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mHealth Education Applications Along the Cancer Continuum

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Abstract The majority of adults worldwide own a mobile phone, including those in under-resourced communities. Mobile health (mhealth) education technologies present a promising mechanism for improving cancer prevention, treatment, and follow-up. The purpose of this study was to summarize the literature related to mobile phone (mhealth) applications for patient education specific to cancer and identify current recommendations from randomized studies. In particular, we were interested in identifying mobile phone applications along the cancer continuum, from cancer prevention to survivorship. The authors identified 28 articles reporting on mobile applications for patients related to cancer. Articles were identified in all categories along the cancer continuum, including health professional involvement in application development. Of these, six involved direct patient education, and eight focused on improving patient/professional communication and patient self-management. However, only six of the studies were randomized interventions. The potential for mobile applications to help overcome the "health care gap" has not yet been realized in the studies from the USA that were reviewed for this paper. However, early recommendations are emerging that support the use of mHealth communications to change behaviors for cancer prevention, early detection, and symptom management and improved patient-provider communication. Recommendations include short messages, use of multiple modalities as patient characteristics dictate comfort with mHealth communication, and the inclusion of patients and health professionals to develop and test applications. Tailoring mHealth to particular cultures, languages, and ethnic groups may also represent a unique possibility to provide accessible information and education at minimal cost for under-resourced communities and individuals.

Keywords mHealth · Mobile phone · Cancer · Cancer education · Mobile health applications

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Introduction

It is estimated that 67.6% of adults worldwide own a mobile phone [1], and over a third of US mobile phone owners have a smart phone. Latinos are significantly more likely than other groups to have mobile Internet access [2]. Surveys of Hispanics found that up to 81 % owned cell phones capable of sending and receiving health-related messages, and that most were receptive to using the technology and felt it would be helpful [3, 4]. Mobile telephone technologies may be an effective method for overcoming the "health care gap" by providing new opportunities to reach underserved populations [5].

The increase in the number of people with mobile phones has resulted in new mobile health (mHealth) interventions that effectively take advantage of this technology to communicate with patients and clinicians [6, 7]. An extensive review of mHealth research identified mobile phone applications in a variety of areas: asthma, diabetes, mental health, heart disease, smoking cessation, cancer, HIV, appointment reminders, cystic fibrosis, physical activity, weight loss, safe sex, sexually transmitted disease, tuberculosis, chronic disease, brain injury, and eating disorders [8].

Mobile health presents a promising mechanism for improving education in cancer prevention and treatment [9]. However, other literature reviews of mobile phone health applications have not focused on cancer [8, 10–15]. The single cancer-specific review identified 295 mobile applications

related to cancer, but the associated literature review did not identify any studies evaluating smart phone applications focused on cancer [16].

The main objective of this paper is to review the literature related to mobile phone applications specific to cancer. In particular, we were interested in identifying patient-centered mobile phone cancer applications along the cancer continuum, from cancer prevention to survivorship.

Methods

A literature review was conducted in early February 2014. PubMed was chosen as the main database for the search, since it is the most used medical database of peer reviewed publications. A variety of searches using keywords and medical subject headings were used, including "smart phone and cancer," "cell phone and cancer," and "mobile health and cancer." A search string was constructed including both the conjunction "AND" and the disjunction "OR" logical operators ("neoplasms" [Mesh] OR "neoplasms" [all fields] OR "cancer" [all fields] AND ("cellular" [all fields] AND "phone" [all fields] OR "cellular phone" [all fields] OR "mobile" [all fields] AND "phones" [all fields] OR "mobile phones" [all fields])). This search string resulted in 236 articles with abstracts. Related references identified through PubMed with relevant sounding titles were also searched, and reference lists of selected studies were checked for potentially relevant studies. The authors reviewed the papers identified using this search strategy.

Selection Criteria

Articles eligible for inclusion had to be written in English and discuss mobile telephone technology as a tool for promoting screening, managing, or monitoring cancer for patients. Articles related to the health effects of mobile phones and studies that described mobile health interventions aimed at clinicians were excluded. Articles that did not include an abstract in PubMed were excluded. All publication dates were eligible for inclusion.

We did not include the many articles related to smart phone applications for smoking cessation, physical activity, and weight control because they were not indexed primarily under cancer. However, it is worth noting that a Cochrane Database Systematic Review found evidence of high quality for mobile phone messaging interventions aimed at smoking cessation [11]. Mobile interventions involving physical activity [17, 18] and dietary intake [19] have also proven successful. We also excluded articles on applications specifically for the use of physicians, including one predicting the probability of lung cancer patient survival [20], and two related to health professional education [21, 22].

Results

Articles related to mobile phones and their usefulness for cancer control were found throughout the cancer continuum, from cancer prevention through survivorship. In addition, there were some articles relevant to the involvement of health professionals in developing mobile applications (see Table 1). In all, 28 papers fit our inclusion criteria. Table 2 provides a summary of findings and recommendations from randomized studies, and although sparse and mostly conducted outside of the USA, these studies provide early data on recommendations for future mHealth work.

Cancer Prevention

We identified three papers in the area of cancer prevention. Armstrong et al. (2009), randomized a sample of 70 community volunteers to receive daily text messages reminding them to use sunscreen, or no reminders. The 6-week trial data demonstrated an increase in the mean daily adherence rate. Other prevention applications included a combination of behaviors. One study described a planned protocol to randomize adolescents and adults in Spain and Mexico to receive recommendations on not smoking, following a healthy diet, doing daily physical exercise, or avoiding becoming overweight [23]. A third study, Healthy Directions 2, is a cluster randomized controlled trial implemented in Boston, Massachusetts to promote change in several behavioral risk factors for cancer. One third of participants were randomized to receive automated reminders; of those, 28% (167/598) chose SMS (phone text) reminders [24].

Early Detection

There were several mobile phone applications focused on cancer early detection, including skin, breast, cervical, colorectal, and ovarian cancer. Three papers discussed using mobile phones for detecting skin lesions. One paper focused on developing a prototype of a patient-oriented system for skin lesion analysis using a smart phone [25], one used a smart phone along with sophisticated image processing and pattern recognition algorithms to interface with a dermoscope in a clinical setting [26], and another compared the accuracy of using mobile telephones to submit patient history and clinical photographs to a remote expert for "face-to-face" consultation to diagnose 30 patients with common skin diseases [27].

Breast cancer early detection was the topic of four papers. One utilized mobile phones to enter survey data on local beliefs and knowledge in Pakistan [28]. SMS text messages were a topic of a couple of studies. One study used short text messages as a reminder to working women in Delhi to practice breast self-examination [29]. Another study randomized women in a Health Insurance Plan in Beirut to receive either

Table 1 Summary of literature

Cancer control continuum	Topic	Citation	Methods	Randomized?
Prevention	Sun protection	(Armstrong, et al., 2009)[a]	SMS/text reminders to use sunscreen; *N*=70	Yes
	Combination prevent behaviors	(Lana, et al., 2013)	Website with SMS/text reminders paper describes study protocol only	Yes
		(Greaney, et al., 2012)[a]	One third of Healthy Directions 2 got automated reminders; *N*=598	Yes
Early detection	Skin lesions	(Rosado, et al., 2012)	Prototype patient-oriented skin lesion analysis with smartphone	No
		(Wadhawan, et al., 2011)	Image processing on smartphone;7-point checklist to detect melanoma	No
		(Tran, et al., 2011)	*N*=30; face to face consult vs. senior dermatologist using phone camera	No
	Breast cancer	(Raza, et al., 2012)	Mobile phones for survey on breast cancer beliefs in Karachi; 200 women	No
		(Khokhar, 2009)[a]	SMS/text reminders to do breast self examination in Delhi; *N*=106	No
		(Lakkis, et al., 2011)[a]	*N*=385; half got SMS invitation for mammogram, half more information	Yes
		(Kratzke, et al., 2013)	*N*=157 rural women surveyed reuse of internet, cell and text	No
	Cervical cancer	(Quinley, et al., 2011)	In-person midwives vs. expert dx using phone photos of cervix; *N*=95	No
		(Kivuti-Bitok, et al., 2013)	Survey of 21 nurses, 12 doctors on cervical cancer challenges, mobile phone potential	No
	Colorectal cancer	(Kreuter, et al., 2012)[a]	CRCCP grantees survey of screening reminders; some use automated phone reminders; 26 CRCCPs	No
	Ovarian cancer	(Wang, et al., 2011)	Microchip ELISA-based module with cell phone to quantify ovarian biomarker	No
Diagnosis	Melanoma	(Massone, et al., 2009)	Telediagnosis of images using cell phones and dermatoscope	No
Treatment	Patient/health professional communication	(Blake, 2008a, 2008b)[b]	Mobile phones used to improve nurse-patient communication	No
		(Rao, et al., 2012)[b]	SMS between 102 breast reconstruction patients and one of two study surgeons	No
	Patient information management	(Klasnja, et al., 2011)[b]	4-week evaluation of HealthWeaver to help 9 patients get care information	No
	Treatment follow-up	(Odigie, et al., 2012)[b]	*N*=1176 Nigerian oncology patients; 1/2 rented phone to call care team	Yes
	Managing chemotherapy	(Kearney, et al., 2009)[b]	Mobile phone based advanced Symptom management System; *N*=112	Yes
		(McCann, et al., 2009)[b]	Mobile phone based advanced symptom management system; *N*=112	Yes
		Larsen, et al., 2008)[b]	Symptom diaries on mobile phone no alert nurses; *N*=6, two cycles	No
		(Weaver, et al., 2007)[b]	*N*=6; mobile phones used to enter chemotherapy symptoms	No
Survivorship	Diet and exercise	(Lee, et al., 2013)[a]	Web-based self-management with tailored SMS messages; 29 patients	No
Health professional involvement in application design		(O'Neill and Brady, 2012)	Review of colorectal apps to assess levels of medical involvement	No
		(Maguire, et al., 2008)	Perceptions of 35 nurses participating in advanced symptom management	Yes
		(Gibson, et al., 2009)	Health professional involvement in advanced symptom management	Yes

[a] Direct patient education application (including behavioral reminders), *N*=6

[b] Applications to improve patient/professional communication, or patient self-management, *N*=8

Table 2 Randomized completed studies: summary of findings and recommendations

Cancer control continuum	Findings and recommendations
Topic	
Prevention	
Sun protection	In the California population, low cost text reminders significantly increased adherence to medical recommendations and a majority (89%) of study participants would recommend the use of text messages to others (Armstrong, et al., 2009)[a]
Combination preventive behaviors	Due to variation in comfort with electronic communication, multiple modalities such as text and automated voice response systems are recommended to reach populations with broad age ranges (Greaney, et al., 2012)[a]
Early detection	
Breast cancer	Among women enrolled in a health insurance plan at American University of Beirut, a short text invitation for a screening mammogram was equally as effective as a longer text invitation describing the benefits of a mammogram (Lakkis, et al., 2011)[a]
Treatment	
Follow-up	In low resource or rural communities in Africa, medical information can be effectively obtained through mobile phones and the inexpensive interaction provides support to patients that is appreciated (Odigie, et al., 2012)[b]
Managing chemotherapy	In the UK, a symptom management system using mobile phones significantly reduced specific symptoms associated with chemotherapy in lung, breast, and colorectal cancer patients (Kearney, et al., 2009[b,c]) and improved communication with healthcare providers (McCann, et al., 2009[b,c])
Health professional	
Application design	Nurses tested and supported an advanced symptom management system for the use of managing chemotherapy-related side effects in an out-patient population in the UK (Maguire, et al., 2008[b,c])
	A mobile phone-based symptom management system for use in young adults received positive feedback by UK based health professionals. (Gibson, et al., 2009[b,c])

[a] Direct patient education application including behavioral reminders)

[b] Applications to improve patient/professional communication, or patient self-management

[c] Same advanced symptom management system study

a general text inviting members to complete a mammogram, or additional information informing them about the benefits of mammograms [30]. The final study in this group was a survey designed to examine the use of Internet, cell, and text among rural women seeking breast cancer early detection information [31].

Cell phone applications were also studied for cervical cancer screening, colorectal cancer screening reminders, and ovarian cancer early detection. Cell phone photographs of the cervix after acetic acid treatment were taken by nurse midwives in Botswana to determine the diagnostic agreement with an off-site expert [32]. A survey of doctors and nurses in Kenya identified the potential of mobile phones to improve cervical cancer management [33]. Automated telephone reminders were used by some Centers for Disease Control (CDC) Colorectal Cancer Control Program (CRCCP) grantees. Nearly all indicated the need for non-English resources [34]. Ovarian cancer is difficult to detect early, and one study reported on a simple and inexpensive microchip ELISA-based detection module coupled with a cell phone to quantify an ovarian cancer biomarker in urine [35].

Cancer Diagnosis

A single article was identified in the area of cancer diagnosis. Similar to the studies in the early detection category for skin lesions, this paper discussed the high diagnostic accuracy achieved through the transfer of images captured with cellular phones coupled with a dermatoscope [36].

Cancer Treatment

Articles discussing mobile applications for cancer treatment included patient/health professional communications, patient information management, treatment follow-up, predicting survival, and managing chemotherapy. Mobile phones have become an important technology for improving nurse-patient communication and monitoring health outcomes [37, 38]. Text messages between surgeons and patients (SMS) were shown to reduce the number of clinic visits and increase the efficiency of those visits in a study of patients undergoing breast reconstruction [39].

HealthWeaver Mobile was designed for cancer patients to manage care-related information when they were away from

home. This information management also enhanced their ability to share information with clinicians [40].

The ability to communicate with the hospital or clinic dramatically increased the proportion of oncology patients who completed follow-up appointments in Nigeria. One half of cancer patients rented a mobile phone, and after two years, 97.6 % of them had completed follow-up, compared with 19.2 % of patients who did not receive the phone intervention [41].

Two studies looked at mobile applications for chemotherapy management. Kearney and colleagues explored different perspectives of a study evaluating a mobile phone-based, remote monitoring Advanced Symptom Management System (ASyMS). Their first paper reported on the randomized controlled trial demonstrated the feasibility of using ASyMS for monitoring six chemotherapy related symptoms in patients with lung, breast, or colorectal cancer [42]. The second paper evaluated the patient's perceptions and experiences when using ASyMs, and found that patients reported many benefits [43]. A separate study involved a mobile phone platform which enabled patients receiving adjuvant chemotherapy for colorectal cancer to enter symptom data twice daily. Six patients used the system for two cycles of oral chemotherapy, and both patients and nurses felt the system was feasible [44, 45].

Cancer Survivorship

Tailored short message services using mobile phones were incorporated into a web-based self-management exercise and diet intervention program for survivors. The program was evaluated by 29 breast cancer survivors, who found it easy to understand and use [46].

Health Professional Involvement in Application Development

Three papers discussed the importance and procedures for involving health professionals in the design of mobile applications. An overview of colorectal smartphone applications found that only 32 % had a medical professional involved in their development or content [47]. Two papers reported on the experiences of health professionals in the randomized control trial of the mobile phone-based Advanced Symptom Management System (ASyMS). One study focused on the perceptions of nurses in using the mobile system to remotely monitor chemotherapy toxicity [48]. The other paper provided a detailed description on the involvement of health professionals in developing a mobile phone system management system for use with young people [49].

Conclusions

This literature review identified 28 papers describing mobile health applications related to cancer. The papers encompassed the cancer continuum, from cancer prevention to survivorship. The majority of papers were related to early cancer detection (11) and treatment (9). Six articles focused on applications for direct patient education, and eight articles on improving patient/professional communication and patient self-management (two of these articles related to the same study). There was an increase in the rate of papers published, with an average of 5.66 per year over the 3 years from 2011 to 2013 compared with 2.75 per year in the 4 years 2007 through 2010. No articles meeting our criteria had been published in 2014 at the time of our search (February 7, 2014).

Few of the papers described randomized studies. There were a total of six randomized studies, with nine papers describing them (four papers represented different perspectives on the same randomized study). Of these randomized studies, three focused on text messaging. Many other papers described ideas related to projects under development, or reported on pilot studies. Given the large number of cancer-related applications available from smartphone app stores [16], it appears that only a small minority of applications are rigorously tested prior to being made available to the public.

Several studies described applications implemented in developing countries. However, studies with populations in the USA were generally not directed toward under-resourced communities or individuals. Interventions in the USA did not describe tailoring messages or applications based on culture, language, or ethnicity.

Given that many developing countries by-passed household landlines and moved directly to mobile phones [15], the comfort level, dependence for connection with the outside world, and trust in mobile phone technology may be higher than observed in populations that grew up with landlines. This aspect makes use of mobile phone technology particularly relevant and important in reaching often underserved and newly migrant populations in developed countries. We should not overlook mHealth's relevancy in changing the way we deliver health care and the face of communication to improve outcomes in multiple population groups.

Reviews for work in this rapidly growing field will always be constrained to the search time frame and this review is no exception. In addition, we relied on the PubMed database so it is possible that searching other databases would have resulted in additional publications.

Mobile applications represent an interesting and challenging opportunity to change behaviors and improve education in the field of cancer, from prevention through survivorship. Summary recommendations include the use of short text messages and provision of multiple modalities to appeal to a diverse population (see Table 2). Moreover, as this field of research matures, it is essential to involve patients and health professionals in developing and testing applications through randomized interventions. The potential for mobile applications to help overcome the "health care gap" has not yet been

realized in the USA-based studies that were reviewed in this paper. Tailoring applications to particular cultures, languages, and ethnic groups may represent a unique opportunity to provide accessible education for under-resourced communities and populations. Evaluating mHealth interventions compared to current standard of care for education, follow-up, and ongoing cancer care needs in diverse populations in the USA represents a significant opportunity.

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