: not applicable
NIH: National Institutes of Health
NLM: National Library of Medicine
PLWH: persons living with HIV
REDCap: Research Electronic Data Capture
STD: sexually transmitted disease

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Original Paper

Evaluation of Social Media Utilization by Latino Adolescents: Implications for Mobile Health Interventions

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Abstract

Background: Trends in social media use, including sending/receiving short message service (SMS) and social networking, are constantly changing, yet little is known about adolescent's utilization and behaviors. This longitudinal study examines social media utilization among Latino youths, and differences by sex and acculturation.

Objectives: The purpose of this study was to examine Latino adolescents' social media utilization and behavior over a 16-month period, and to assess whether changes in use differed by sex and acculturation.

Methods: This study included 555 Latino youths aged 13-19 who completed baseline and 16-month follow-up surveys. Prevalence of social media utilization and frequency, by sex and acculturation categories, was examined using generalized estimating equations.

Results: Women are more likely to use SMS, but men are significantly more likely to SMS a girl/boyfriend ($P=.03$). The use of Internet by men and women to research health information increased over time. Facebook use declined over time ($P<.001$), whereas use of YouTube ($P=.03$) and Instagram ($P<.001$) increased, especially among women and more US acculturated youths.

Conclusion: Social media is ubiquitous in Latino adolescents' lives and may be a powerful mode for public health intervention delivery.

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KEYWORDS

acculturation; Latino/a; sex; short message service; social networking

Introduction

Background

Today, adolescents are consumed by a dynamic, technology-filled world. Social media, such as social networking sites (SNSs, ie, platforms utilizing the Internet and mobile technology to enable social interactions) [1] and short message

services (SMSs or texting) allow adolescents to connect to peer and other social networks that are larger and more diverse than they would normally have access to face-to-face. Adolescents are the most extensive users of new technology and are more likely to be connected to the virtual world, regardless of socioeconomic status, family structure, or race [2]. In fact, many adolescents use social media to interact with peers and others

whom they may not even know on a personal basis [3]. Given that almost all US youths use social media in their daily lives, research suggests these media may have negative consequences related to alcohol use, sex, suicide ideation, and bullying [4-7]. At the same time, the rise in social media use over the last decade has spawned an increase in using media platforms to deliver public health messages and information [8-11]. Many health interventions target adolescents and young adults because of their increased risk behavior during this time and their extensive social media use. However, little is known about how, why, and how much ethnic and minority youths use social media, and if social media are an avenue to reach specific populations within minority communities for health interventions.

Latino youths are one of the fastest-growing minority youth populations in the United States, and by 2025, it is estimated that they will comprise one quarter of the total US youth population [12]. Despite being a minority population, typically characterized as a “low-income” group, a recent Pew Internet and American Life Project report noted that 86% of Latino youths own a cell phone, similar to whites (84%) and blacks (90%) [13]. Furthermore, Latinos are just as likely as their white and black peers to own a smartphone—49% versus 46% and 50%, respectively. Latino youths are also extensive users of mobile technology, particularly SMS and social networking, with 55% of Latino youths using SMS as their primary method to communicate, and sending a median of 100 SMS/day [2,14].

Previous studies have indicated that adolescent women and men have very different communication styles. Women use communication to develop more intimate social relationships, whereas men tend to restrict emotional expressions [15,16]. Thus, it is plausible that adolescent women and men communicate differently through social media as well. Traditionally, men watch more television and share videos online, whereas women blog, email, or instant message [17]. In a national study, female adolescents (84%) were more likely than male adolescents (79%) to have a social networking account, and they sent/received a median of 100 SMS/day, compared with 50 SMS/day that men sent/received [2]. Different communication styles may also exist when using mobile technology for obtaining health information or initiating health discussions. Examining whether this phenomenon exists in the Latino community is particularly important because there is a strong emphasis on distinct sex differences between men and women. Sex is viewed as an organizing feature of family life during the socialization process [18], and Latino parents are generally considered as being more protective and stricter about their daughters’ activities as compared with their sons’ activities [19]. Thus, understanding sex differences is crucial to the development of mobile health interventions, as this may play a key role in understanding who is more likely to participate in these types of interventions.

Acculturation, defined as a cultural modification by adapting to or borrowing traits from another culture [20], is another factor that may influence social media utilization and behavior. Previous studies have found a strong relationship between acculturation and risk behaviors among Latino youths [21,22]. Preliminary evidence showing differences in utilization of social

media by acculturation was reported in a descriptive study [14]. The study [14] examined proxy measures of acculturation, nativity, and language spoken at home, and reported that 65% of US native teens communicate with friends using SMS versus 26% of foreign-born teens. Other findings from the same study showed that 68% of English-dominant and 50% of bilingual young Latinos used SMS daily, compared with only 19% of Spanish-dominant Latinos. Furthermore, native-born Latinos were 3 times more likely than foreign-born youths to use SNSs to socialize with friends [14].

Study Objective

The purpose of this study was to examine Latino adolescents’ social media utilization and behavior over a 16-month period, and to assess whether changes in use differed by sex and acculturation.

Methods

Participants

The data for this study were derived from self-identifying Latino adolescents aged 13-19 (mean 15.33, SD 1.03), recruited from 12 public high schools in Maryland. Participants completed baseline and 16-month follow-up surveys conducted as part of a program evaluation of the Empowering Latino Youth Project (ELYP) between spring 2012 and fall 2013 (n=555). ELYP is a 5-year cluster-randomized control trial of a teen pregnancy prevention program. Parental consent and youths’ assent to participate in ELYP were obtained. Because the data are from an intervention study, all final analyses controlled for the intervention/control group. The control group was an attention-control program that focused on fitness and nutrition.

Data Collection

To ensure privacy and reduce reporting bias, surveys were administered via individual laptops with audio capability for youths with low-literacy levels. Study participants chose to complete the survey in English or Spanish and were given US\$ 10 gift cards for completing the baseline survey and US\$ 20 gift cards for completing the 16-month survey. The survey instruments were translated and back-translated, and pretested for readability and accuracy. Upon survey completion, the data were stored in an encrypted file to be read only by the survey design software *Snap Surveys* [23].

Measures

Demographic and background variables included age, sex, grade, US born, years in the United States, and acculturation. Age was calculated as a continuous variable from the participants’ self-reported date of birth. Participants self-reported the variables “US born” or “years they have been in the United States,” which was categorized into US born, 0-3 years, 4-10 years, and 10+ years.

Acculturation

This study used an adapted version of a validated bilinear scale consisting of items from the US and Latino cultural identity subscales of the Abbreviated Multidimensional Acculturation Scale [24]. Participants were asked to indicate their level of

agreement with 6 statements measured on a 5-point Likert-type scale (1=strongly disagree, 5=strongly agree): “I am proud of being (Latino/American),” “I feel good about being (Latino/American),” and “I think of myself as being (Latino/American).” The 2 subscales, measuring US culture and Latino culture had very high internal consistency (Cronbach alpha=.9298 and .9517, respectively). After creating the subscales, we conducted a 4-group k-means cluster analysis. Each cluster contains participants such that the degree of association is strong between members of the same cluster and weak between members of different clusters. Each cluster describes the category to which participants belong, including high Latino-high American, low Latino-high American, high Latino-low American, and low Latino-low American identities.

Social Media Use

Social media use includes SMS, Internet, and social media questions adapted from the Pew Internet Project’s 2011 teen survey [2]. Participants reported if they had a cell phone, used SMS, and the frequency of SMS/day (high SMS > 100/day; low SMS ≤ 100/day). SMS frequency was dichotomized based on Pew data that suggested that the median number of SMS/day for Hispanic adolescents is 100 [13]. Participants reported how often they texted their friends, parents, and a boy/girlfriend (1=less often or never, 4=several times a day), which was dichotomized (at least once/day versus less often). In addition, participants with a cell phone reported the following behaviors using their phone: send or receive email, take pictures, play music, send or receive instant messages, record videos, play games, or access Internet.

Participants were asked if they use the Internet; if so, for what purposes and how often (0=never, 6=several times a day). Finally, participants were asked if they had accounts on SNS: Facebook, Myspace, Twitter, Yahoo!, YouTube, Instagram, Tumblr, Google Buzz, Flickr, and Ustream. Those with any of these accounts reported certain behaviors (ie, instant messaging,

posting comments, private messaging, tagging people, and posting updates or videos) and frequency of logging that was dichotomized into daily login versus less frequent.

Statistical Analysis

Analyses were conducted based on participants who completed both the baseline (T1) and 16-month follow-up surveys (T2). Bivariate analyses were conducted to examine the proportions of social media use at different time points by sex and acculturation. To adjust for correlation among repeated measures within individuals, we examined the prevalence of social media use and frequency at T1 and T2 using generalized estimating equations (GEEs) with an unstructured correlation structure and robust standard errors to calculate parameter coefficients and 95% CI. Final GEE models measured whether social media behaviors and frequencies between T1 and T2 differed by sex or acculturation, after controlling for age and the intervention/control group. All analyses were conducted in STATA 12.0 (StataCorp, College Station, TX, USA) [25]. This study was reviewed and approved by the George Washington University Internal Review Board (IRB No 011217).

Results

Demographics of the Study Sample

Table 1 lists the self-reported demographic characteristics of the study sample at baseline. There were slightly more female (325, 58.6%) than male participants (230, 41.4%). The majority of participants were in ninth grade (404, 72.8%) and slightly less than half were born in the United States (268, 48.3%). Of those born outside of the United States, 24.5% (136) had been in the United States for 0-3 years, 18.4% (102) for 4-10 years, and slightly less than 5% (27) for 10 years or more. As much as 50.1% (278) of participants reported high Latino and high American cultural identities, whereas 3% (17) reported low cultural identity on both scales.

Table 1. Study sample characteristics at baseline (N=555)^a.

Variables	Category	n (%)
Sex		
	Men	230 (41.4)
	Women	325 (58.6)
Grade		
	9th	404 (72.8)
	10th	151 (27.2)
Length of time in the United States		
	US born	268 (48.3)
	0-3 years	136 (24.5)
	4-10 years	102 (18.4)
	10+ years	27 (4.9)
	Missing	22 (4.0)
Acculturation scores		
	Latino culture ^b	0.88 (4.6) ^c
	American culture ^d	1.12 (4.0) ^c
	High Latino High American	278 (50.1)
	Low Latino High American	121 (21.8)
	High Latino Low American	112 (20.2)
	Low Latino Low American	17 (3.1)
	Missing	27 (4.9)

^aThe data for this study were derived from self-identifying Latino adolescents aged 13-19 (mean 15.33, SD 1.03).

^bCronbach alpha=.9517

^cData presented as mean (SD)

^dCronbach alpha=.9298

In terms of social media use and behaviors (Table 2), a vast majority (488, 87.9%) owned or had access to a cell phone at baseline, and by the 16-month follow-up (T2), nearly all participants (494, 89.0%) gained access to a cell phone. Of the 7 measured activities on cell phones, emailing (334/466, 71.7%,

versus 427/485, 88.0%, $P<.001$) and accessing Internet (430/479, 89.8%, versus 474/488, 97.1%, $P<.001$) had the largest percentage point increase over the 16 months. Ninety-five percent (467/488) of participants used SMS at baseline and nearly all (486/493, 98.6%) used SMS at follow-up ($P=.01$).

Table 2. Social media use and behaviors at baseline (T1) and 16-month follow-up (T2).

Variables of interest	T1, n/N (%)	T2, n/N (%)	P value
Cell phone access (yes)	488/555 (87.9)	494/555 (89.0)	.04
Missing data on cell phone access	5/555 (0.9)	18/555 (3.2)	—
Cell phone activities			
Email	334/466 (71.7)	427/485 (88.0)	<.001
Pictures	451/476 (94.8)	477/489 (97.6)	.01
Listen to music	445/482 (92.3)	475/492 (96.5)	.001
Instant messages	438/474 (92.4)	469/489 (95.9)	.01
Record videos	381/467 (81.6)	427/478 (89.3)	<.001
Play games	394/470 (83.8)	412/478 (86.2)	—
Access Internet	430/479 (89.8)	474/488 (97.1)	<.001
Mean number of activities on cell phone (SD)	5.9 (1.61)	6.3 (1.26)	<.001
SMS use			
More than 100 SMS/day	149/438 (34.0)	135/484 (27.9)	.02
100 or fewer SMS/day	289/438 (66.0)	349/484 (72.1)	—
SMS parents at least once/day	239/448 (53.4)	260/481 (54.1)	—
SMS friends at least once/day	403/460 (87.6)	418/486 (86.0)	—
SMS boy/girlfriend at least once/day	283/437 (64.8)	322/469 (68.7)	—
Internet use	533/550 (96.9)	529/537 (98.5)	—
Internet activities			
Send/read email	420/516 (81.4)	464/523 (88.7)	<.001
Research health information	184/504 (36.5)	307/518 (59.3)	<.001
Information for homework or school	454/517 (87.8)	486/521 (93.3)	.001
Use Internet once/day	415/531 (78.2)	416/529 (78.6)	—
Has social networking account			
Facebook	458/552 (83.0)	390/534 (73.0)	<.001
Twitter	324/552 (58.7)	298/534 (55.8)	—
YouTube	341/552 (61.8)	357/534 (66.9)	.03
Instagram	82/555 (14.8)	130/555 (23.4)	<.001
Social networking activities			
Send instant messages	421/512 (82.2)	412/507 (81.3)	—
Post comments	440/522 (84.4)	425/520 (81.7)	—
Send private messages	357/519 (68.8)	353/509 (69.4)	—
Tag people	387/512 (75.6)	385/510 (75.5)	—
Post status updates	391/508 (77.0)	354/505 (70.1)	.003
Post photos or videos	466/517 (90.1)	454/512 (88.7)	—
Logging in to social networking sites ≥ 1 time/day	417/527 (79.1)	426/519 (82.1)	—

At both baseline and follow-up survey points, Internet use was above 95% (533/550 and 529/537, respectively). Utilization of the Internet to research health information had the largest gain (184/504, 36.5%, versus 307/518, 59.3%, $P<.001$). Social networking remained high between survey points with over 93% (528/552 and 518/534, respectively) having at least one

SNS account. Facebook use significantly declined between the 2 surveys (458/552, 83.0%, versus 390/534, 73.0%, $P<.001$), whereas use of YouTube (341/552, 61.8%, versus 357/534, 66.9%, $P=.03$) and Instagram (82/555, 15%, versus 130/555, 23.4%, $P<.001$) significantly increased.

Sex

Results indicate that women were significantly more likely to use SMS at baseline (see [Multimedia Appendix 1](#)), but men were more likely to SMS a girl/boyfriend (124/175, 70.8%, versus 159/262, 60.6%, $P=.03$). Women were more likely than men to use the Internet for schoolwork (277/302, 91.7%, versus 177/215, 82.3%, $P=.001$) and to have a Twitter or Instagram account. Women were more active on SNS with tagging people and posting status updates or photos/videos. Women also had slightly more SNS accounts at baseline as compared with men (mean 5.18 versus 4.92, $P=.048$).

At the 16-month follow-up (T2), women reported higher cell phone access than men ($P=.005$), and were more likely to SMS their parents ($P=.003$). There was an increase in using the Internet for health information by T2 for both men and women, but only significant for women (202/314, 64.3%, versus 105/204, 51.4%, $P=.004$). At T2, women continued to have a significantly higher presence on Twitter and Instagram (tagging people, posting status updates, and posting photos/videos). Women were also significantly more likely to login to an SNS at least once a day at T2 (265/311, 85.2%, versus 161/208, 77.4%, $P=.02$).

Acculturation

At baseline, participants in the *high Latino-high American* category used their cell phone for significantly more activities compared with participants in the *high Latino-low American* category (mean 6.14 versus 5.57, $P=.02$). Sending SMS to friends also significantly varied between cultural identities with 91.0% (213/234) of those in the *high Latino-high American* category sending more SMS to friends, compared with 83% (88/105) in the *low Latino-high American* category.

At the 16-month follow-up (T2), there was an increase in differences between acculturation categories. Most notably, those in the *high Latino-high American* category performed significantly more activities with their cell phone than those in the *low Latino-high American* and the *high Latino-low American* categories (mean 6.53 versus 6.04 and 5.92, respectively, $P=.009$). Participants in the *high Latino-high American* and *low Latino-high American* categories were significantly less likely to have a Facebook account compared with the *high Latino-low*

American and the *low Latino-low American* categories (194/285, 68.0%, and 88/122, 72%, versus 82/99, 83%, and 16/18, 89%, respectively, $P=.01$). By contrast, and compared with other categories, the *high Latino-high American* category was significantly more likely to have a Twitter (181/285, 63.5%) or Instagram (79/287, 28%) account ($P<.001$ and $P=.04$, respectively).

Multivariate GEE Models

Final multivariate GEE models included change between baseline and 16-month follow-up for selected social media variables, stratified by sex and acculturation categories and controlling for age and the intervention/control group ([Table 3](#)). Over time, access to a cell phone (adjusted odds ratio, aOR, 2.34, 95% CI 1.126-4.844) and Internet use (aOR 10.40, 95% CI 1.829-59.194) significantly increased for women. Women were more likely to research health information over time (aOR 2.29, 95% CI 1.576-3.341), and although both men and women experienced declines in Facebook use, women had a larger decline (aOR 0.260, 95% CI 0.167-0.406 versus aOR 0.318, 95% CI 0.169-0.600). Between baseline and T2, both men and women increased the mean number of activities performed on a cell phone (adjusted beta coefficient men=.551, 95% CI 0.222-0.879 and adjusted beta coefficient women=.675, 95% CI 0.413-0.938), as well as use of YouTube and Instagram ([Table 3](#)).

The *high Latino-high American* cultural group reported a significant increase in the number of activities performed on a cell phone over time (adjusted beta coefficient .517, 95% CI 0.262-0.772), whereas the *low Latino-high American* group significantly declined in high-frequency SMS (aOR 0.484, 95% CI 0.238-0.983). Except the *low Latino-low American* group, all acculturation group types significantly increased in researching health information on the Internet with the *low Latino-high American* group experiencing the greatest increase (aOR 2.54, 95% CI 1.398-4.606). Excluding the *low Latino-high American* group, all acculturation groups significantly decreased Facebook use over time. YouTube use increased for both high Latino groups, and Instagram use increased for all groups except the *low Latino-low American* group, which was omitted because there were no Instagram users in that group.

Table 3. Changes in social media access and behaviors between baseline (T1) and 16-month (T2) follow-up, stratified by sex and acculturation categories^a.

Social media variables	Sex		Acculturation categories			
	Men, Beta or OR (95% CI) ^b	Women, Beta or OR (95% CI) ^b	High Latino-high American, Beta or OR (95% CI) ^b	Low Latino-High American, Beta or OR (95% CI) ^b	High Latino-low American, Beta or OR (95% CI) ^b	Low Latino-low American, Beta or OR (95% CI) ^b
Cell phone access (yes)	0.804 (0.452-1.429)	2.34 (1.126-4.844) ^c	1.67 (0.842-3.318)	0.453 (0.136-1.504)	1.38 (0.603-3.172)	Omitted ^d
Mean number of activities on cell phone ^e	.551 (0.222-0.879) ^f	.675 (0.413-0.938) ^f	.517 (0.262-0.772) ^f	.458 (-0.016 to 0.932)	.275 (-0.224 to 0.773)	.571 (-0.191 to 1.333)
Send/receive more than 100 SMS/day	0.938 (0.571-1.541)	0.844 (0.568-1.254)	0.956 (0.630-1.451)	0.484 (0.238-0.983) ^g	1.45 (0.651-3.215)	1.22 (0.182-8.227)
Internet use	1.76 (0.343-9.043)	10.40 (1.829-59.194) ^c	1.01 (0.986-1.043)	1.03 (0.976-1.085)	1.07 (0.995-1.144)	0.959 (0.884-1.041)
Research health information on Internet	1.40 (0.924-2.135)	2.29 (1.576-3.341) ^f	1.573 (1.041-2.378) ^g	2.54 (1.398-4.606) ^c	1.97 (1.019-3.809) ^g	1.86 (0.382-9.072)
Facebook	0.318 (0.169-0.600) ^f	0.260 (0.167-0.406) ^f	0.173 (0.100-0.300) ^f	0.541 (0.273-1.070)	0.381 (0.148-0.984) ^g	0.001 (0.004-0.232) ^g
Twitter	1.49 (1.056-2.107) ^g	0.965 (0.690-1.351)	1.06 (0.739-1.529)	0.867 (0.504-1.493)	1.03 (0.603-1.758)	0.505 (0.059-4.295)
YouTube	1.89 (1.228-2.916) ^f	1.87 (1.327-2.637) ^f	1.86 (1.247-2.786) ^c	1.29 (0.734-2.278)	2.68 (1.445-4.968) ^c	0.350 (0.061-2.003)
Instagram	3.99 (1.854-8.571) ^f	3.22 (2.095-4.950) ^f	1.19 (1.101-1.290) ^f	1.25 (1.139-1.374) ^f	1.16 (1.049-1.292) ^c	Omitted ^d

^aAll models controlled for age and the intervention/control group.

^bOdds ratios (OR) or beta coefficients represent the change in social media variables from baseline to 16-month follow-up stratified by sex or acculturation categories.

^c $P < .01$

^dOmitted odds ratios are due to perfect prediction of the outcome variable in that group.

^eData presented as beta coefficient (95% CI)

^f $P < .001$

^g $P < .05$

Discussion

Principal Findings

To our knowledge, this is the first longitudinal study to examine specific social media use and behaviors among Latino youths by sex and acculturation. Consistent with prior research on overall social media use [2,14], participants in this sample were extensive social media users, but differences by sex and acculturation did emerge. This is important for public health practitioners who target minority youths as part of mobile health interventions.

Social Media Use

As expected, social media-related access, utilization, and activities increased over the 16 months. Using cell phones increasingly for emailing and Internet activities at follow-up were likely a result of maturity, with email being more professional and used for schoolwork. A particularly interesting finding was the large increase in searching for health information

online between the 2 periods. This is consistent with prior studies of youths reporting that they would rather receive information online (versus traditional forms), especially sexual health information [26-29]. The participants of this study belonged to the 9th to 10th grade, which corresponds to a period when adolescents are becoming more autonomous, curious, and searching for their own information as opposed to asking a parent or guardian, or even a health care provider [26]. Future health-focused interventions should consider how youths could receive accurate and developmentally salient information via the Internet and mobile technologies.

Sex Differences

Women were earlier adopters of newer technology and applications such as Instagram, and were more active on SNSs. This is consistent with prior research suggesting that the primary purpose for female communication is to build connections and acquire confirmation and support [16]. One possible explanation for this finding is that adolescent women may use social media as a way to develop intimacy and share their feelings with their

peers and social networks [30]. However, being more expressive on social media can also lead to more vulnerability and potential cyber bullying or cruelty on these platforms [31,32], and therefore, it is crucial to train youths on how to safely use these new and changing platforms. Women were more active on SNSs, but they also used the Internet for positive purposes, such as researching health-related information.

Despite Latino parents generally being more protective of women [18], results suggest that women in this sample obtained cell phone access at a greater rate than men. One plausible explanation is that parents may relax their protective principles when it comes to cell phone use compared with in-person exposure and relationships because they feel they can monitor their children more closely with a cell phone [33,34]. Alternatively, participants come from a large immigrant population where parents may not be aware of how much time is spent on media or their children's behaviors on these platforms. Immigrant parents might have less strict principles regarding limiting excessive use and monitoring mobile activities or networks. Nonetheless, this provides an opportunity for mobile health interventions to reach Latina women and provide targeted health information—particularly in protective environments where it is taboo to discuss reproductive health issues [35].

Acculturation Differences

Similar to previous research, participants belonging to the high Latino and American cultural group were more active on cell phones over time. Prior research suggests that higher acculturation levels may lead to increased risk behaviors [14,21]. At the same time, individuals in this group can be easily targeted with mobile-based interventions based on their social media access and use.

The low Latino-high American group was the only group to show a decline in high-frequency SMS. One explanation for this finding is that the higher American groups may be faster to adopt newer platforms and apps compared with the low

American identity groups. Traditional SMS may also be declining because of new features available in popular apps, such as commenting on photos in Instagram and other interactive communication features. However, the insignificant change in the high Latino-high American group could be explained by SMS being a low-cost way to communicate with people across the world, especially for this sample of immigrant Latinos where family members may remain in home countries. Although both groups self-identify with higher American culture, the high Latino group may still have strong family ties in their home country, and thus, SMS remains an important communication tool.

Limitations

Despite the longitudinal nature of this study, results should be considered in light of limitations. First, the data were self-reported and could be subject to response bias due to social desirability. However, this was attenuated by the use of personal laptops and audio capability to increase data dependability [36]. Second, because several social media outcomes were examined, there is a possibility of a multiple comparisons problem. However, an increased sample size is a method of limiting multiple comparison problems [37], and the sample size of 555 in this study was deemed sufficient to detect differences between groups and not due to random chance alone.

Conclusions

We know young people from diverse cultures and backgrounds quickly adopt social media, and it evolves rapidly. The public health community has a unique opportunity to disseminate health-related messages via digital platforms for high-risk Latino youths, given their rapid adoption of newer applications and sites, and this is especially important for Latino youths who have been cited as harder to reach or retain in health-promotion programs [38,39]. At the same time, policies and programs must formulate better methods for youths to safely engage with social media [7,8,40,41].

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Authors' Contributions

ML and AV designed the analysis. ML conducted the analyses and modeling, in addition to preparing the manuscript and tables. AV, MT, and SG provided advice on data analyses. MT and SG provided comments to the manuscript. AV edited the manuscript. SW provided guidance on the project and data collection. All authors reviewed, read, and approved the final manuscript.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Bivariate relationships of social media use at T1 and T2, by sex and acculturation.

[PDF File (Adobe PDF File), 370KB - [mhealth_v3i3e89_app1.pdf](#)]

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Abbreviations

- aOR:** adjusted odds ratio
- ELYP:** Empowering Latino Youth Project
- GEEs:** generalized estimating equations
- SMS:** short message service
- SNSs:** social networking sites

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Original Paper

Home Telehealth Video Conferencing: Perceptions and Performance

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Abstract

Background: The Flinders Telehealth in the Home trial (FTH trial), conducted in South Australia, was an action research initiative to test and evaluate the inclusion of telehealth services and broadband access technologies for palliative care patients living in the community and home-based rehabilitation services for the elderly at home. Telehealth services at home were supported by video conferencing between a therapist, nurse or doctor, and a patient using the iPad tablet.

Objective: The aims of this study are to identify which technical factors influence the quality of video conferencing in the home setting and to assess the impact of these factors on the clinical perceptions and acceptance of video conferencing for health care delivery into the home. Finally, we aim to identify any relationships between technical factors and clinical acceptance of this technology.

Methods: An action research process developed several quantitative and qualitative procedures during the FTH trial to investigate technology performance and users perceptions of the technology including measurements of signal power, data transmission throughput, objective assessment of user perceptions of videoconference quality, and questionnaires administered to clinical users.

Results: The effectiveness of telehealth was judged by clinicians as equivalent to or better than a home visit on 192 (71.6%, 192/268) occasions, and clinicians rated the experience of conducting a telehealth session compared with a home visit as equivalent or better in 90.3% (489/540) of the sessions. It was found that the quality of video conferencing when using a third generation mobile data service (3G) in comparison to broadband fiber-based services was concerning as 23.5% (220/936) of the calls failed during the telehealth sessions. The experimental field tests indicated that video conferencing audio and video quality was worse when using mobile data services compared with fiber to the home services. As well, statistically significant associations were found between audio/video quality and patient comfort with the technology as well as the clinician ratings for effectiveness of telehealth.

Conclusions: These results showed that the quality of video conferencing when using 3G-based mobile data services instead of broadband fiber-based services was less due to failed calls, audio/ video jitter, and video pixilation during the telehealth sessions. Nevertheless, clinicians felt able to deliver effective services to patients at home using 3G-based mobile data services.

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KEYWORDS

telehealth; video conferencing; reliability; effectiveness, home care; mobile data networks; broadband

Introduction

Overview

The Flinders Telehealth in the Home trial (FTH trial) was conducted in South Australia during 2013 to 2014. The trial introduced telehealth services in community-based palliative care and home-based rehabilitation services for the elderly (Textbox 1).

Textbox 1. Services introduced during the Flinders Telehealth in the Home trial (FTH trial).

Service	
1.	Community-based palliative care: Patients and their carers received video-conferencing and remote monitoring services from a palliative care nurse using a tablet device (eg, iPad), a self-assessment application to record their health status, and electronic devices and scales to monitor their physical activity and weight.
2.	Home-based rehabilitation services for the elderly: Patients were remotely monitored by a therapist who made video calls as required [1]. They also had access to rehabilitation and speech therapists using a tablet device (eg, iPad), a self-assessment application to record their health status, and an exercise tracking device to monitor their physical activity.

Technology

Clinical care was delivered from the Repatriation General Hospital, Adelaide, South Australia to participants using Internet Protocol-based video conferencing. Connectivity between the hospital and participants was achieved through the following mechanisms (1) the Australian National Broadband Network (NBN), a fixed line fiber to the premise network (FTTP) and (2) an Internet Service Provider (ISP) such as third and fourth generation (3G/4G) mobile data services (provided by a national telecommunications carrier (eg, Telstra).

Participants in their own homes were lent an Apple iPad tablet with WiFi connectivity to a NBN "ready" router with inbuilt wireless IEEE 802.11n (WiFi) and a NBN connection with a bitrate of 25 Mbps/5 Mbps (Figure 1) or an Apple iPad tablet with wireless connectivity through a standard commercial 3G/4G

For all groups, clinical teams emphasized the need for solutions appropriate for patients ≥65 years of age. The applications needed to be simple to use and interoperable with existing information and communications technology (ICT) infrastructure used by the health services. The equipment chosen was low-cost, consumer-grade, and as far as possible, based on non-proprietary standards.

mobile plan (Figure 2). Palliative care patients were lent WiFi connected scales.

The video conferencing application used by the clinicians and FTH trial participants was based on a proprietary system Vidyo [2] hosted in the Flinders University data center to ensure low latency performance. Hospital-based clinicians scheduled calls to their patients using the Vidyo application. Clinicians conducted consultations from purpose built video consultation suites or iPads and participants answered video calls on their loaned iPads.

Prior work has identified the importance of technology factors on the success of home telehealth [3]. The research aims of our study are to identify which technical factors influence the quality of video conferencing in the home setting and to assess the impact of these factors on clinical perceptions and acceptance of video conferencing for health care delivery into the home.

Figure 1. NBN network architecture.

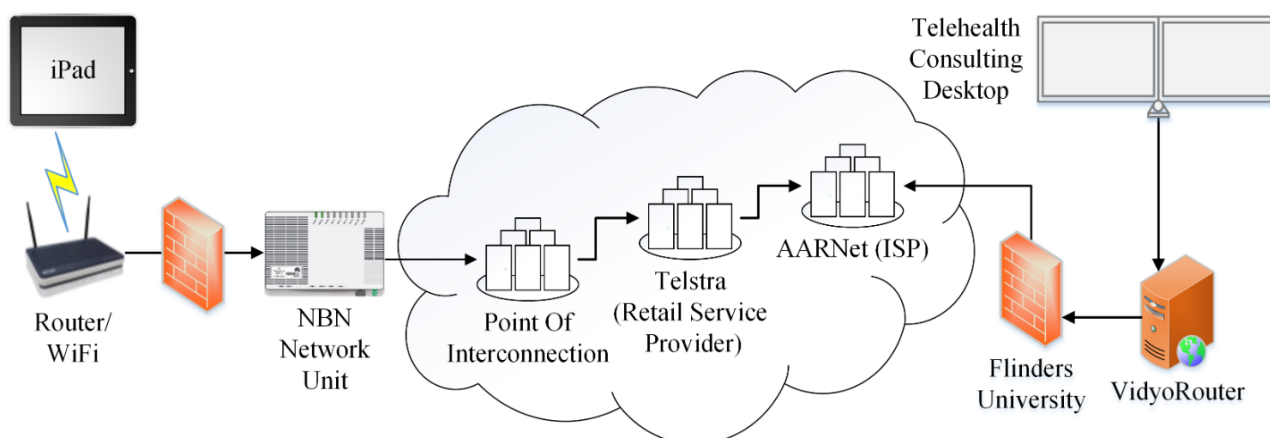
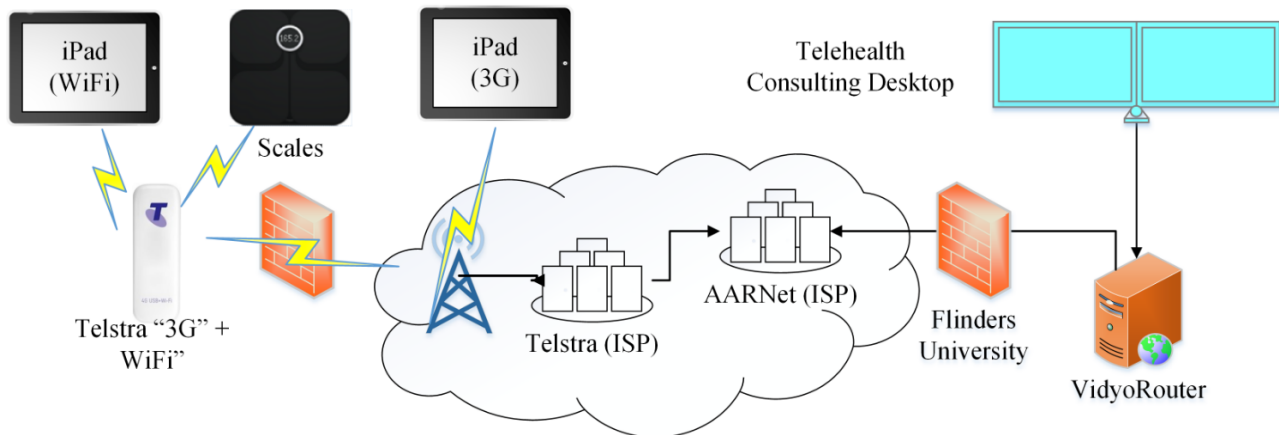


Figure 2. Mobile data network architecture.

Methods

Ethical Approval

An action research process developed several procedures during the FTH trial to investigate technology performance and users' perceptions of the technology (Textbox 2).

Textbox 2. Procedures developed during the Flinders Telehealth in the Home trial (FTH trial) investigation.

Procedures

1. Simple tests of signal power, data download, and upload rates for Telstra mobile data 3G services (Telstra 3G) for differing received signal powers were undertaken at selected locations. Measurements of the signal powers for 4G services were not undertaken because in areas of poor coverage the equipment falls back to use 3G services.
2. Development of an experimental method to objectively measure the quality of audio, video, and failed calls in the field using Telstra 3G and FTTP services provided by the NBN.
3. Assessment of the reliability of video conferencing calls over the NBN and Telstra 3G using call log data from the Vidyo system to determine the average duration of calls, possible failed calls, and reconnection attempts.
4. A questionnaire for clinical video conferencing users of the NBN and Telstra 3G services to assess their experiences between the 3rd of March, 2013 and the 25th of July, 2014.

Data Transmission Rates for Mobile Data Services

Due to the variable nature of radio propagation in the bands used by mobile data services it was difficult to validate Telstra 3G geographical coverage maps. In order to sample the real life performance of Telstra 3G services, a total of 249 measurements of the signal power levels (dBm) reported by the FieldTester (Staircase 3, Inc) application on the iPad tablet device [4], bitrates (kbps; up and down), and latency for a 64 Byte packet return trip reported by the Speedtest (by Ookla) application [5] were made at 14 locations using an iPad connected to the 3G network. Measurements provided a representative sample of high, medium, and low signal powers. The signal power at 10 second intervals was recorded for between 10 and 54 minutes at each location. Observations made during each minute were averaged to provide an indication of the signal power during each minute. Microsoft Excel software was used to analyze the results.

Experimental Comparison of NBN and Telstra 3G services

To investigate the influence of using NBN compared with Telstra 3G networks on video conferencing an experimental method was developed to measure the quality of audio and video conferencing between a tablet device used by patients and a clinician's computer. Each test involved a patient tablet that was placed in front of a media source which streamed the content to the clinician's computer using a video conferencing client (Figure 3). As the log files provided by the Vidyo client did not provide network statistics related to video quality such as video packet loss, a staff member monitored each stream to determine the quality of the conference.

Clinical users felt that the key quality markers for a video conference were the number of times a call failed and had to be re-established, absent or delayed audio or video (jitter), and significant pixilation of the video. Using database software specifically developed to record the observations of the number

and durations of negative events, each individual event (jitter and/or pixilation) observed was assigned with a start and end time. Failed calls were also counted. A failed call was a call that was unexpectedly terminated and included calls that were unable to complete a connection. While the results can be considered subjective, the same ICT staff member conducted all tests to minimize variances in the evaluation process.

Round trip Ping delay and signal power (dBm), as reported by the FieldTester application, were recorded using a second tablet at 10-second intervals; the begin and end timestamps of the other events were recorded with a one-second granularity throughout a call session time of 2700 seconds (approximately 45 minutes). A call session time of 45 minutes represented the

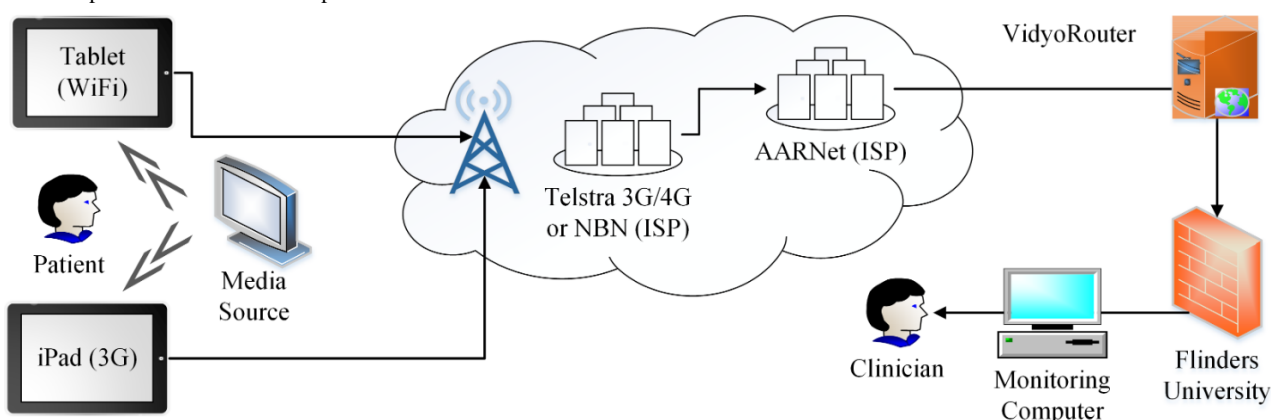
average duration of a rehabilitation session. Average durations for palliative care were shorter (8 minutes).

Devices were configured to use Telstra 3G mobile data services only, because all 4G services will fall back to 3G services when the 4G signal power fades. This represented a more realistic telehealth conference as the targeted patient geographical locations were often in areas with poor 3G or 4G coverage. The different test combinations of broadband technology (Telstra 3G or NBN) and the different tablet devices that were tested are shown in Table 1. The tests were conducted over several days with a total duration of 58.11 hours using the Vidyo conferencing client.

Table 1. Test scenarios for networks, devices and test duration.

Broadband technology	Tablet connectivity	Tablet type	Duration, hours
NBN	WiFi to NBN router	iPad	9.85
3G	Telstra 3G SIM card	iPad	15.75
3G	WiFi to 3G access point	Samsung Galaxy	10.5
3G	WiFi to 3G access point	iPad	2.05
3G	3G SIM card	Android FonePad	8.25

Figure 3. Experimental field tests setup.



Reliability of Video Conferencing

An automated log of the calls made during the FTH trial using the Vidyo video conferencing system provided data for reliability analysis using the statistical software package SPSS. Call log records (N=4763) covered the period from October 20, 2013 to July 25, 2014. The call log contained data regarding the call duration, patient or clinician identifier and device identifier, the call start and end times, whether the call was via a conference room or direct, information on whether the call completed successfully or failed, and the call direction (incoming or outgoing). Data in the call log was cleansed of call records unconnected with clinical service (eg, test calls), and calls records were grouped to represent telehealth sessions

when clinicians provided services to patients. A telehealth session comprised one or more calls and lasted between 5 to 45 minutes. If the first call to a patient failed for any reason, subsequent calls may have been made to re-establish the telehealth session. A total of 1021 (21.43%, 1021/4763) valid successful or unsuccessful telehealth sessions were identified.

Clinical Perceptions of Video Conferencing

After each clinical consultation clinicians were asked to complete a computer-based questionnaire about the telehealth consultation that had just taken place. A total of 687 responses were received for consultations that used Telstra 3G and NBN technologies (Textbox 3).

Textbox 3. Computer-based questionnaire.

Questions

- Clinicians' perception of video and audio quality (1 very poor - 5 very good)
- Whether the patient appeared to be comfortable with the technology (1 not at all - 5 completely)
- Why was the patient uncomfortable with the video conference? (video/audio quality/connection issues/other)
- Rate and comment on the effectiveness of using telehealth with patients compared with home visit (1 much worse - 5 much better)
- Rate and comment on experience of using telehealth with patients compared to home visit (1 much worse - 5 much better)

To facilitate statistical analysis in SPSS, responses to questions about video and audio quality responses merged from 5 categories to 3. The "very good" responses were recoded as "good". Similarly, the "very poor" responses were recoded to "poor". Questions requesting further information as free text comments were graded for relevance to results of respondent's assessments using NVIVO 10 qualitative analysis software.

Results

Data Transmission Rates for Mobile Data Services

Clinical teams did encounter poor coverage in areas previously identified by analysis of Telstra 3G coverage maps. It was also

Table 2. Signal power, data rates (kbps), and latency (milliseconds).

Signal power	Data rate down/up, kbps		Latency, mean (SD)
	Mean (SD)	Minimum	
Weak, N=70	4304/789 (4304/345)	72/39	96 (66)
Moderate, N=99	7376/1255 (3084/1001)	999/123	62 (18)
Strong, N=80	11077/2543 (4477/1542)	4477/1542	59 (26)

Most noticeable were the high variability of the upload (SD 0.61) and download (SD 0.56) rates, which in some cases, when signal powers were low, could reduce the minimum bitrates to values which could limit video and audio quality. At low power levels the average network latency rose to 96ms which may reduce the audio quality.

Experimental Comparison of NBN and Telstra 3G services

The majority of the testing was undertaken when signal power was moderate but many instances of weak signal power were observed. Visual examination of 37 hours of experimental recordings of Telstra 3G signal power and events such as network packet "Ping" delay and/or audio and video jitter showed no time correlation between signal power and other events (Figure 4).

A comparison of the mean number of adverse events during each video conferencing session for each test combination shows

observed that the location of the home and its construction could result in poor interior reception and that weather conditions were an additional factor. At one location signal power measurements (N=54) made during wet weather showed lower mean signal levels and greater variability than at the same location (N=32) during dry weather at -96.1 dBm (SD 8.3) and -86.7 dBm (SD 0.6), respectively. The analysis of all 249 measurements by signal power levels (weak 97 to -109 dBm; moderate -86 to -96 dBm, strong >-86 dBm) for data transmission rates, and latency in milliseconds is provided in Table 2.

the best performance was achieved by an iPad tablet via WiFi and NBN (Figure 5). While the rank order may change depending on the parameter chosen to rank each scenario (video and audio jitter or video pixilation events), the NBN-based scenario was always the best.

Across all test combinations, with the exception of those involving the NBN, the duration of the video, audio pixilation, and video jitter events varied from about 5 to 45 seconds with mean values between 15 and 20 seconds. Failed call events were of particular interest because these caused significant issues to telehealth sessions. Only one failed call was observed on the NBN. For the principal configuration deployed in the FTH trial (an iPad connected via Telstra 3G), 4 calls failed during 21 sessions lasting 45 minutes each. Differences between the performance of the iPad, Samsung Tab, and Android FonePad devices were observed for similar connections.

Figure 4. Typical recording of events, signal power and jitter.

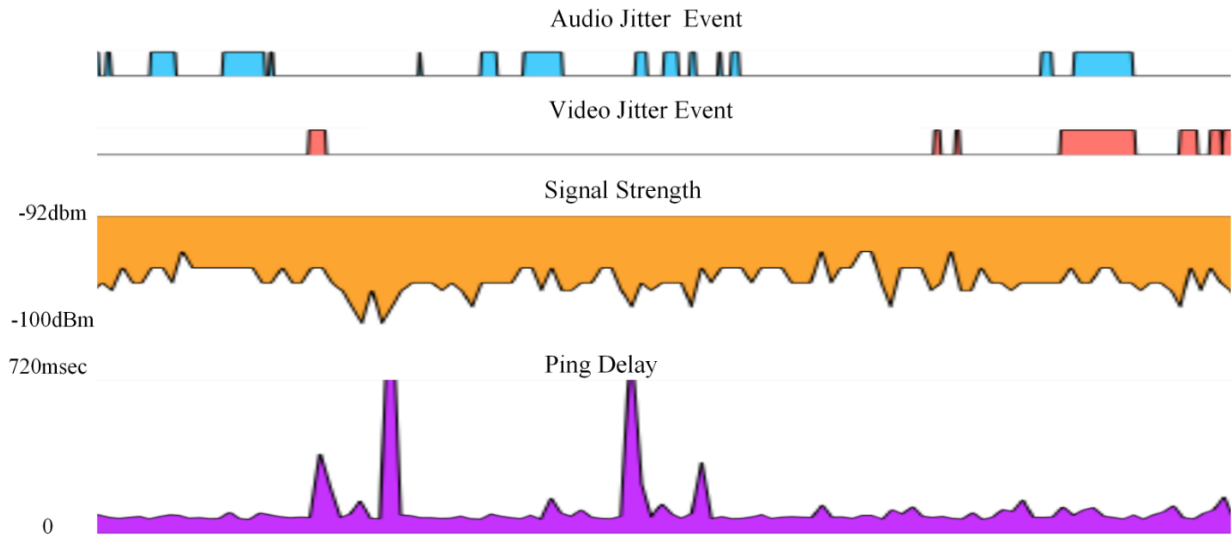
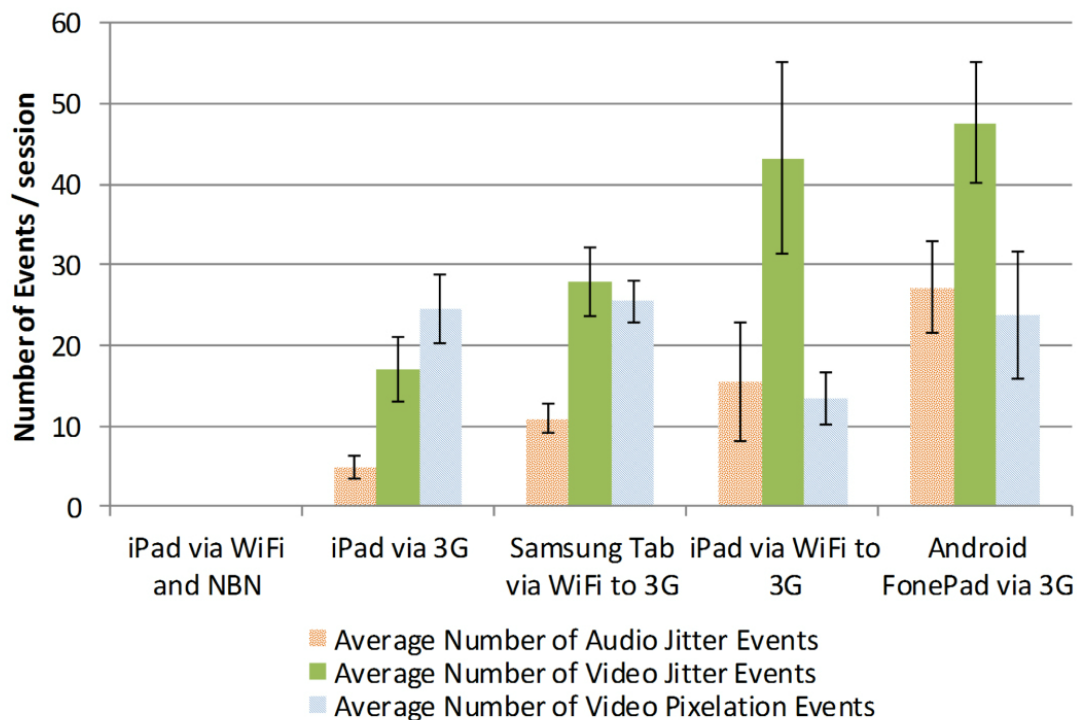


Figure 5. Comparison of Telstra 3G and NBN services (means and SE of session tests).



Reliability of Video Conferencing

Of all the telehealth sessions identified in the call log, 936 (91.67%, 936/1021) were deemed successful. A successful session comprised one or more completed calls in the Vidyo call log. During the successful telehealth sessions, 220 (23.5%, 220/936) required more than one completed video call to be made by clinicians. There were 85 (8.33%, 85/1021) failed telehealth sessions due to more than one call terminating for any reason.

Clinical Perceptions of Video Conferencing

A statistically significant positive association existed between clinical perceptions of video and audio quality ($P < .001$, Pearson chi-square coefficient 325.7). This was to be expected since both video and audio quality is related to the data transmission quality. In the clinician survey the quality of the audio and video for all types of connections was rated by clinicians as good for the majority of telehealth sessions. No statistically significant association existed between the NBN or Telstra 3G connection types and audio or video quality. Examples of clinician comments on audio, video, and reliability issues for the sessions that experienced technical difficulties are shown in Table 3.

Table 3. Examples of technical difficulties from the questionnaire responses (N=687).

Technical difficulty	Comments, n	Example quotes
Audio timing (echoes and delays)	22	"The audio was very poor today, the patient sounded like a robot ... it was very distorted and unclear, also very delayed".
Image quality	50	"Not crisp, but good enough for clinical purpose", or "Not receiving all frames so picture a bit jumpy" or "Not sharp but adequate".
Image timing (picture freezing, lack of synchronization with audio stream)	60	"Froze at least once every ten minutes" or "Froze x 1 however recovered" or "frozen picture, distorted, audio and visual not in sync, unable to continue therapy session"
Unsuccessful calls or reconnection attempts	22	"Patient unable to see and hear clinician for approx. 1 min (frozen), nil issues on clinician's end. Dropped out. No issues after re-dial" or "Regular freezing of picture requiring 3x hang ups and redials.

A statistically significant association was found between audio quality and patient comfort with the technology ($P<.001$, Pearson chi-square coefficient 95.3). When the patient was comfortable with the technology, audio quality was judged as good (86.3%, 403/467). When the patient was ambivalent, the audio quality was good in 67.6% (46/68) of the responses. When the patient was uncomfortable with the technology, the audio quality was poor in half (50.0%, 16/32) of the responses. An analysis of responses for different Internet types was not possible due to small sample sizes.

A statistically significant positive association existed between video quality and patient comfort with the technology ($P<.001$, Pearson chi-square coefficient 63.4). When the patient was comfortable with the technology, the video quality was rated as good in 404 (72.4%, 404/558) of the responses. Some patients were uncomfortable with the technology when initially learning how to use it (2.0%, 14/687), for example "couldn't turn machine on, then volume had been switched off". Some required ongoing supervision (2.3%, 16/687) possibly due to cognitive problems: "Continues to require phone call to open Vidyo prior to call".

Clinicians rated the effectiveness of conducting a session using telehealth compared with a home visit as equivalent or better 88.5% (478/540) of the time. A statistically significant association existed between audio quality and the effectiveness of conducting a session compared to a home visit using telehealth ($P<.001$, Pearson chi-square coefficient 142.1). The clinicians rated the audio quality as good on 444 (82.4%, 444/539) occasions. When clinicians rated the effectiveness of telehealth as equivalent to or better than a home visit, audio quality was reported as good in 313 (65.6%, 313/477) occasions. A statistically significant association also existed between video quality and the effectiveness of conducting a telehealth session compared with a home visit ($P<.001$, Pearson chi-square coefficient 96.4). When the telehealth effectiveness was rated as equivalent or better, video quality was reported as good in 368 (77.1%, 368/477) occasions.

Clinicians proved to be remarkably resilient in dealing with issues they encountered in using telehealth. Some significant issues did not prevent them from rating telehealth as effective or more effective than a home visit. For instance, out of 20 comments from clinicians rating telehealth as equivalent, one said "Interruption of video freezing impacted on the flow of the session". Another said "Relatively equivalent, some tasks unable

to be completed however easily substituted with other tasks". A third stated:

Lost 20+ mins in establishing a connection. Session equivalent once connection established.

Clinicians rated the experience of conducting a session using telehealth compared with a home visit as equivalent or better 90.3% (489/540) of the time. Clinicians were also asked to comment on the how easy it was to provide a telehealth session compared to a home visit. Responses showed that on 71.6% (192/268) of the occasions, clinicians rated telehealth sessions as easier than a home visit focusing on time, travel, and efficiency savings (22 comments) as being key advantages. For example, one stated "Better as more efficient, achieved equivalent outcomes with no restrictions", and another said "No travel involved, often when you visit in person you may need to wait while the patient is finishing something else, but the patients' give priority to the videoconference". Clinical issues were cited by clinicians rating the telehealth session as less easy than a home visit. For instance, one said "abandoned session", and another:

More difficult this time. Previously ok when patient was non weight bearing and not allowed any ankle active movement. Now as weight bearing status has changed it was more difficult to perform my assessment and treatment.

Discussion

Principal Findings

The main findings of this study are that the effectiveness and experience of home telehealth was judged by clinicians as equivalent to or better than a home visit and that the quality of video conferencing using 3G-based mobile data services in comparison to broadband FTTP services is less, due to failed calls during successful telehealth sessions, audio, video jitter, and video pixilation. However, clinicians were still able to deliver effective services to patients at home using this less than perfect technology.

Experimental field tests demonstrated significantly better performance of video conferencing over the NBN FTTP network, which provided an almost error-free performance for audio and video and no failed calls, whereas a greater proportion of adverse audio and video events were observed when using Telstra 3G mobile data connections. Recent work [6] has also

reported that participants connected via 4G mobile data services experience more audio and visual difficulties than participants on the NBN. Earlier work [7] reported similar problems with 3G connectivity in areas of poor signal strength. Since NBN rollout has been slow and patchy, current (and likely future) telehealth services will continue to rely on 3G/4G mobile services. One recent study of videoconferencing over 4G networks found that 4G networks were an appropriate technology to deliver real-time video consultations; but due to known variability in performance of 4G networks, these (networks) should be evaluated prior to establishing a telemedicine service [8]. Other work has highlighted the value of understanding the actual mobile data coverage in urban New York in order to provide reliable services based on text messaging [9]. Laboratory-based tests discuss the performance of video conferencing used in emergency medical dispatch situations and report that video transmissions over a 3G network to a mobile phone froze for short periods during 21% of calls, which is consistent with our results [10,11]. Further research is required to determine if higher levels of reliability can be obtained using 4G services.

Measurements of data transmission rates over a Telstra 3G mobile data connection showed that 3G signal strength was a poor indicator of download or upload bitrates, and transmission rates can drop below levels needed to maintain good video and audio quality when the signal strength was weak or moderate. The extreme variability of transmission rates that can drop to less than half the average rate was a little surprising, and can only be the result of mobile data base stations and the associated backhaul network managing data rates to accommodate multiple users in real-time within an allocated base station capacity and other factors such as interference from other radio frequency sources or variable radio propagation due to weather related atmospheric layers. These findings support the reservations expressed by Holma that:

One common belief in the industry and among consumers is that a "faster network" provides a better user experience, meaning that a consumer's experience with a smartphone will be inherently superior in an LTE network than an HSPA+/DC-HSDPA network. The reality can be somewhat different. [12] [12]

It was anticipated that there could be an obvious correlation between intervals during which the 3G signal power was low and audio or video events. Further it was thought that there could be a correlation between intervals during which the "Ping" round trip delay time was high and the number/frequency of audio or video jitter events. In reality, even though large numbers of audio and video events occurred, there was no obvious time correlation observed between signal power and adverse audio, video or pixilation events, or the network delay time for 64 byte "Ping" packets.

Possible explanations for this behavior are that in a mobile data wireless environment the radio base station allocates resources continuously on a sub-second time scale. Data is transmitted in 2 ms or 10 ms blocks, and depending on signal power, interference or the presence of other users, modulation schemes

and coding schemes may change from block to block [12]. These sub-second changes may reduce data throughput and increase packet delay. Video client decoding algorithms process video and audio packets on a sub-second time scale in order to manage delayed or missing data. Users simply see the combined results of this complex interaction. Degradations to audio and video quality are only observable when the information loss is so great that neither the network nor video client can compensate for the delayed or missing information. While fixed line Internet networks also experienced network transmission impairments such as congestion which could impact video and audio quality, significant network transmission problems were not observed on the NBN connection used in the experimental tests.

The relatively high ratio of failed calls to successful calls (compared to fixed and mobile telephony calls) made per telehealth session using Telstra 3G services is concerning. An average call failure rate of 23.5% during a telehealth session is high. By comparison, Telstra claims that the probability of a call failure will be less than 3% for mobile phone customers. We have no explanation for this application behavior. In theory, signaling messages between video conferencing clients require little network capacity, so calls should not fail even when video and audio quality is poor. In practice, calls do fail and fail to connect even when network capacity appears high. Despite the high failure rate of calls compared with the performance of calls on the mobile telephony network, clinical users appear to be willing to persist and try to make new calls to establish a telehealth session or re-establish a session if a call failed. On the whole, clinicians expressed satisfaction with the effectiveness of telehealth services in this health care setting even when using less than perfect telecommunications.

Limitations

Many limitations to this study arose from the live, in-service nature of the research. Measurements of signal power depended on the FieldTester application for the iPad. This application has no publically traceable calibration of field strengths (volts/m) to signal power readings (dBm). Packet loss and packet jitter in networks can also significantly impact audio and video quality, but we were unable to find an application for tablet devices that would measure these parameters. Measurements of download and upload bitrates using the Ookla application were dependent on a pre-determined methodology over which we had no control. Finally it should be noted that sample sizes from the clinician questionnaire were insufficient to enable comparisons between the ways different clinical services perceived video conferencing technology.

Conclusions

Clinicians felt that the effectiveness and experience of home telehealth was equivalent to or better than a home visit even though the survey data indicated that audio and video quality during telehealth sessions was less than perfect. Clinicians persisted with using mobile data services even when calls failed and video or audio quality was degraded. We used a repeatable experimental method to measure video conferencing performance on mobile devices in the field and showed video conferencing services using 3G technology frequently suffer from failed calls, audio and video jitter, and video pixilation.

Analysis of call logs also confirmed that failed calls were a frequent occurrence. As well, measurements of the data transmission capacity showed a high degree of variability, which may degrade video and audio quality.

The performance of tablet hardware and operating systems (Android and Apple IOS) differed, reinforcing the need to carefully select and test telehealth systems prior to deployment. While there was no significant association between the type of Internet connection used by the patient and audio or video quality as rated by clinicians, statistical analysis of clinical

perceptions shows that the effectiveness of telehealth sessions and client comfort were closely linked to audio and video quality.

Field measurements for the video calls using the NBN demonstrated an almost error-free performance for audio and video. Given that 85.4% (587/ 683) of the telehealth sessions took place over mobile data services, it is reasonable to infer that the majority of audio and video quality issues experienced by clinicians could have been avoided if NBN connections had been available to participants in the project.

Acknowledgments

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Authors' Contributions

AT, GM, and SR designed and conducted the study. GM, JP, and SR carried out the data collection and performed the analysis. AT drafted the manuscript. All authors critically reviewed and approved the final manuscript.

Conflicts of Interest

None declared.

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Abbreviations

FTH trial: Flinders Telehealth in the Home trial
FTTP: fiber to the premises
ICT: information and communications technology
NBN: Australian National Broadband Network
3G/4G: third and fourth generation mobile data service

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Original Paper

My Interventional Drug-Eluting Stent Educational App (MyIDEA): Patient-Centered Design Methodology

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Abstract

Background: Patient adherence to medication regimens is critical in most chronic disease treatment plans. This study uses a patient-centered tablet app, “My Interventional Drug-Eluting Stent Educational App (MyIDEA).” This is an educational program designed to improve patient medication adherence.

Objective: Our goal is to describe the design, methodology, limitations, and results of the MyIDEA tablet app. We created a mobile technology-based patient education app to improve dual antiplatelet therapy adherence in patients who underwent a percutaneous coronary intervention and received a drug-eluting stent.

Methods: Patient advisers were involved in the development process of MyIDEA from the initial wireframe to the final launch of the product. The program was restructured and redesigned based on the patient advisers’ suggestions as well as those from multidisciplinary team members. To accommodate those with low health literacy, we modified the language and employed attractive color schemes to improve ease of use. We assumed that the target patient population may have little to no experience with electronic tablets, and therefore, we designed the interface to be as intuitive as possible.

Results: The MyIDEA app has been successfully deployed to a low-health-literate elderly patient population in the hospital setting. A total of 6 patients have interacted with MyIDEA for an average of 17.6 minutes/session.

Conclusions: Including patient advisers in the early phases of a mobile patient education development process is critical. A number of changes in text order, language, and color schemes occurred to improve ease of use. The MyIDEA program has been successfully deployed to a low-health-literate elderly patient population. Leveraging patient advisers throughout the development process helps to ensure implementation success.

KEYWORDS

drug-eluting stents; health informatics; Kolb's learning theory; mHealth; patient-centered design; patient education

Introduction

Overview

Patient medication adherence is challenging across all health care domains [1]. One area where nonadherence bears a high mortality risk is after a percutaneous coronary intervention (PCI). PCI is the most common form of revascularization performed worldwide for the treatment of hemodynamically significant coronary artery stenosis, with over 1 million procedures performed in the United States every year [2]. PCI is performed when the arteries have an increased amount of plaque or have become narrowed. In its most common practice, the cardiologist places a drug-eluting stent (DES) at the site of the narrowing to displace the plaque from against the wall of the artery, which results in improved blood flow. For a year after undergoing the procedure, patients must adhere to a strict drug regimen of 2 antiplatelet medications taken once a day, every day for a year. A previous study [3] noted that 1 of 7 myocardial infarction patients who received a DES during a cardiac catheterization stopped taking their dual antiplatelet therapy (DAPT) within 30 days of the procedure. This failure leads to a *9 times greater* risk of death in the following year due to stent thrombosis [3-6]. DAPT discontinuation rates are 14-57% [7-9]. Multiple authors have called for research improving adherence to DAPT [10,11], with recognition that patient education is one of the few modifiable factors to reduce risks after a PCI [3,12].

Use of Mobile Technology to Educate Patients

Mobile technology provides a unique opportunity to engage and educate PCI patients about the importance of DAPT. However, technology alone cannot improve patient education, especially education related to patient behavior. However, incorporating learning theories into patient-centered educational material is one way to improve this scenario [13-15]. Indeed, Kolb's experiential learning theory [13] has been successfully applied to patient education in a number of health-related areas [16-24]. Kolb's theory is notable for its 4-stage learning circle to engage learners who have different learning styles. A Kolb's learning circle includes (1) a concrete experience, (2) reflective observations, (3) abstract conceptualization, and (4) active experimentation.

In addition to the health care need and the educational theories, another area unique to technology is designing tools to meet the needs of the users. Designing technology interfaces with user participation has been performed for a number of years [25]. The concept of human-centered interfaces has become so standardized that the International Standardization Organization (ISO) has created a standard to ensure the ergonomics of interactive systems [26]. However, the vast majority of patient-centered educational materials are still paper based, with a limited number of studies evaluating electronic patient educational materials [27]. Most patient-centered software app

development has focused on the technical correctness of the algorithm [28]. However, collaborative approaches to biomedical communication have long been advocated [29]. The unique field of health-related patient software using biomedical communication techniques has not applied the concepts from the merging of the fields. We found nothing in the literature that explains the methodology as applied to interactive patient education using a participatory design process. Working with a team, all of whom have had experience with postcardiac rehabilitation, the goal was to explain the process in both technology terms and patient-care phrases. The objective of this paper is to describe the design, methodology, limitations, and results about the ability of the patients to use this tablet app as measured by time of completion and interactive recordings of an electronic mobile technology-based patient education app designed to improve DAPT adherence.

Methods

Development of the Drug Adherence Electronic Tablet App

A multidisciplinary health care team of cardiologists, pharmacologists, patient educators, nurses, and health informatics professionals assisted in development of a Kolb's theory-based drug adherence electronic tablet app called "My Interventional Drug-Eluting Stent Educational App (MyIDEA)." This tablet app was meant to be a stand-alone educational tool to supplement the education of the nurse and physician in medication adherence following the procedure. The team completed a literature review on the DES and the PCI procedure. Initially, a biomedical illustrator (KM) met with the team members and asked for their input about concepts and objectives for DAPT for DES patients. In addition, the biomedical illustrator observed that both the nurse and physician gave verbal instructions to the patient population of interest. She integrated the observed concepts into the development of the app. The team also reviewed the printed educational material typically sent home with a DES patient.

Patient viewpoints and engagement were crucial in the app development. To identify patients who were willing and able to share input, the research team reached out to the local Chicago chapters of Mended Hearts. Mended Hearts is a national nonprofit organization that offers the gift of education, information, hope, and encouragement to heart disease patients, as well as to their families and caregivers. The team was looking for active members who would like to assist in the development a patient-centered educational app. A total of 5 patient advisers agreed to participate. Over several meetings, they gave input into the development based on their personal experiences. Based on the input from our team and the patient advisers, 4 crucial attributes of the target patient population were identified, including (1) low health literacy, (2) aged older than 50 years, (3) able to speak English, and (4) received a PCI with a DES

at the University of Illinois Hospital. Indeed, the typical DES patient may be affected by low literacy, have low health literacy, and little to no higher education as well as an average age of about 65 years [30].

Wireframes and Final App Development

The educational content for the app was first created as a primitive wireframe. A wireframe is a simple schematic similar to a blueprint of a house where major concepts can be discussed before formal development is initiated. Over a 4-month period, we created 6 different versions of the app wireframe and enhanced them with collective observations and collaboration. We showed a paper version of the wireframe to 3 patients in an Institutional Review Board (IRB)-approved study in the hospital for additional feedback (2009-0711) using a semistructured interview.

After agreement on the final HTML5 design of the app, we created static HTML pages for the tablet. The static Web pages could not be customized to individual patients but simulated a single interaction for a demonstration patient.

After vetting the static Web pages, an investigation into platforms occurred. Because of some technical limitations of the iOS platform, the software engineer recommended a switch to the Android platform. He also recommended building in multilingual capability and replacing the graphical text with actual text so that it could be changed as needed without requiring recompilation.

The complete system consists of a hybrid HTML5 Android tablet app, a Health Insurance Portability and Accountability Act secure patient-tracking and data portal, a human-computer interaction monitoring “click-tracking” server, an audio upload server, and a configuration control server for dynamically reconfiguring or updating the text and formatting the app. The tablet app has 2 audio components: narration and recording and playback of the patient’s impressions. The text of the program was written at a sixth-grade reading level. The narration provides an additional method for individuals with low literacy to understand the text-based information, which is at a sixth-grade level. Reflective observation was one of the key aspects of learning in the Kolb’s theory [13]. We have the audio recording and playback to gain a better understanding of what the patients are thinking, how they verbalize concerns, and solve problems based on their reflections of overcoming their obstacles. All audio components contained words and phrases that can be readily understood.

After the MyIDEA program was fully functional, the team and all patient advisers reviewed it. A few modifications were then made including the creation of a summary or recap screen before the learner could exit the app and captioning of instructions on the interface tutorial screens for scenarios where the app was muted. An IRB-approved pilot randomized control trial was initiated, with the interventional arm having access to the functional app. Here, we report the results of the design process overview, which was presented in the earlier section, and initial time utilization of MyIDEA for the interventional arm.

Results

Framework of the App

When the patient advisers and development team first met, we discovered that none of the advisers had any experience with software development, which necessitated description of the purpose of the wireframe (Figure 1) and the envisioned educational app. One of the novel aspects of the patient-centered education was customizing the program to the findings of the individual patient, such as symptoms, medication, and procedure findings. The advisers indicated that the pictures and draft diagrams were too vague for meaningful critique. They indicated that the program should also include an audio component, that the app objectives for medication adherence needed to be explained in the initial screen, and that the duration of DAPT needed to be clearly stated.

The framework of the app was built integrating Kolb’s experiential learning theory. This theory is a 4-part cyclical model aiming to address 4 types of learning styles: converger, diverger, assimilator, and accommodator [13]. Kolb’s 4-stage learning cycle shows how experience can be translated into concepts. The 4 stages are concrete experience, reflective observations, abstract conceptualization, and active experimentation [13].

A second iteration (Figure 2) of the wireframes was created and discussed with patient advisers and team members during a second meeting. This discussion revealed that the overall message of the purpose of the DAPT was not portrayed adequately. The patient advisers suggested that the main message be integrated throughout the app with persuasive reasons for adherence clearly demonstrated, instead of only giving the information at the conclusion. Another identified issue was that the wireframes did not adhere sufficiently to Kolb’s theory. In response, we added patient stories and reflective observations about the stories, along with the patient’s symptoms to ensure integration of the entire Kolb’s learning cycle, which was a large-scale restructuring of the app. This procedure offered reinforcement of several critical points, information on proper postcardiac medication regimen, rapid communication with the physician’s staff, and a comfort zone if symptoms should reoccur.

The updated app outline had 5 chapters and text rewritten to reflect the purposes of the DAPT (Figure 3). The specific program features were mapped to the Kolb’s experiential learning theory (Figure 4). Because of scheduling challenges, the patient advisers and the multidisciplinary team separately discussed the subsequent third wireframe. The patient stories developed from the prior comments focused on the following 5 reasons for medication discontinuation: (1) exhaustion after hospitalization, (2) information about duration of medication, (3) cost of medication, (4) travel and challenges of refills, and (5) side effects (Figure 4). Only 2 issues emerged from the discussions concerning the third wireframe: the need for an additional feature, a replay audio button in case someone wanted to hear the audio again, and the need to increase the size of the buttons and controls. Patient advisers focused on giving input about certain slides saying, “Since there are more

recorded/narrative sections later on, is there a need to insert an audio practice example at this point (slide 23)? This will help validate clarity of patient’s speech and possibly make him/her adjust his/her voice for maximum playback quality.”

Although additional meetings occurred for iterations 4-6 of the wireframes, most of the suggestions were about the educational level of the language, layout, and text phrasing; no additional major functional issues emerged. MyIDEA was designed for patients with a sixth-grade reading level so that most patients could understand the information. The patient advisers suggested sentences be shorter, which are conducive to a sixth-grade reading level. Advisers also concluded that if the patients have less than a sixth-grade reading level, the audio track and images will help supplement the written text.

When a hard copy of the final wireframe was shown to 3 IRB-approved consented research participants in a hospital setting, their feedback was extremely positive. They were excited and appreciative to learn more about their PCI procedure. They also liked the idea of patient stories and being able to relate and learn from others in understandable language, through the audio component and graphics of those going through the same experience as themselves.

The seventh wireframe focused on information simplicity and clarity for the patient. The buttons were located at the bottom of the screen, so the patient would focus on the content, not the buttons. One patient adviser said, “Using the program is essential; do not skip the introduction. The patient needs to know what all the buttons are for and where to call or email for program assistance. Make this as simplistic as possible because many patients many not be computer literate. Most may dislike computers and have been fighting it for years. The key is getting the patients to follow the postcardiac instructions.” Of the 2 color designs, the patient advisers were concerned with the text being difficult to read. Another concern was the font size. MyIDEA color design concept 2 was simpler but was described as “not eye-catching.” Another patient adviser stated, “Make this pleasing and eye-catching. It needs to have a positive vibe, so shades of yellow, green, or roman red can be used to create a continuum.” MyIDEA color design concept 2 also incorporated the color palettes of a sports team the patient advisers favored. Patient advisers strongly recommended colors that were bright, as well as common color combinations. MyIDEA color design concept 3 and 4 were created (Figure 5) as a result and patient advisers suggested using MyIDEA color design concept 3. After a few final touches improved the concept for the final design, the patient advisers said it was innovative, and easy to follow.

Figure 1. Sample page from the initial wireframe shown to the multidisciplinary team and patient advisers for feedback.

Kaitlin Fitz

Interactive to explain the PCI treatment.

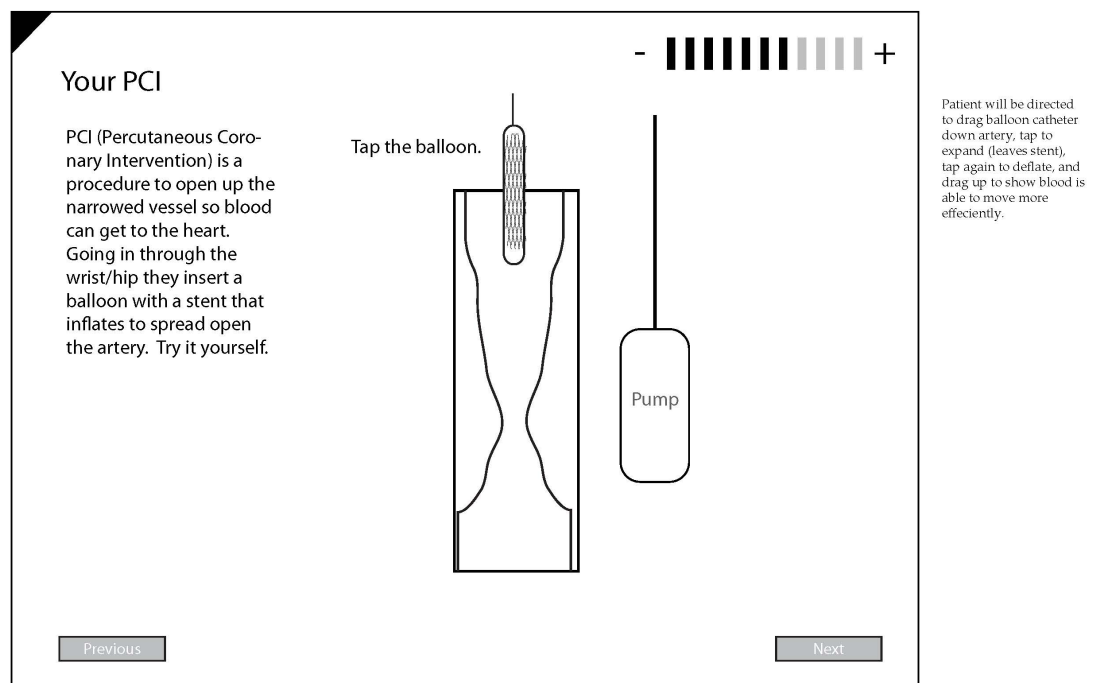
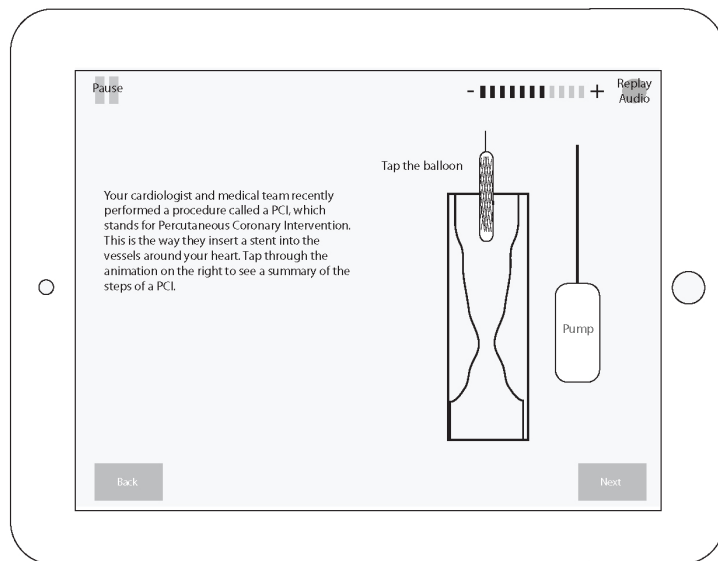


Figure 2. Wireframe number 2 sample page about how a stent works.



Post-PCI Interactive Wireframe (December 2012)

PCI overview. Includes step-by-step walkthrough of procedure. Animated steps are started each time patient taps the illustration.

- 1) Steps and direction included in this step-by-step interactive of a PCI:
 - 1) Tap the balloon (balloon with stent drops down between narrowed area)
 - 2) Tap the pump (balloon in vessel inflates)
 - 3) Tap the pump again (balloon deflates and leaves stent embedded in vessel wall)
 - 4) Tap the balloon (balloon rises back up out of narrowed area)
 - 5) The balloon has been removed, but the stent you put there stays behind to clear the path for blood. (This is the final message.)

Figure 3. Outlines of the My Interventional Drug-Eluting Stent Educational App learning module. (A) Initial outline. (B) Revised outline based on feedback and closer adherence to Kolb's theory.

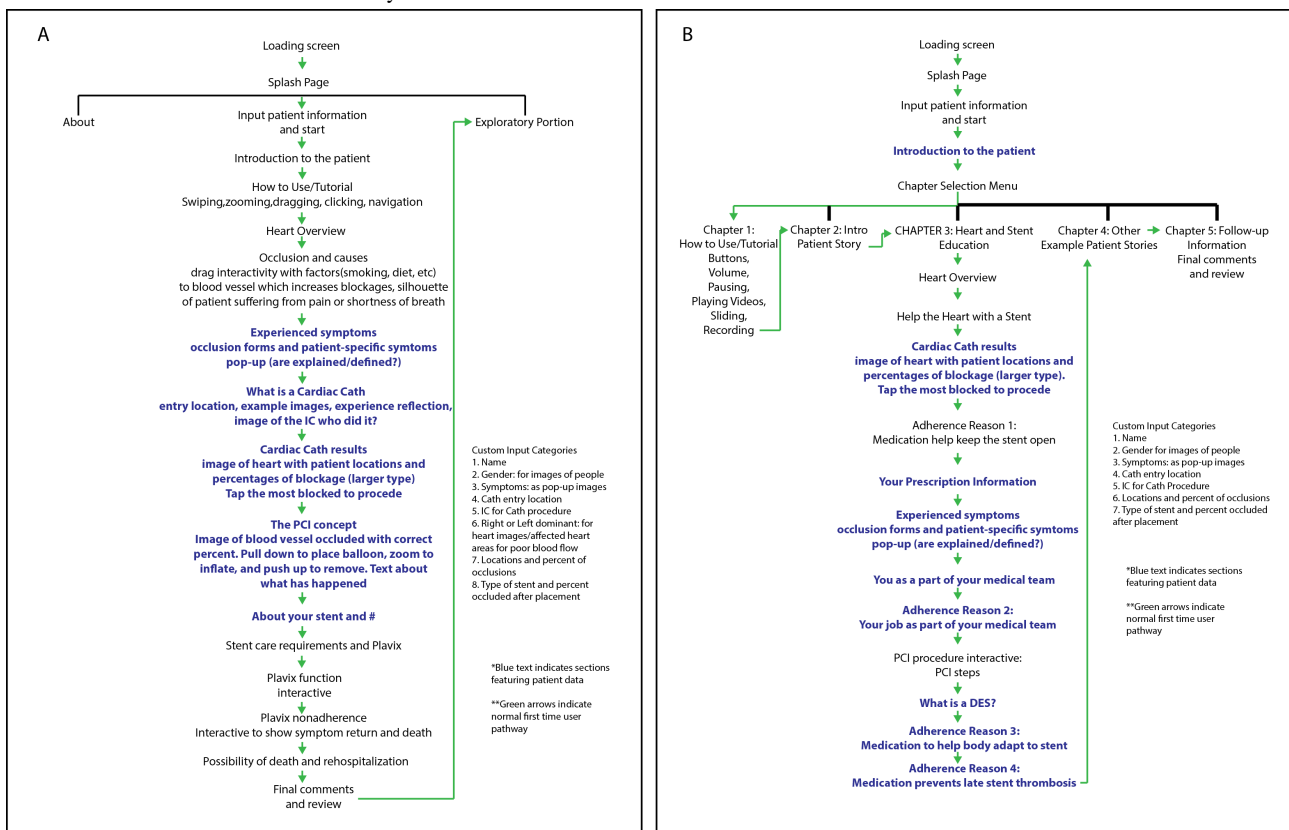


Figure 4. Conceptual framework for the My Interventional Drug-Eluting Stent Educational App. Integration of the multiple aspects of the project with Kolb’s experiential learning theory. The patient will start at the concrete experience of the symptoms of the disease and patient stories. The patient will then reflect on the patient stories. The biomedical visualization pulls in information from the percutaneous coronary intervention report and provides the learning content (abstract conceptualization). Finally, the active experimentation allows the patient to see the potential outcomes of failure to adhere to the suggested medication regimen.

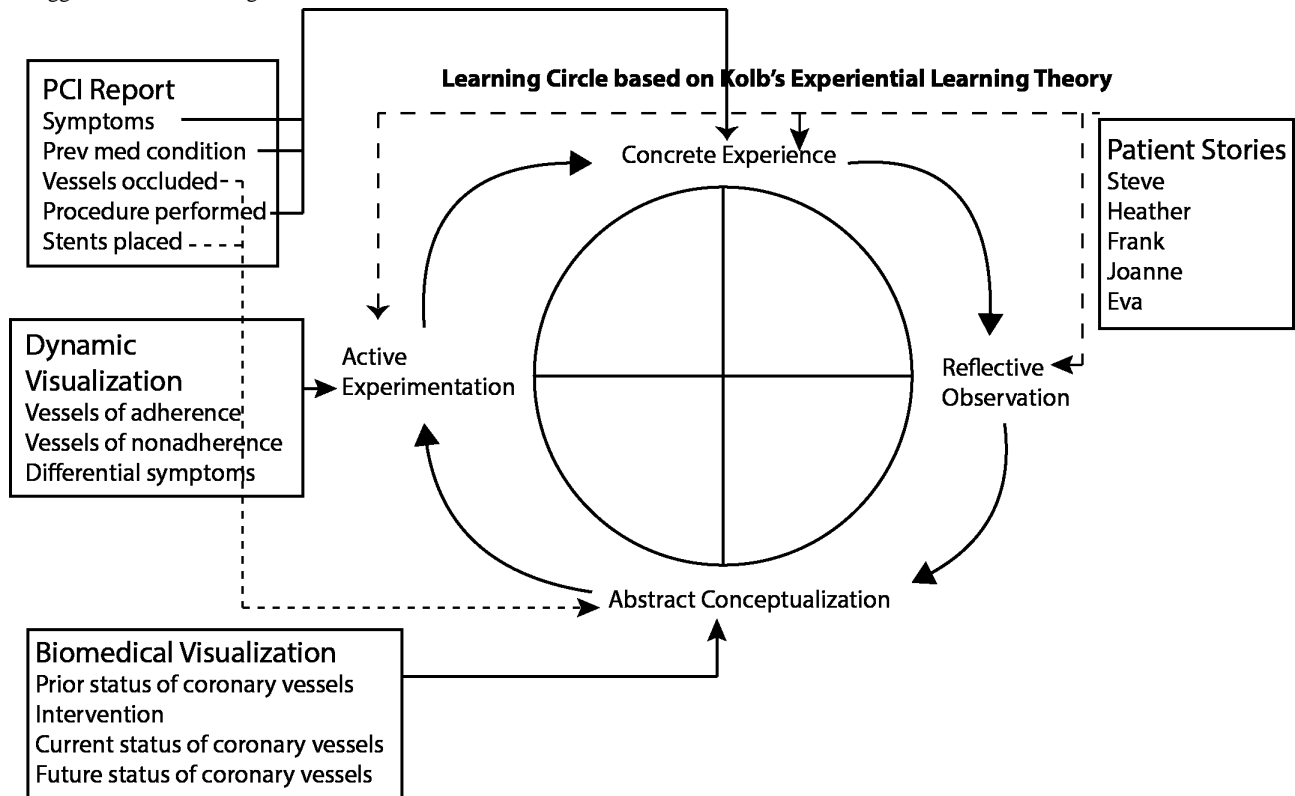
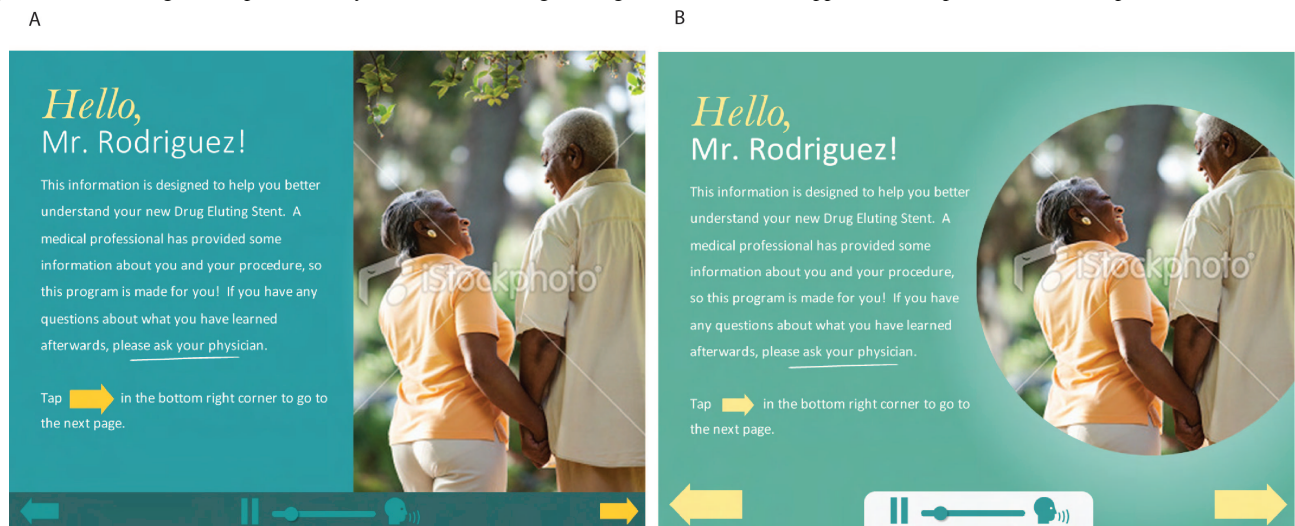


Figure 5. Color design concepts of the My Interventional Drug-Eluting Stent Educational App: (A) Concept 3 and (B) Concept 4.



Data Storage

After final design approval of MyIDEA, the programming of the databases, app servers, and the Android app began. The University of Illinois has a policy that prohibits the storage of personal health information on electronic mobile devices. As a result, the app has been designed to load a patient’s individual information only when loading the app through an encrypted communication to the server where the data are stored. The patient’s data are inserted into the app upon entry; however, when the app is exited, all data are purged from the tablet. All

audio recording and interactivity with the program are recorded and sent through an encrypted connection back to the server.

Final Design and Deployment

After the MyIDEA program was complete, the team evaluated the fully interactive and functional app. A common challenge arose in the ability to click with the tablet. The challenge with the app was that the test users were unable to advance to the next screen. The inability to advance to the next screen was the limited definition of a click on the tablet. What many individuals considered a click was read by the tablet as another advanced

feature on the tablet. The Android app was thus reprogrammed, enabling any touch-screen action by the advance arrow button to be interpreted as a single click. In addition, it was also noted that because elderly patients often better understand lower-pitched, male voices, it would be beneficial to include such a voice option as well. Additional feedback was directed at the narrations and certain portions were rerecorded to ensure proper pronunciation. Other text was reworked to account for the presence or absence of bare metal stents when multiple stents are used.

To facilitate the patient's reflection (Figure 4), the MyIDEA app asks questions and records the answers through the tablet's microphone. The recording starts with a simple click of a recording icon. Playback of the recording is an option available to the patient.

The logistics of when and where the patient-centered education would occur was discussed with the patient advisers. It was noted that the patient would not be very attentive shortly after their procedure because of stress related to the hospitalization or medications. It was determined that for the MyIDEA app to enhance medication adherence, it would likely be more advantageous to have this education a few days after the procedure. Based on this feedback, the MyIDEA app is offered both in the hospital setting for the first visit, which is right after the procedure, and again at the follow-up appointment in 1-3 weeks, which is scheduled for the same day as the research participants' follow-up appointment with their cardiologist.

Clinical research nurses approached the patients for consent. Upon consent, the clinical research nurses present the MyIDEA program to the research participant randomized to the intervention. The clinical research nurses are also present for the second visit. This app is used as an educational tool in which the participants interact with the tablet app to learn more about their procedure and postprocedure medication plan. All research questions are directed to the clinical research nurses who are on-site. Participants are advised to contact their physician or clinical nurses should they have any questions about their stent or postprocedure drug adherence issues. The app has slides that reiterate this point.

The MyIDEA program is deployed in a pilot randomized control trial that is ongoing. This randomized study had an inclusion criterion of a patient who received at least one DES. Recruitment occurred after the PCI procedure, and after the cardiologist had placed the type of stent he/she decided would be used. The study has a control arm, which consists of normal physician and nurse education that all patients receive, and an interventional arm exposing the participants to the MyIDEA program in the hospital and at the follow-up appointment. A total of 14 participants have consented to be in the trial; 6 participants have been randomized to the educational arm and successfully completed the app in the hospital and again during their second visit. The initial acceptance of this program is a critical aspect of the design methodology. The average time it takes to complete the MyIDEA tablet app, from beginning to the end, is 17.6 ± 3.2 minutes (Table 1).

Table 1. Average time taken to complete the MyIDEA app.

	Initial educational intervention (minutes)	Second educational intervention (minutes)
Participant 1	18.8	14.5
Participant 2	16.3	15.7
Participant 3	14.3	14.7
Participant 4	24.9	N/A
Participant 5	20.2	18.6
Participant 6	18.1	N/A

Discussion

Development of the MyIDEA App

The involvement of the patient advisers in the development of the MyIDEA app was integral to its success. While it is tempting to wait to seek users or patient advice until a finished product is available, the insight and critique early in product development helped in ways that could not have been envisioned at the beginning of the process. Despite their lack of software development experience, the patient advisers provided valuable comments and insight, which were vital to the development of MyIDEA. Because the patient advisers had been cardiac patients themselves, it was a beneficial experience to have them see the new technology as it was developed from a patient's point of view. Some of the ideas that patient advisers focused on were color choice, word usage, and ease of use of the app. Team members readily added their own analysis on color scheme, creating a reflective interaction between collaborators. In the

layout and design phase of MyIDEA, patient population attributes were integrated in the early stages [30]. There were 7 wireframes that were created before the final tablet app was finalized. Elements such as lines, boxes, colors, and text were altered after consultation with both the health professional team and the patient advisers.

Kolb's experiential learning theory was used to create the framework for the multidimensional educational tablet app using the following 4 stages: concrete experience, reflective observations, abstract conceptualization, and active experimentation [13]. There was use of concrete experience with the slides focused on patient stories and having the research participants respond to questions about symptoms of their disease. Reflective observation was used as the participants chose which of the patient stories they most related to and then solved the newly presented concerns raised in those stories. Abstract conceptualization was integrated into slides with a visual depiction about vessel blockage before and after the

operation for the research participants to learn about the importance of DES and medication adherence using their PCI report to tailor the program to each individual. Active experimentation was used in the app for research participants when slides focused on how other patients overcame the obstacles in the stories and to apply that information to themselves.

In addition, this educational, interventional tablet app can be classified in terms of behavioral change techniques (BCTs) [31]. A structured taxonomy has been established to categorize BCTs used in behavior change interventions [31]. This particular tablet app includes features from 7 of the 16 known clusters. A total of 8 BCTs were analyzed within the 7 clusters that showed how this tablet app is used to change behavior such as increase medication adherence. Use of behavior rehearsal/practice, covert conditioning, problem solving/coping planning, review of outcome goals, modeling of the behavior, mental rehearsal or successful performance, comparative imagining of future outcomes, and instruction on how to perform a behavior were the 8 BCTs that this tablet app targeted. These techniques are shown to modify behavior and, in this study, are expected to increase medication adherence after the surgical procedure. Within the biomedical communication literature, collaborative research is the norm [29]. During discussions, researchers indicated that the engagement of patient evaluators is critical; however, they only obtain patient evaluation of a finished product [32] or for insight into the amount of visual noise in images [29]. In this study, patient advisers were involved from an early stage, which is unique to the experience of the biomedical communication community. The use of multimedia and images with a multimedia approach has resulted in increased learning of similar content compared with traditional text for patient education [33]. The MyIDEA development of dynamic customized content expands on these concepts.

Within the health informatics literature, eHealth interventions have been shown to be promising compared with normal treatment [27]. However, in that review only 12 interventions were evaluated [27]. As with MyIDEA, the vast majority of interventions were derived from a health behavior theory [27]. The health literature also stresses the importance of tailoring care to the patient [34]. The MyIDEA app is customized, reflecting the patient's procedure findings, symptoms, and prescriptions.

Three main concepts of participatory design have been discussed in computer science literature: the politics of design, nature of participation, and methods [25]. The politics of MyIDEA are unique in that multiple health professions and patients all came together for a common goal. The professional domains and experience were leveraged to have all participants contribute equally to ensure the project was a success. The nature of

participation was unique compared with other software development projects. Participation by faculties and patient advisers was voluntary, because no grant money was available at the time of development. The development of MyIDEA was done using internal departmental funds with no salary for either the faculties or patient advisers. After completion of a fully functioning app, the National Institutes of Health pilot grant money enabled us to enroll research participants. The app was completely debugged before the funding was received. If a member of the development team decided not to fully participate, they were able to leave at any point in the development process. The method of participation was regular meetings with prototyping.

Our approach was consistent with the ISO standard 9241-210:2010, which was a revision from the 1999 standard [26]. One of the revisions included in this standard was that human-centered methods could be used throughout the system life cycle [26]. The use of patient advisers from the initial wireframe of MyIDEA is following the reimaged technical specifications of the ISO standard. A detailed analysis of the over 30 different parts of the ISO standard are beyond the scope of this paper. We avoided conventional methodology such as Patient Education Materials Assessment Tool and Assessing the Quality of Decision Support Technologies Using the International Patient Decision Aid Standards instrument because this study focuses on the unique challenge of postprocedure education [35,36]. Other evaluation tools focus on checklists. No checklists were used before the PCI procedure as it is unknown whether a patient will have a DES or a BMS.

Conclusions

The patient-centered educational program, MyIDEA, incorporates patient-specific information for tailoring. Patient adviser participation in the early phases of mobile patient education development is a critical key to the success of the intervention. From the initial response of the patients, the MyIDEA app is ready for efficacy trials. The future of patient education will have the expectation to include tailored information to enhance the overall quality of care. Multidisciplinary literature, collaborative design, and patient engagement early in the design are critical for success. Patients are sophisticated consumers, who desire knowledge about their health and procedures to help make informed choices. Thus, working with patient advisers to help design and present information for consumption is an invaluable process. Each patient adviser had a postcardiac experience and was well aware of the questions, anxiety, and need for understandable information in a form that would be rapidly available. Mobile patient education has the potential to transform health care; however, without *early* patient participation the potential of this new technology will remain unfilled.

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Conflicts of Interest

None declared.

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Abbreviations

- BCT:** behavioral change technique
- DAPT:** dual antiplatelet therapy
- DES:** drug-eluting stent
- IRB:** Institutional Review Board
- ISO:** International Standardization Organization
- MyIDEA:** My Interventional Drug-Eluting Stent Educational App
- PCI:** percutaneous coronary intervention

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