Research-tested mobile applications for breast cancer care: a systematic review.

Towards the creation of a safe and empowering mHealth environment.

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Abstract

Background: The use of mobile health (mHealth) applications in clinical settings is becoming more and more common. They have been employed to promote prevention, to improve early detection, to manage care, and to support survivors and chronic patients. However, data on the efficacy and utility of mHealth applications are scant.

Objectives: The main objective of the present review is to provide an overview of the available research-tested interventions using a mHealth application and their effectiveness in breast cancer care.

Method: A systematic search of Medline, PsycINFO, Embase and Scopus was undertaken to identify relevant studies. From the selected studies, the following information was extracted: authors, publication date, study objectives, study population, study design, interventions’ features, outcome measures and results. The quality of the studies was assessed.

Results: Fourteen empirical studies were identified that described a healthcare intervention using a mHealth application in breast cancer care. One of the 14 studies concerned the use of a mHealth application in an intervention for prevention of breast cancer; 2 targeted early detection; 7 were on care-management; and 4 focused on survivors of breast cancer.

Conclusions: We provided an overview of interventions using a mHealth applications in breast cancer care. Our results indicate consistent and promising findings of interventions using mHealth applications targeting care-management in breast cancer. Within the categories of mHealth applications focusing on cancer breast early detection and survivorship findings are conflicting and less conclusive and further investigation is warranted. As only one study detected through our search investigated a mHealth application on breast cancer prevention, we advocate further investigation to confirm and strengthen this evidence. Future research...
Research-tested mobile applications for breast cancer care should continue to explore the effectiveness of mHealth applications in breast cancer care to build on these initial recommendations.

Keywords

mHealth applications, breast cancer care, mobile applications, breast cancer prevention, breast cancer management, breast cancer survivorship
Introduction

Mobile health known as mHealth is a way to deliver healthcare or related services through portable devices [1]. mHealth is broadly accessible and often freely delivered in the app stores of app providers. The online application market is open to developers and allows them to create applications selling or offering them for free. The current estimates suggest that there are more than 40,000 mHealth applications [2]. According to a recent report by Grand View Research, Inc., the global mHealth market is expected to reach 111.8 billion American dollars by 2025 with the need to reduce long waiting periods to access health care services the primary driver responsible for the adoption of mHealth [3].

mHealth applications are extremely relevant for both industrialized nations and developing countries as it enhances extended access to healthcare and health pertinent information in a cost-effective way [4]. Scholars and healthcare professionals have shown interest for this new technology, and the use of mHealth in clinical settings is becoming more and more common [5]. Recent reviews showed that in cancer care mHealth applications have been employed to promote prevention, to improve early detection, to manage cancer care, and to support cancer survivors [5, 6]. Furthermore, research-tested applications have shown to be a unique possibility to provide accessible information and education at minimal cost along the cancer care continuum [5].

Despite their impressive and promising potential, the utility and effectiveness of this e-health technology remain unclear. Scholars have reviewed the use of mHealth applications in several fields [4, 7-10]. Mobasheri and colleagues [4] reviewed 158 mHealth applications regarding breast cancer and found that there is a lack of evidence on their utility, effectiveness and safety. Most mHealth applications lack expert involvement and do not adhere to relevant medical evidence or do not reflect patient’s needs [11]. Moreover, given the large number of available mHealth applications, it seems unrealistic that a great deal is
thoroughly and scientifically tested before being made available [4, 5]. A recently developed mHealth application had negative effects on patients, augmenting their anxiety after breast cancer surgery [12]. The mHealth application aimed at giving extensive information to patients, however, controls, who did not use the application, had lower anxiety levels, which correlated to higher quality of life [12].

The possibilities of patients’ empowerment through the use of mHealth technology should be fully explored and tailored to patients’ needs [13-15]. Scholars and stakeholders advocate for more medical professional involvement, patients’ preferences inclusion, and specific regulations [4].

The need for integration between research-tested and privately developed mHealth application has been widely stressed as it play a crucial role to achieve the necessary fundamentals of an effective evidence-based care [10, 16, 17]. Research should provide the scientific basis on which build elements that can be effective for patients.

In this theoretical framework, it is especially relevant to understand which mHealth application has been scientifically tested and give an overview of the interventions using mHealth applications. Our focus is on mHealth applications in breast cancer care. The present review aims to provide an overview of the available evidence on research-tested interventions using mHealth applications in breast cancer. Our findings provide valuable information to healthcare professionals, mHealth applications developers, breast cancer patients and other stakeholders on the characteristics of existing research-tested applications used in breast cancer care, their advantages and pitfalls in order to correctly, effectively, but most of all safely empower breast cancer patients.

Methods

Search Strategy and Selection of Articles
An extended bibliographic search was conducted in the following databases: Medline, PsycINFO, Embase and Scopus. The following search string was used:

((phone OR mobile OR smartphone*) AND (app* OR application*)) AND ((breast* OR mammary) AND (cancer* OR neoplasm* OR carcinom* OR tumor*))

Search was limited to studies published between 2008 (when the first mobile application was created) to 16 January 2017, the last date searched. The review was registered in PROSPERO with the following registration number: CRD42017056239. All detected articles were screened according to the following inclusion and exclusion criteria.

**Inclusion criteria:**

- Original studies
- English language
- Studies that include the use of a mHealth application
- Studies that include patients’ use of a mHealth application
- Studies that concern the prevention/detection/care-management/survivorship of breast cancer

**Exclusion criteria:**

- Studies that use websites, text messaging, emails or other technological interventions that do not include mobile applications.
- Studies that use mobile applications without applying it to breast cancer patients (e.g.: healthcare professionals that use mHealth applications)
Data collection and extraction process

A data extraction form was developed based on the Centre for Reviews and Dissemination templates[18]. Two reviewers independently extracted the data from the included studies using the extraction form. Disagreements in data extraction were resolved through discussions between the authors until agreement was reached. Relevant articles were then selected by cross-examining the articles and reviewed. Data collected included information on authors, publication date, intervention’s features, study design, sample size, outcome measures and results. The quality of the quantitative studies was evaluated independently by two researchers with the EPHPP Quality Assessment Tool for Quantitative Studies [19]. This tool provides a standardised means to assess quantitative study quality leading to an overall methodological rating of strong, moderate or weak in eight sections: selection bias; study design; confounders; blinding; data collection methods; withdrawals and dropouts; intervention integrity; analysis. The quality of the qualitative studies was evaluated with the Joanna Briggs Institute Critical Appraisal Checklist for Qualitative Research [20]. Discordances in quality rating were resolved through discussion between the researchers.

Results

Study selection

The results of the systematic search are summarized in Figure 1 in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [21]. We detected a total of 155 articles (20 from Medline, 3 from PsycINFO, 81 from Embase and 51 from Scopus) from which we subsequently excluded 91 duplicates. Abstracts and titles were screened to identifying 32 articles considering an intervention using a mHealth application in breast cancer patients’ care, further screening on the basis of the entire text according to our inclusion and exclusion criteria brought to a final selection of 14 articles.
139**Figure 1 - Flow diagram of identification, screening, eligibility and inclusion of studies.**

141**Studies characteristics**

142The 14 studies in identified were published between 2011 and 2017. Four of the 14 studies described randomized controlled trials, eight were prospective cohort studies and two used qualitative analysis. Using the EPHPP Quality Assessment Tool for Quantitative Studies [19], 4 studies were rated as strong, 6 as moderate and 2 studies as weak. The two qualitative
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Studies assessed with the Joanna Briggs Institute Critical Appraisal Checklist for Qualitative Research [20] revealed a methodological quality that allowed their inclusion in the review. One of the 14 studies concerned the use of a mHealth application in breast cancer prevention; 2 targeted early detection; 7 were on care-management; and 4 focused on survivors of breast cancer. The sample included in the studies reported on adult patients in different countries and with different ethnic background. Seven studies were performed in the USA; 3 in Europe; and 4 in Asia. Table 1 provides a summary of features of the included studies.

**mHealth applications in breast cancer prevention**

We identified one paper in the area of breast cancer prevention. Hartman and colleagues [22] designed a randomized weight-loss intervention in order to reduce breast cancer risk. The intervention combined commercially available technology-based self-monitoring applications with individualized phone calls. In particular, the intervention entailed an electronic calorie-counting tool, and accelerometer-based activity meter that provides real-time feedback of number of steps taken and minutes of moderate-intensity activity, and 12 phone calls (30 minutes each) over the 6-month intervention period. After six months, the 36 participants in the experimental group had lost significantly more weight and a greater percentage of starting weight.

**mHealth applications in breast cancer early detection**

Two studies considering mHealth applications on early breast cancer detection were identified in the review. Eden and colleagues [23] studied decisional conflict and decisional self-efficacy in 75 women before and after the use of a mammography screening decision aid in the form of a mHealth application. Their results showed that the use of the mHealth application decreased the decisional conflict and increase the decisional self-efficacy. Heo and colleagues [24] developed a mHealth application to encourage breast self-examination.
The mHealth application included a breast self-examination reminder, a record keeping function and educational features. After using the application, out of the 45 participants the ones who positively changed their breast self-examination grew non-significantly from 28 to 32. However, participants under 30 years did significantly more, and more appropriate breast self-examination compared to participants over 30.

**mHealth applications and care-management**

Seven papers investigating the usage of a mHealth applications in breast cancer care-management emerged from our review. Five studies focused on care-management and monitoring of treatments’ side effects [25-29]; one on personal data management [30]; and one on educational aspects [12]. The five mHealth applications that included the monitoring and care-management of treatments’ side effects included wound monitoring [26], sleep quality collection [28], daily functional activity stabilization [25], mental-health tracker [27] and chemotherapy dose adaptation [29]. These applications were developed for and focussed on the reliable collection and communication of relevant breast cancer data between patients and oncologists.

In the Hwang’s study [26] the post-operative wound e-monitoring application significantly decreased readmission to hospital, an unscheduled visit to the emergency department or walk-in clinic. The mHealth application intervention is a virtual care platform that consists of a smartphone app and secure password-protected online account that allows patients to take a photo of their wounds postoperatively and to attach the photos to electronic messages and send them to the surgeon using the smart phone app. The surgeon then responded to each patient message within 24 hours. The vast majority (95%) of patients felt that electronic wound monitoring improved their care and would recommend such technologies to a friend or colleague.
Min and colleagues [28] analysed the feasibility of and compliance with a mHealth application for sleep disturbance-related data collection from breast cancer patients receiving chemotherapy. Participants self-recorded three health experiences that may be caused by breast cancer diagnosis and treatments: (1) sleep-disturbance symptoms related to mild depression, (2) acute symptoms related to cytotoxic chemotherapeutic agents, and (3) medication diary for antihormonal treatment. The overall compliance during the 90-day longitudinal collection of daily self-reporting sleep-disturbance data was about 45% confirming the feasibility of the intervention. Women without any form of employment exhibited the higher compliance rate. No other association between patient characteristics and compliance was found. An intervention using a mHealth application on patient-reported daily functional activity in a supervised and unsupervised setting showed that the use of the mHealth application in collaboration with physicians was associated with stabilized daily functional activity and with fewer and more precise entries than the unsupervised use of the mHealth application. The mHealth and Web app allows patients to record daily functional activity or symptoms with indication of severity [25]. Kim et al. [27], evaluated the validity and the screening performance for depression of a mHealth application that gather self-reported mental-health ratings from breast cancer patients. The app tracked three daily mental-health indicators for depression (sleep satisfaction, mood, and anxiety). Their results strongly support the potential of a mobile mental-health tracker as a tool for screening for depression in breast cancer patients. A mHealth application developed to collect and monitor real-time symptom in patients receiving oral chemotherapy showed that both patients and oncologists felt reassured by the use of the mHealth application [29]. The intervention entailed patients completing a symptom, temperature and dose diary twice a day using a mHealth application. This information was encrypted and automatically transmitted in real time to a secure server, with moderate levels of toxicity automatically prompting self-care
symptom management messages on the screen of the patient’s mHealth phone or in severe cases, a call from a specialist nurse to advice on care according to an agreed protocol [29].

Klasnja and colleagues’ [30] tested the feasibility of a mHealth application for data management. The mHealth tested includes a web component and a mobile component. Using the mHealth application, patients can create, edit, and view the full range of information stored in the website and share them with family members and healthcare professionals. In addition, patients can create photo, audio, and text notes to quickly capture information and they can immediately link those notes to related appointments. The mobile application synchronizes the app calendar to the phone’s native calendar application, letting patients see their care events alongside their other commitments.

Their study highlighted an empowering effects of the mHealth analysed. Foley and colleagues [12] educated patients about breast cancer surgery by using a mHealth application realising information on surgery procedure tailored to the individual patient. They found that seven days after surgery participants who were more educated about their breast cancer surgery procedure, experienced more anxiety than controls.

mHealth applications in survivorship

Four studies focusing on mobile applications in breast cancer survivors were identified in this review. All four studies aimed at lifestyle changes; in particular they concentrated on improving physical activity or reinforcing weight loss [31-34].

Three studies found significant effects of mHealth applications on weight loss [32-34]. McCarroll et al. [32] assessed one-month lifestyle intervention using a web and mHealth weight loss application called LoseIt!. The intervention with emphasis on nutrition quality, physical activity, and improving eating self-efficacy delivered via a web and mHealth weight-loss application by a multi-disciplinary team who provided real-time feedback notifications. Uhm et al. [33] tested and compared a 12-week home-based program of aerobic and...
resistance exercises using a smartphone exercise application and a pedometer with a conventional exercise program using a brochure. Physical function, physical activity, and quality of life were significantly improved regardless of the intervention method, and changes were not significantly different between the two interventions.

The feasibility and preliminary efficacy of two self-regulation interventions using mHealth app and website and tailored feedback emails to prevent weight gain among African American breast cancer survivors were evaluated [34]. The interventions focused on daily self-weighing and used objective monitoring and tailored feedback about weight and physical activity. Both the interventions were successful in controlling weight and both intervention groups perceived the interventions as positive, and 100% of participants would recommend the program to other breast cancer survivors. The remaining study did a thematic qualitative analysis, identifying the themes that mattered for successful weight loss in breast cancer survivors undertaking a group phone-based weight loss intervention, such as the importance of being part of a group and internal motivation [31].
<table>
<thead>
<tr>
<th>Authors and year</th>
<th>Country</th>
<th>Study design</th>
<th>Sample size</th>
<th>Participant characteristics</th>
<th>Duration and follow-up</th>
<th>Intervention components</th>
<th>Outcome measures</th>
<th>Results</th>
<th>Quality of the study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hartman et al. [22]</td>
<td>USA</td>
<td>RCT</td>
<td>N=36</td>
<td>Women age 40–75 years with increased risk of breast cancer (Gail Model)</td>
<td>6 months</td>
<td>Combined technology-based self-monitoring tools with individualized feedback</td>
<td>Weight and accelerometer-measured activity data</td>
<td>At 6 months, intervention participants had lost significantly more weight (4.4 kg) and had less decisional conflict, and on all subscales (p&lt;0.01), increased decisional self-efficacy mean scores (p&lt;0.01), different screening intentions (19%) but not significant.</td>
<td>Strong</td>
</tr>
<tr>
<td>Ede et al. [23] (2015)</td>
<td>USA</td>
<td>Prospective cohort study</td>
<td>75</td>
<td>Women age 40–49 years with no known high or moderate risk for breast cancer and no mammography during the previous year</td>
<td>Before and after use of app (same day)</td>
<td>The decision aid (Mammopad) included educational modules on breast cancer, mammography, risk assessment, and priority setting about screening</td>
<td>Decisional conflict, Decision Self-efficacy scale</td>
<td>Less decisional conflict, and on all subscales (p&lt;0.01), increased decisional self-efficacy mean scores (p&lt;0.01), different screening intentions (19%) but not significant.</td>
<td>Mode rate</td>
</tr>
<tr>
<td>Heo et al. [24] (2013)</td>
<td>Korea</td>
<td>Prospective cohort study</td>
<td>45</td>
<td>Women aged ≥19 years with no history of breast cancer and own a smartphone.</td>
<td>Before and after use of app</td>
<td>A smartphone application developed with functions including a breast self-examination date alarm, a reminder to encourage mother and daughter to practice breast self-examination together, record keeping, and educational content with video clips</td>
<td>Survey: increased breast self-examination</td>
<td>An increase from 28 to 32 women who did breast self-examination (p&lt;0.5), subgroups: ≥30 years of age increased from 36.4% to 81.8% (p&lt;0.05), breast self-examination during optimal time increased (2.2% to 33.3%, p&lt;0.01), 8% detected abnormal mass leading to hospital visit</td>
<td>Weak</td>
</tr>
<tr>
<td>Egbring et al. [25] (2016)</td>
<td>Switzerland</td>
<td>RCT</td>
<td>N=41, Controls N=45</td>
<td>Women aged ≥18 years, with early breast cancer initiating adjuvant or neoadjuvant chemotherapy and own a smartphone.</td>
<td>3 visits</td>
<td>Mobile and Web app to record daily functional activity and adverse events: Patients could report daily functional activity or symptoms with indication of severity</td>
<td>Functional activity, Eastern cooperative oncology group scoring, common terminology criteria for adverse events</td>
<td>Daily functional activity declined from the first to third visit for C and the E1(app) group (p&lt;0.05) but not in the E2 (app and physician) group (p&gt;0.05), questionnaire and interview</td>
<td>Strong</td>
</tr>
</tbody>
</table>
Table 1 – Description of the characteristics of the studies presented in the review

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Discussion

Given the growing numbers of mHealth applications available to patients and their increasing usage in breast cancer care, it is important to understand their utility and effectiveness. Therefore, we conducted a systematic review on studies that scientifically tested interventions using a mHealth application in breast cancer care. We identified a total of 14 studies. The studies encompassed important phases in breast cancer care, covering from prevention to survivorship. The majority of the studies focused on applications for breast cancer care-management, four on survivorship, two on early detection and one on prevention.

Overall, the results of the studies in mHealth applications for breast cancer care are promising. The majority of the identified studies showed a positive effect of the use of mHealth applications. Many hopeful opportunities offered by the mHealth applications rely in the amelioration of the communicative process between patient and doctors, favoring an effective exchange of information [29, 30]. Furthermore, this technology may result in interesting chances to improve lifestyle of individuals at risk of breast cancer [22] or breast cancer survivors [32]. However, there is no consistent evidence regarding the effectiveness of interventions using mHealth applications in breast cancer early detection, patients’ education and survivors care. A considerable amount of studies were feasibility or pilot studies [24, 28, 29, 32, 34] restricting the strength of their results. These data indicate that more evidence is needed. The need for more evidence is highlighted in particular by the studies of Foley and colleagues [12] and Heo and colleagues [24], who found that the effects of their mHealth applications were contrary to what they intuitively expected based on literature the effect of education in managing treatments’ side-effects and in facilitating adaptation in women with breast cancer [35, 36], Foley et al. [12] hypothesized that more information regarding breast cancer would decrease anxiety levels before and after breast cancer surgery. However, their
preliminary results showed that women who used the mHealth application experienced higher anxiety levels seven days after surgery than women in the control group. A possible explanation may lay in the particular educational materials or the method used to deliver it.

Similarly, Heo et al. [24] hypothesized that the use of the mHealth application would augment women’s intentions to regularly perform breast self-examination. This appeared to be true only for women younger than thirty, but contrarily, in women older than thirty this intention decreased. These results could be due to the higher familiarity of younger women with mobile applications or could be related to the small sample size of the study.

Several aspects have to be considered that may limit the generalizability of our results. The restricted number of studies in each sub-group of the breast cancer care continuum and the differences in the survey methods may have affected replies and partially account for the heterogeneity of results.

Despite these limitations, the studies identified through our search show that caution is needed in implementing interventions using mHealth applications in breast cancer care. The effects of using mHealth applications in the field of breast cancer are only recently explored and may be unpredictable. Our considerations build upon previous evidence highlighting the need for strict regulations in this field, and a solid integration between privately and research-tested mHealth applications [4, 6]. Breast cancer patients should at all times be safely empowered with regard to the effective management of their health.

For these reasons, applications need to be extensively research-tested before making them available to the public. Scientifically sound data are needed before it is possible to draw strong conclusions on the utility, effectiveness and safety of mHealth applications in breast cancer care.
Conflicts of Interest

No author has any conflicts of interest to disclose in relation to this manuscript.
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