



PCORI Evidence Map: The Impact of mHealth for Self-Management of Chronic Disease on Patient-Centered Outcomes

Prepared by

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Submitted May 2018



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Executive Summary

The literature on mHealth for chronic disease self-management has developed rapidly over the last decade, to the extent that many systematic reviews have been published on this topic. These reviews provide sufficient data for creation of evidence maps. Evidence maps are products used in systematic review to visually display and summarize research findings. They are also used to identify gaps in knowledge or future research needs. The mHealth evidence maps document areas where the literature supports (or does not support) the use of mHealth technologies to enhance patient self-management of various chronic diseases.

ECRI Institute's Director of Health Technology Assessment and Evidence-based Practice Center (EPC) Information Center performed a comprehensive literature search of the PubMed, EMBASE/Medline, PsycINFO and Cochrane Library databases from January 2010 to November 2017. Additionally, she searched ClinicalTrials.gov and the PCORI Web site to identify PCORI-funded trials in the topic area. ECRI restricted the inclusion criteria of the search to English-language systematic reviews (SRs) that performed separate analyses of mHealth interventions for self-management of any chronic disease/disorder. Further, the reviews must have formally assessed risk of bias of their included studies. In collaboration with PCORI, ECRI assembled a technical expert panel (TEP) of three members and a clinical subject matter expert (SME) who provided input into our searches, inclusion criteria, analytic framework, and protocol. The main categories of relevant mHealth intervention included text messages, mobile applications, and wearable devices. Functions performed by the interventions included the following categories: alert, educate, counsel, monitor, and record. SR results were coded as having no effect, unclear, possible positive effect, or positive effect based on an assessment of outcome categories reported in a given review. ECRI used the GRADE categorization (High, Moderate, Low, or Very low) to determine strength-of-evidence ratings for each included SR. ECRI's systems architect and systems engineer constructed all evidence maps using HTML, SVG and JavaScript.

Our searches identified 99 SRs and 19 ongoing PCORI studies that met inclusion criteria. The 99 SRs covered 13 broad categories of chronic conditions, with diabetes, obesity, mental disorders, and respiratory disorders being the most commonly evaluated conditions.

Two of the four evidence maps compared the SRs and PCORI studies based on chronic conditions, populations, outcomes, mHealth technologies, and mHealth functionalities. There was considerable overlap in chronic conditions represented in each group, with only a few chronic conditions uniquely covered in SRs or the PCORI studies, respectively. The majority of PCORI studies (11 of 19 studies) focused on vulnerable populations representing a variety of chronic diseases, while relatively few SRs had this focus (5 of 99 SRs; all 5 SRs evaluated interventions for smoking). Relatively few SRs (5 of 99) focused on pediatric populations, while 4 of 19 PCORI studies focused on this populations. Outcomes reported were mostly similar between groups except quality of life appeared more frequently in PCORI studies than in SRs. Cost savings, healthcare utilization, increase in access, and quality of care were reported in very few SRs and PCORI studies. For mHealth technologies, both SRs and PCORI studies frequently evaluated mobile apps and text messages, while relatively few SRs and PCORI studies evaluated wearable devices. Most mHealth functions (alert, educate, counsel, monitor) were relatively



well-distributed across SRs, PCORI studies, and different chronic diseases. Fewer SRs and PCORI studies evaluated mHealth interventions with record functions.

The other two evidence maps focused on the results and strength-of-evidence ratings for the mHealth SRs. The PCORI studies are not included in these maps because most are ongoing and the results have not yet been published. The results show that although the findings of the SRs ranged from “no effect” to “positive effect,” the majority of SRs had “unclear” findings, meaning that the efficacy of the mHealth interventions is uncertain. This was usually due to heterogeneity in findings or imprecision in summary effect estimates for interventions. Furthermore, the strength of evidence for the majority of SRs was rated as “low.” This was due either to studies having high risk of bias or a combination of moderate risk of bias and imprecision (uncertainty) in the results. The general pattern of findings was similar across different chronic conditions, age groups, outcomes, technologies, and technology functions. However, some SRs with a “moderate” strength-of-evidence rating did find a positive effect of mHealth interventions. Examples include SRs that found text messaging helps maintain adherence to medication in patients with HIV, diabetes and asthma, and SRs that found text messaging and mobile apps were associated with short-term weight loss in individuals who are overweight/obese.

The SRs included in the evidence maps often identified evidence gaps and provided recommendations for future research. Although many gaps and recommendations refer to a specific chronic condition and/or mHealth intervention, several common themes emerged across the various conditions and interventions. First, most of the literature concerning mHealth interventions for self-management of chronic diseases is comprised of low-quality studies. Relatively few studies were randomized and most RCTs had small sample sizes, lacked adequate statistical power to confirm intervention efficacy, and were poorly reported. The majority of RCTs evaluated short-term efficacy, with few studies evaluating long-term efficacy/sustainability of mHealth interventions. Second, relatively few RCTs enrolled pediatric patients. Thus, future RCTs focusing on this age group are needed for all relevant chronic conditions. Relatively few studies focused on vulnerable populations, and only a few SRs evaluating mHealth interventions for smoking cessation fit within this category. Many studies used multicomponent interventions and did not separately evaluate the effect of the mHealth component. Many mobile apps have never been evaluated in a clinical study, so there is a great need for future research to address this gap. Some categories of outcomes (including healthcare utilization, increase in access, quality of care, quality of life, and cost savings) were rarely evaluated in the identified literature. Finally, studies that measured adherence to medications most frequently used self-reported measures that are considered less reliable than objective measures of adherence.

The evidence gaps identified above suggest the need for future research in several areas where PCORI funding could be directed to improve the evidence base surrounding mHealth interventions for self-management of chronic disease. Indeed, the Maps of Systematic Review and PCORI Studies suggest that ongoing PCORI studies are already addressing some of these gaps, particularly those involving vulnerable populations and pediatric populations. Given the proliferation and continued evolution of mHealth technologies, we expect that PCORI will continue to address these and other gaps in their funding of future research.



Background

Chronic diseases (including heart disease, cancer, type 2 diabetes, mental disorders, obesity, and stroke, among others) comprise a substantial public health burden in terms of morbidity, mortality, and cost to the health care system. According to the CDC, roughly half of all adults have one or more chronic conditions and a quarter of adults have two or more conditions

(<https://www.cdc.gov/chronicdisease/overview/index.htm>). By educating and assisting patients to take an active role in the monitoring and management of their conditions, self-management strategies for chronic disease have the potential to improve patient-oriented outcomes, maintain or slow the worsening of progressive conditions, and reduce costs by minimizing the need for hospital visits.¹

mHealth employs mobile and wireless technologies such as short messaging services (SMS), personal digital assistants (PDA), patient monitoring devices, mobile phones and tablet computers (among others) to achieve the goals noted above. These devices enable more frequent patient-provider interaction in the form of treatment reminders, education, and goal setting, as well as remote monitoring. About 95% of Americans have cell phones that allow text messaging and 77% have smartphones that enable mobile applications. A 2017 review noted that over 318,000 mobile health apps were available worldwide. The same study estimated that 40% of health apps focused on condition management, and 16% of health apps focused on specific diseases (mostly chronic). Of the latter, the top five target conditions include mental health conditions, diabetes, cardiovascular disorders, neurologic disorders, and musculoskeletal disorders.² The widespread dissemination of these technologies provides the opportunity to help a substantial number of patients more efficiently implement strategies for self-management of their chronic conditions.¹

The literature on mHealth for chronic disease self-management has developed rapidly over the last decade, to the extent that numerous systematic reviews have been published addressing this topic. These reviews provide sufficient data for creation of evidence maps. Evidence maps are products used in systematic review to visually display and summarize research findings. They are also used to identify gaps in knowledge or future research needs. The mHealth evidence maps document areas where the literature supports (or does not support) the use of mHealth technologies to enhance patient self-management of various chronic diseases. These evidence maps will also be used to show relevant PCORI-funded research and its potential to address evidence gaps.



Methods

Selection and Engagement of Technical Expert Panel (TEP)

To ensure that this project meets the needs of PCORI and its stakeholders, ECRI (in collaboration with PCORI staff) assembled a technical expert panel (TEP) of three members qualified to provide clinical and technical guidance during the course of this project along with a clinical subject matter expert (SME). Our TEP and SME contributed input concerning our proposed analytic framework, protocol, and desired visualizations during teleconferences and through e-mail communications. Table 1 lists the names and credentials of the TEP members and SME.

Table 1. TEP Members and SME

Name	Title	Affiliation/Organization
Carolyn Turvey, PhD, MS	Core Investigator	Veterans Administration Comprehensive Access & Delivery Research & Evaluation (CADRE)
Wendy Nilsen, PhD	Program Director, Smart and Connected Health	National Science Foundation
Susan Day, MD, MPH	Professor of Clinical Medicine, Director, Population Health	Division of Internal Medicine, University of Pennsylvania
Neha Patel, MD (SME)	Director, Mobile Strategy and Applications	University of Pennsylvania

Literature Search

ECRI Institute’s Director of Health Technology Assessment and Evidence-based Practice Center (EPC) Information Center performed all searches for this project. A preliminary search was conducted in Medline and EMBASE from January 2006-September 2017. After the preliminary search identified a large body of literature, the date was changed to January 2010 following discussion with PCORI to limit the scope to fit within the time and budget allotted for the project. Our final comprehensive search protocol included searching the PubMed, EMBASE/Medline, PsycINFO and Cochrane Library databases from January 2010 to November 2017. We present the strategies in Embase.com syntax (using Emtree) in Appendix A. We translated controlled vocabulary terms and syntax for the PubMed and PsycINFO searches. To identify PCORI-funded trials in this topic area, we searched ClinicalTrials.gov and the PCORI Web site.

Operational Definition of Self-Management Interventions

Due to a lack of consistent definitions of self-management interventions in the literature, ECRI adapted an operational definition proposed by Jonkman et al. (2016).³ According to the original definition, self-management interventions are:

interventions that aim to equip patients with skills to actively participate and take responsibility in the management of their chronic condition in order to function optimally through at least knowledge acquisition and a combination of at least two of the following: stimulation of independent sign/symptom monitoring, medication management, enhancing problem-solving and decision-making skills for medical treatment management, and changing their physical activity, dietary, and/or smoking behavior.³



ECRI adapted this definition to require only knowledge acquisition and at least one of the additional activities noted in the list above.

Inclusion Criteria

ECRI's inclusion criteria were informed by discussions with PCORI, TEP and SME. For all evidence maps we set the following inclusion criteria:

- English language publication
- Systematic review (SRs) or PCORI-funded study related to mHealth interventions for self-management of any chronic disease/disorder
- Patients with a chronic disease/disorder (any type)
- Any age group (adult [age ≥ 18], pediatric or both)
- Studies/reviews must have evaluated at least one relevant mHealth intervention that uses electronic communication over a distance (not within a clinic/hospital setting).
- Relevant mHealth interventions include wireless devices that use text messaging or mobile applications and wearable monitoring devices
- SRs that covered broader interventions (e.g. telehealth) must have included a separate evaluation of mHealth interventions.
- Comparator interventions may include usual care or other mHealth interventions.
- The majority of studies included in SRs must have been conducted in populations from the United States, Canada, Australia, or Europe.
- Studies/reviews must have reported one or more relevant outcome categories. These include prevention, adherence to medications, clinical, quality of life, quality of care, healthcare utilization, increase in access, patient activation/engagement, and cost savings.
- mHealth interventions must involve communication between a patient or caregiver and the healthcare system over a distance, rather than within a clinic/hospital setting.
- SRs must have conducted a risk-of-bias assessment of individual studies using a validated instrument.

Abstract and Full Article Screening

The literature search identified 1,000 abstracts for initial screening, divided among the three project investigators, who excluded references not meeting inclusion criteria. The reviewers ordered and obtained full journal publications of references that potentially met inclusion criteria. SRs that initially appeared to meet inclusion criteria were screened in duplicate by at least two reviewers.

Data Extraction

ECRI project investigators extracted data from SRs and PCORI-funded studies into an Excel Spreadsheet. The extracted information for SRs included the following: author, year of publication, PubMed link, chronic disease/condition, broader disease category, number of included studies in SR, number of RCTs in SR, population addressed (adult, pediatric, or both), whether vulnerable populations were addressed, mHealth technology (text message, mobile app, wearable device, other), mHealth functionality (alert, educate, counsel, monitor, record), outcomes reported (see list under Inclusion Criteria above), results (no effect, unclear, possible positive effect, positive effect), and strength of evidence (Very low, Low,



Moderate, or High). ECRI investigators also extracted information on future research needs and evidence gaps identified in the SRs. Data extraction for PCORI-funded studies did not include results and strength of evidence since the results have not yet been reported. All of this information was used to populate the evidence maps described later in this report.

Definitions for mHealth Functionality

ECRI reviewers adapted the following definitions for mHealth functionality from Farzandipour et al. (2017):⁴

- Alert – Send alert or reminder to the user.
- Educate – Provide information in a variety of formats (text, photo, video) or provide instruction to the user.
- Counsel – Provide guidance based on user-entered information (e.g., recommend a physician consultation or course of treatment).
- Monitor – Automatic detection of patient behavior/activity or clinical measures by a monitoring device.
- Record – Capture user-entered data.

Summarizing Systematic Review Findings (Direction of Effect)

ECRI investigators adapted a coding system developed by the Pacific Northwest Evidence-Based Practice Center to summarize SR findings.⁵ The SR results were coded as no effect, unclear, possible positive effect, or positive effect based on an assessment of outcome categories reported in a given review. If the results had a consistent direction of effect for one of the relevant outcome categories (e.g. clinical), ECRI reviewers used the codes of no effect or positive effect. If the results for another outcome category (e.g. prevention) had inconsistency in direction of effect and/or review authors could not reach a conclusion, the findings were coded as unclear for that outcome category. If one or more outcome categories had minor inconsistency in findings, the findings were coded as possible positive effect. Therefore, some SRs could have more than one code if they reported more than one outcome category.

Strength-of-Evidence Ratings

Strength of evidence (SOE) refers to the confidence one can have in research findings. The ECRI reviewers used the AHRQ EPC methods guidance to rate SOE of reviews that did not report their own rating. The AHRQ method is adapted from the GRADE system and draws on the following domains: the risk of bias of the included studies, directness of comparisons, consistency of results across different studies, precision of study findings, and possibility of reporting bias.⁶ ECRI used the GRADE categorization (High, Moderate, Low, or Very low) to determine strength-of-evidence ratings for each outcome category in the included systematic review. Our definitions for these ratings are as follows:

- High – We are very confident in the stated direction of effect.
- Moderate – We are moderately confident in the stated direction of effect, but there is a possibility that the true effect is substantially different from the estimate.
- Low – Our confidence in the stated direction of effect is limited; the true effect may be substantially different from the estimate.
- Very low – We have very little confidence in the stated direction of effect; the true effect is likely to be substantially different from the estimate.



SOE assessment begins with determining the risk of bias of the evidence base in each SR. ECRI used the risk-of-bias ratings reported in each review. For example, if the risk of bias was Moderate and there were no deficiencies in other domains, the SOE for that SR would be rated as Moderate. However, if there was an additional deficiency in another domain (e.g. imprecision in treatment effect estimates) then the SOE would be downgraded to Low. Since SOE assessment was performed separately for different outcome categories, SRs that reported multiple outcome categories could have more than one SOE rating.

Map Construction

ECRI's systems architect and systems engineer constructed all maps using HTML, SVG and JavaScript. Based on suggestions from the ECRI and PCORI project team, they made iterative improvements to optimize usability and informativeness. Graphic designers informed design of colors and layout.

Results

Evidence Base

Our searches for SRs yielded 1,000 potentially relevant abstracts (see article flow in Figure 1 **Error! Reference source not found.** on following page). Abstract screening resulted in exclusion of 518 references from further consideration. The three most common exclusion reasons were 1) not an SR, 2) no relevant mHealth intervention, and 3) did not evaluate self-management of chronic disease. The reviewers ordered and obtained the remaining 482 references for full-article screening. An additional 383 references were excluded at this stage. The most common reason for exclusion was no risk-of-bias assessment. Other reasons included no mHealth interventions evaluated, no separate analysis of mHealth interventions, no comprehensive literature search, no pre-specified inclusion criteria, no relevant outcomes, majority of studies from non-relevant geographic regions, study not an SR, or meeting abstracts with insufficient methods details. ECRI reviewers extracted data from the remaining 99 SRs into an Excel spreadsheet used for creation of evidence maps 1-3.

In addition, PCORI staff provided the ECRI reviewers with 28 summaries of ongoing PCORI-funded studies that evaluated mHealth interventions. Upon review of these documents, ECRI reviewers determined that 19 PCORI studies addressed the use of relevant mHealth interventions for self-management of chronic diseases. These 19 studies appear in maps 1 and 2 alongside the 99 included SRs. Characteristics of these studies are summarized in Table 2 (Appendix B).

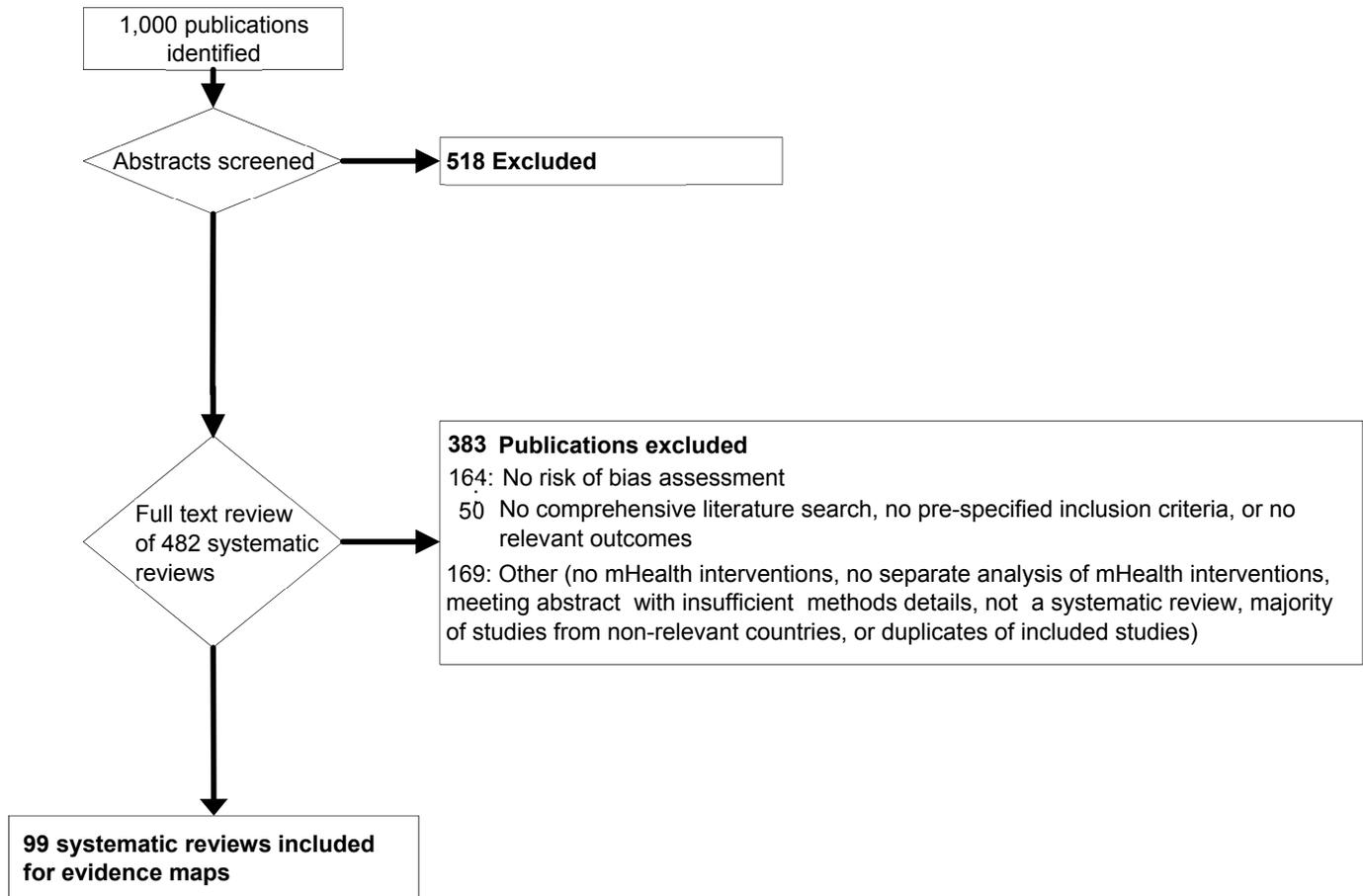
Summary of the Systematic Reviews in Evidence Maps

The 99 included SRs covered 13 broad categories of chronic conditions: diabetes (26 SRs), obesity (21 SRs), mental disorders (22 SRs), respiratory disorders (18 SRs), cardiovascular disorders (11 SRs), smoking (12 SRs), infectious diseases (9 SRs), neurologic disorders (5 SRs), chronic kidney disease (2 SRs), chronic pain (2 SRs), cancer (2 SRs), multiple comorbid conditions (2 SRs), and other (4 SRs). These numbers add up to greater than 99 because 18 SRs addressed multiple chronic conditions (conditions from different broad disease/condition categories) in the same review. Clinical outcomes were the most frequently evaluated outcomes in SRs of diabetes (e.g. HbA1c), mental disorders, neurologic disorders, chronic kidney disease, cancer, and chronic pain. Clinical outcomes and adherence to medication were about equally common in SRs of respiratory disorders and cardiovascular disorders. Adherence to



medication was the most frequently evaluated outcome in SRs of smoking and infectious disease. Prevention-related outcomes were most frequently reported in SRs of obesity.

Figure 1. Article Flow

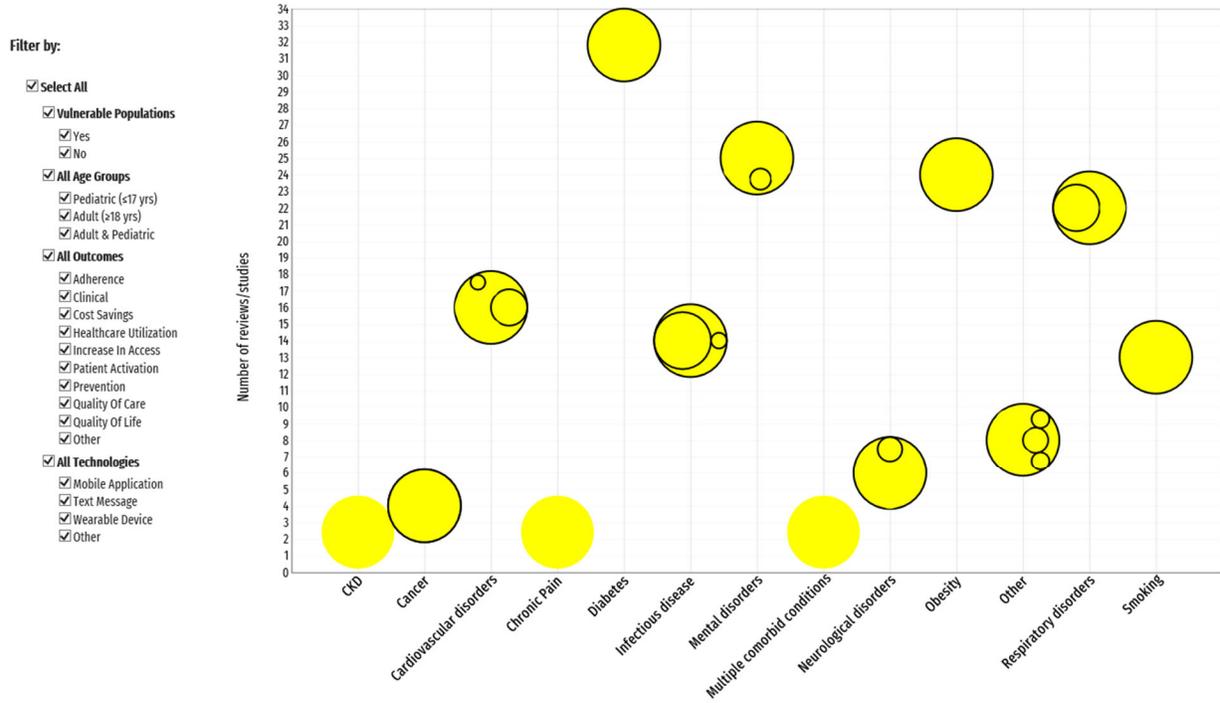


Map of mHealth Systematic Reviews and PCORI Studies

This evidence map displays chronic conditions (on the X axis) against the number of PCORI studies and SRs (on the Y axis). The total study counts for each chronic condition includes SRs and ongoing PCORI studies. The large yellow circles represent broad categories of chronic conditions (e.g. cardiovascular disorders, mental disorders). Some of the large circles contain packed circles representing specific conditions within those broader categories (e.g. hypertension within the cardiovascular disorders circle, HIV within the infectious diseases circle). Also, a black outline around a yellow circle means that a PCORI study (or studies) is evaluating mHealth interventions for that chronic condition. Hovering over each circle displays pop-up text providing the total study counts as well as separate counts for the number of SRs and number of PCORI studies addressing that condition. The map also includes filters allowing readers to look at number of studies/SRs for vulnerable populations, different age groups, specific outcome categories, and specific mHealth technologies.

Figure 2 provides a screenshot of this evidence map. SRs evaluated studies of mHealth interventions most frequently for patients with diabetes (28 SRs), which was also the chronic condition most frequently addressed in ongoing PCORI studies (5 studies). Other conditions with high numbers of SRs include mental disorders, obesity, and respiratory disorders. The PCORI studies also covered these chronic conditions. Two conditions only represented by PCORI studies include stem cell transplants and systemic sclerosis, while chronic kidney disease, chronic pain, multiple comorbid conditions, and glaucoma were represented in SRs but not PCORI studies. The majority of PCORI studies (11 of 19 studies) focused on vulnerable populations representing a variety of chronic diseases, while relatively few SRs had this focus (5 of 99 SRs: all 5 SRs evaluated interventions for smoking). Relatively few SRs (5 of 99) focused on pediatric populations, while 4 of 19 PCORI studies focused on this age group. Clinical outcomes were the most commonly reported outcome category, particularly in SRs evaluating diabetes, but also for obesity, mental, cardiovascular and respiratory disorders. Also, 17 of 19 PCORI studies reported clinical outcomes. Adherence (to medication) was commonly reported in SRs focusing on diabetes, infectious disease, cardiovascular, mental, and respiratory disorders. Prevention-related outcomes were commonly reported in SRs of obesity, smoking, and mental disorders. Although reported in relatively few SRs (15 of 99), quality of life appeared frequently as an outcome in PCORI studies (15 of 19). Cost savings, healthcare utilization, increase in access, and quality of care were reported in very few SRs and PCORI studies. For mHealth technologies, both SRs and PCORI studies frequently evaluated mobile apps and text messages, while relatively few SRs and PCORI studies evaluated wearable devices.

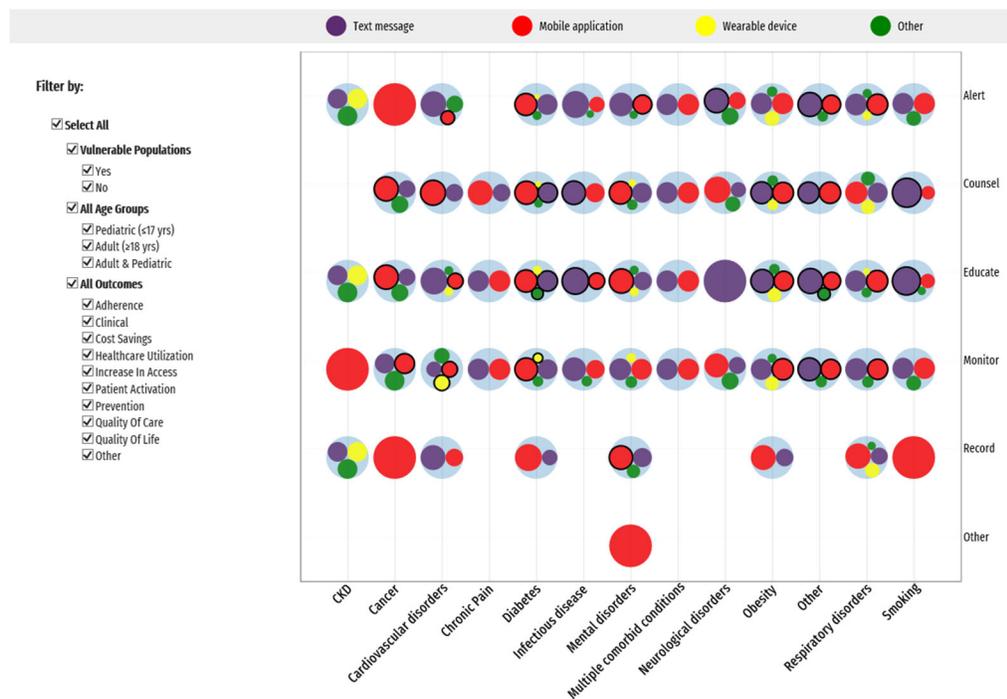
Figure 2. Screenshot of Map of mHealth Systematic Reviews and PCORI Studies



Map of Systematic Reviews and PCORI Studies by mHealth Intervention and Functionality

This map displays chronic conditions (the X axis) against the functional purpose (alert, educate, counsel, monitor, record, or other) of the mHealth interventions (the Y axis) in the SRs and PCORI studies. The colored packed circles within the larger circles indicate different mHealth interventions. As in the previous map, a black outline around a circle indicates the presence of a PCORI study. In addition, hovering over each circle generates pop-up text indicating the number of SRs and PCORI studies. The graph shows that most of the functions (alert, educate, counsel, monitor) were relatively well-distributed across SRs, PCORI studies, and different chronic diseases. Fewer SRs and PCORI studies evaluated mHealth interventions with record functions. The one SR that was categorized as “other” function evaluated a mHealth device for speech generation for patients with autism spectrum disorders. Figure 3 provides a screenshot of SRs and PCORU Studies by mHealth Intervention and Functionality.

Figure 3. Screenshot of Map of Systematic Reviews and PCORI Studies by mHealth Intervention and Functionality



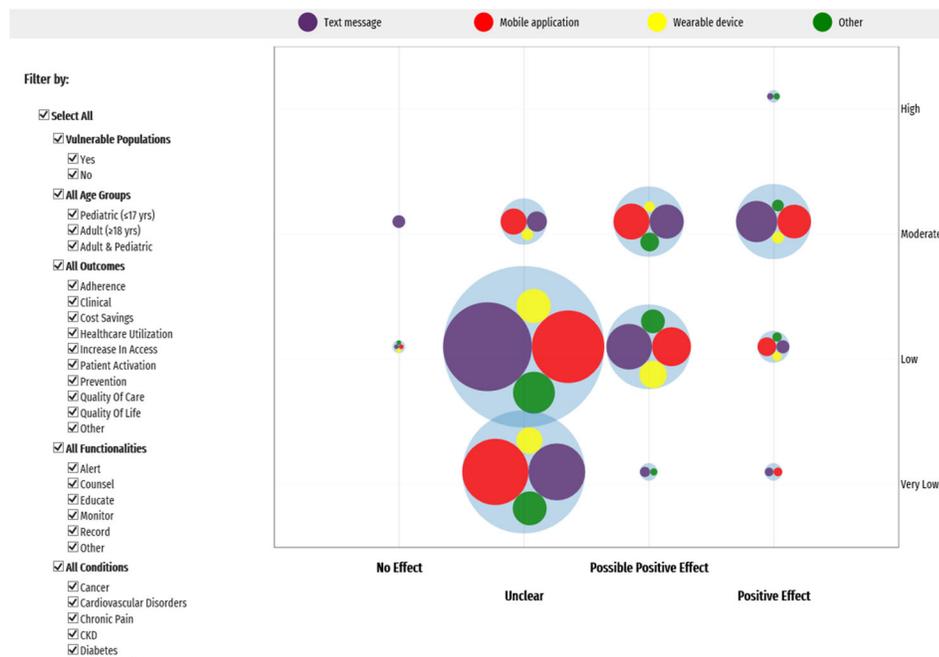
Map of Strength-of-Evidence Ratings across mHealth Interventions

This map focuses on the results and strength-of-evidence (SOE) ratings for the mHealth SRs. The PCORI studies are not included in this map because most are ongoing and the results have not yet been published. Results of mHealth interventions are reported on a scale ranging from “no effect” at the lower end to “positive effect” on the upper end, while the strength of evidence ranges from “very low” at the bottom to “high” at the top. As in map 2, the colored packed circles within the larger circles indicate different mHealth interventions. In this map, the size of the circles indicates the number of SRs; larger circles include more SRs than smaller circles. Hovering over each circle generates pop-up text providing the number of SRs and also provides weblinks for the individual SRs within the circles. Clicking on a link will bring up the PubMed abstract for that particular SR. This map also includes a filter for

chronic conditions, which allows a reader to select one specific chronic condition (e.g. diabetes) and examine the results and strength of evidence for that condition alone.

The results show that although the findings of the SRs ranged from “no effect” to “positive effect,” the majority of SRs had “unclear” findings, meaning that the efficacy of the mHealth interventions is uncertain. This was usually due to heterogeneity in findings or imprecision in summary effect estimates for interventions. Furthermore, the strength of evidence for the majority of SRs was rated as “low.” This was due either to studies having high risk of bias or a combination of moderate risk of bias and imprecision (uncertainty) in the results. The remaining SRs divided into “very low” and “moderate” strength of evidence, with evidence from only one SR on respiratory disorders scoring as “high” strength. The general pattern of findings was similar across different chronic conditions, age groups, outcomes, technologies, and technology functions. For some chronic conditions (e.g. respiratory disorders, mental disorders), the strength of evidence varied substantially among SRs that found a positive or possible positive effect. Explanations for these differences include different study inclusion criteria (which resulted in differences in the evidence base or number of studies selected in each SR), differences in instruments used to assess risk of bias in different SRs, differences in outcomes evaluated in each SR, and differences in the specific chronic conditions (e.g. different mental disorders) evaluated across SRs. Therefore, readers should be wary about simply averaging the strength of evidence across SRs for a given chronic condition, as this would not take into account the differences in the above variables among different SRs. Figure 4 provides a screenshot of SOE Map across mHealth Interventions.

Figure 4. Screenshot of Map of Strength-of-Evidence Ratings across mHealth Interventions



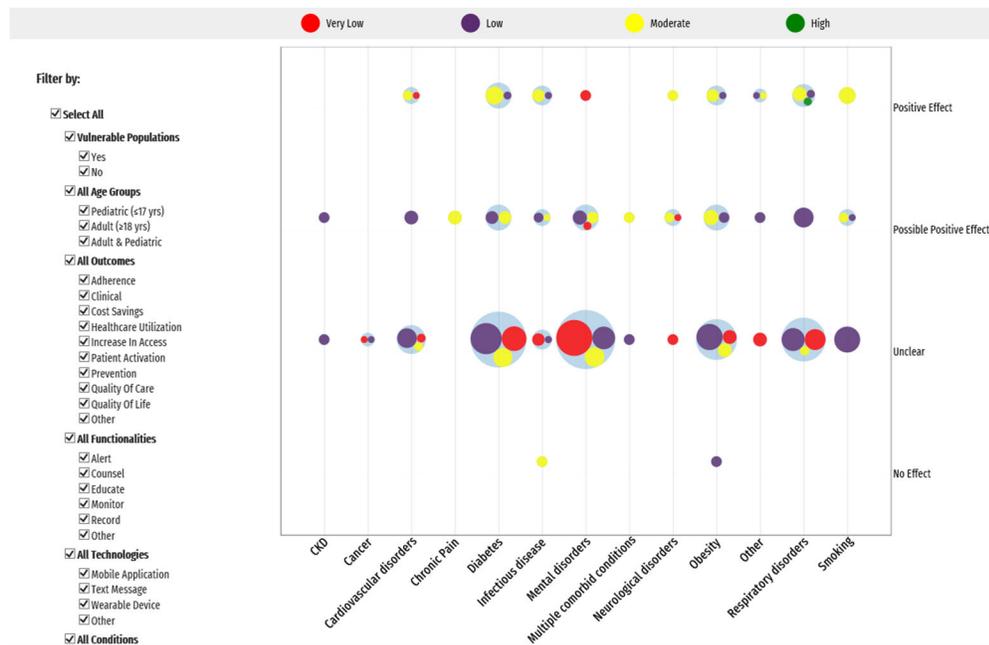
Map of Strength-of-Evidence Ratings across Chronic Conditions

Like the previous SOE map, this map focuses on the results and strength-of-evidence ratings for the mHealth SRs. The PCORI studies are not included for the same reasons as discussed above. This map

provides a different way to display the SOE findings. It allows the user to view the direction of effect (on the y axis) and strength of evidence (colored circles) for all of the chronic conditions (on the x axis) simultaneously. One of the filters allows individual chronic conditions to be examined separately. In this map, strength of evidence appears as colored circles, ranging from “very low” (red) to “high” (green); “low” and “moderate” strength evidence are represented by purple and yellow circles, respectively. As in the above SOE map, the size of the circles indicates the number of SRs; larger circles include more SRs than smaller circles. Hovering over each circle generates pop-up text providing the number of SRs and also provides weblinks for the individual SRs within the circles. Clicking on a link will bring up the PubMed abstract for that particular SR.

The results show that for almost every chronic condition, the majority of the SRs had “unclear” findings regarding intervention efficacy. Furthermore, examination of the colored circles reveals that the majority of SRs received a “low” rating for strength of evidence. These findings were similar across different age groups, outcomes, technologies, and technology functions. However, some SRs with a “moderate” strength-of-evidence rating did find a positive effect of mHealth interventions. Examples include SRs that found text messaging helps maintain adherence to medication in patients with HIV, diabetes and asthma, and SRs that found text messaging and mobile apps were associated with short-term weight loss in individuals who are overweight/obese. Figure 5 provides a screenshot of SOE Map across Chronic Conditions.

Figure 5. Screenshot of Map of Strength-of-Evidence Ratings across Chronic Conditions



Future Research

The SRs included in the evidence maps often identified evidence gaps and provided recommendations for future research. Specific evidence gaps and future research recommendations for each chronic disease/disorder appear in Table 3, Appendix C.



Although many gaps and recommendations refer to a specific chronic condition and/or mHealth intervention, several common themes emerged across the various conditions and interventions. First, most of the literature concerning mHealth interventions for self-management of chronic diseases is comprised of low-quality studies. Relatively few studies were randomized and most RCTs had small sample sizes, lacked adequate statistical power to confirm intervention efficacy, and were poorly reported. The majority of RCTs evaluated short-term efficacy, with few studies evaluating long-term efficacy/sustainability of mHealth interventions. However, long-term evaluation of interventions in a field with rapidly changing technology can be challenging, in that sometimes a technology may become outdated by the time a long-term study is completed. Second, relatively few RCTs enrolled pediatric patients. Thus, future RCTs focusing on this age group are needed for all of the chronic conditions covered in the evidence maps. Relatively few studies focused on vulnerable populations, and only a few SRs evaluating mHealth interventions for smoking cessation fit within this category. Many studies used multicomponent interventions, with mHealth devices representing only one component, and did not separately evaluate the effect of the mHealth component. Given the influx of mHealth mobile apps, including many that have never been evaluated in a clinical study, there is a great need for future research to address this gap. Mobile apps that have similar functions should ultimately be compared in clinical studies to help clinicians identify the most useful apps to recommend for their patients. Some categories of outcomes (including healthcare utilization, increase in access, quality of care, quality of life, and cost savings) were rarely evaluated in the identified literature. Finally, studies that measured adherence to medications most frequently used self-reported measures that are considered less reliable than objective measures of adherence.

The evidence gaps identified above suggest the need for future research in several areas where PCORI funding could be directed to improve the evidence base surrounding mHealth interventions for self-management of chronic disease. Indeed, evidence maps 1 and 2 suggest that ongoing PCORI studies are already addressing some of these gaps, particularly those involving vulnerable populations and pediatric populations. Given the proliferation and continued evolution of mHealth technologies, we expect that PCORI will continue to address these and other gaps in their funding of future research.

Limitations

We acknowledge several important limitations to this work. First, the large literature base necessitated that the literature search be limited to SRs published in the last eight years. Second, we excluded SRs that did not assess risk of bias of their included studies using a validated instrument. We did this to restrict the evidence base to SRs that met a standard for minimum methodological quality, but this means that the true number of relevant SRs for each chronic condition is higher than the numbers recorded in the evidence maps. Third, our inclusion criteria regarding mHealth interventions may have excluded interventions that other stakeholders might have included (for example, this report excluded SRs that focused predominantly on web-based interventions that did not require mobile devices). In addition, our method for assessing strength of evidence of the studies included in each SR relied predominantly on the risk-of-bias assessment provided by the SR authors as a starting point, and the instruments used to assess risk of bias varied widely across SRs. Finally, had we performed our own risk-of-bias assessments using a single instrument across studies, this might have changed our strength-of-evidence assessments for some SRs.

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Appendices

Appendix A: Literature Search Methods

Literature Search:

In November 2017 and January 2018, we conducted a literature review to identify systematic reviews focused on the use of mHealth technologies for managing chronic disease. Our search protocol included PubMed and EMBASE/Medline. We also searched the National Guideline Clearinghouse to identify clinical practice guidelines that addressed this topic. We present the strategies in Embase.com syntax (using Emtree) in the table below. We translated the controlled vocabulary terms and syntax for the PubMed searches.

Clinical Trials and NIH Funding Announcements:

To identify PCORI-funded trials in this topic area, we searched ClinicalTrials.gov and the PCORI website. Search terms used for ClinicalTrials.gov include:

("multiple sclerosis" OR MS OR RRMS OR PPMS OR SPMS) AND patient-centered outcomes [Sponsor]

Bibliographic Search Strategies:

Embase.com [2010 - 2017]

Set Number	Concept	Search Statement
1	mHealth	('mHealth' OR 'm-Health') AND [2010-2017]/py
2		('cell phone' OR 'iPhone' OR ((mobile OR wireless OR Bluetooth) NEAR/2 (health* OR device OR phone OR internet OR application OR app))) AND [2010-2017]/py
3		('Mobile phone'/de OR 'wireless communication'/de OR 'mobile application'/de) AND [2010-2017]/py
4		('social media'/de OR 'social media' OR twitter OR tweet OR Facebook) AND [2010-2017]/py
5		((wearable NEAR/3 device*) OR fitbit) AND [2010-2017]/py
6		(laptop OR (tablet NEAR/3 computer*) OR iPad) AND [2010-2017]/py
7		('text messaging'/de OR texting OR (text* NEAR/2 messag*) OR 'SMS' OR 'short message service') AND [2010-2017]/py
8		('smartphone' OR 'smartwatch' OR 'personal digital assistant' OR 'information technology-based' OR 'app-based' OR 'application based' OR Android OR jawbone OR 'web 2.0' OR sensewear) AND [2010-2017]/py
9	Combine sets – mHealth	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8
10	Chronic disease - general	('chronic disease'/exp OR chronic*:ti) AND [2010-2017]/py

Set Number	Concept	Search Statement
11	Cardiovascular disease	('cardiovascular disease'/exp OR (((cardiovascular OR cardiac OR heart OR 'coronary artery' OR 'peripheral arter**') NEAR/2 disease*):ti) OR chf:ti OR 'heart failure':ti OR arrhythmi*:ti OR hypertension:ti OR 'high blood pressure':ti OR 'cad':ti OR 'PAD':ti OR 'CVD':ti) AND [2010-2017]/py
12	diabetes	('diabetes mellitus'/exp OR diabet*:ti OR 'T2DM':ti OR 'T2-DM':ti OR 'type 2 diabetes':ti OR 'type-2 diabetes':ti) AND [2010-2017]/py
13	stroke	('cerebrovascular accident'/exp OR stroke*:ti OR 'CVA':ti) AND [2010-2017]/py
14	cancer	('malignant neoplasm'/exp OR cancer*:ti OR carcinoma*:ti OR adenocarcinoma*:ti OR sarcoma*:ti OR glioma*:ti OR glioblastoma*:ti OR malignancy:ti OR leukemia*:ti OR lymphoma*:ti) AND [2010-2017]/py
15	obesity	('obesity'/exp OR 'weight reduction':ti OR 'body mass':ti OR 'weight':ti OR obes*:ti OR ((weight NEAR/2 (manage* OR reduc* OR loss*)):ti)) AND [2010-2017]/py
16	Lung diseases	('lung disease'/exp OR 'obstructive airway disease'/exp OR (asthma* OR COPD OR emphysema OR 'chronic obstructive lung disease' OR bronchitis):ti) AND [2010-2017]/py
17	Serious mental illness	('mental disease'/exp OR 'mood disorder'/exp OR 'psychosis'/exp OR ('affective disorder' OR depression* OR depressive OR 'MDD" OR bipolar OR schizo* OR psychos* OR mental):ti) AND [2010-2017]/py
18	Chronic pain	('chronic pain'/exp OR (pain NEAR/3 (intractable OR refractory OR chronic))) AND [2010-2017]/py
19	Medication self-management	'medication therapy management'/de OR 'drug therapy'/exp OR (medication* NEAR/2 manage*):ti)
20		(Self NEAR/4 (care OR efficac* OR manag* OR monitor*)):ti
21		'self care'/exp OR ('self care' OR 'self management' OR 'self treatment'):ti
22		(#19 OR #20 OR #21) AND [2010-2017]/py
23	Hearing loss	('hearing impairment'/exp OR 'hearing disorder'/de OR deaf*:ti OR (hearing NEAR/2 (defect* OR difficult* OR impair* OR loss*)):ti) AND [2010-2017]/py
24	Smoking cessation	('smoking cessation'/de OR 'smoking'/exp OR 'tobacco use'/de OR (smoking NEAR/2 (quit* OR cessation)):ti) AND [2010-2017]/py
25	Systemic sclerosis	('systemic sclerosis'/exp OR 'systemic sclerosis':ti OR ((generalized OR generalised OR progressive OR diffuse OR limited OR systemic) NEAR/2 scleroderma):ti OR ('CREST' NEAR/2 syndrome):ti) AND [2010-2017]/py

Set Number	Concept	Search Statement
26	Caregiver distress	('distress syndrome'/de OR 'mental stress'/de OR 'caregiver'/de OR 'caregiver burden'/de OR (caregiver* NEAR/3 distress):ti OR (caregiver AND 'psychological distress'):ti) AND [2010-2017]/py
27	Combine sets	#10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #23 OR #24 OR #25 OR #26
28	Combine sets – mHealth for specific diseases	#9 AND #27
29	Limit to SRs/Meta-analyses	#28 AND ('systematic review'/de OR 'meta analysis'/de OR (meta NEAR/2 analy*) OR 'systematic review')
30	Limit by publication type	#29 NOT ('editorial'/exp OR editorial:it OR 'erratum'/exp OR letter:it OR 'note'/exp OR note:it OR 'short survey'/exp)
31	Limit to humans	#30 AND [humans]/lim
32	Limit to English	#31 AND [English]/lim

National Guideline Clearinghouse

Search:

mHealth

“Mobile health”

“cell phone”

Texting

ClinicalTrials.gov: Since the topic was so broad it was most efficient to search for trials where PCORI was listed as a Sponsor/Collaborator. 305 studies were identified and titles were reviewed and compared with the list provided by PCORI.

Targeted search: PCORI OR “patient-centered outcomes research institute”

Appendix B: Related PCORI-funded projects

Table 2. Related PCORI-funded Projects

Author	Title	Study Duration	# of Patients	Project Overview	mHealth Intervention	Outcomes
Baer, H. https://www.pcori.org/research-results/2015/using-online-weight-management-program-and-support-primary-care-practices-help	Integrating Online Weight Management with Primary Care Support: Patient-Centered Strategies for Addressing Overweight and Obesity in Primary Care	9/1/2015-7/15/2019	840	Online/mHealth texting weight management intervention integrated with population management support from PCP practices	Mobile application for weight management	<i>Primary:</i> Change in body weight <i>Secondary:</i> Changes in blood pressure, cholesterol, triglycerides, fasting glucose, HbA1c levels, diet and physical activity, health status, weight-related QoL
Bailey, J. https://www.pcori.org/research-results/2016/improving-self-care-decisions-medically-underserved-african-americans	Improving Self-Care Decisions of Medically Underserved African-Americans with Uncontrolled Diabetes: Effectiveness of Patient-Driven Text Messaging vs Health Coaching	5/1/2016-8/31/2020	800	Diabetes self-care promoted through patient-driven text messaging or health coaching in primary care setting with vulnerable patients. Compares the effectiveness of behavioral intervention with use of mobile phone	Patient-driven text messaging for managing uncontrolled diabetes	<i>Primary Patient Outcomes:</i> Diabetes self-care activities including diet, exercise and medication adherence <i>Secondary Patient Outcomes:</i> Diabetes-specific QoL: Primary Care engagement; Average Blood Sugar (A1c)
Ben-Zeev, D. https://www.pcori.org/research-results/2014/comparing-mobile-health-and-clinic-based-self-management-interventions-serious	Comparing Mobile Health (mHealth) and Clinic-Based Self-Management Interventions for Serious Mental Illness: Patient Engagement, Satisfaction, and Outcomes	9/1/2014-9/30/2018	160	Comparison on illness self-management interventions for SMI involving a clinic-based protocol vs mHealth smartphone intervention to track symptoms and prompt self-management. All responses to patients are automated (app and/or text). No provider interaction through the app.	FOCUS smartphone application system to improve self-management in serious mental illness	Study did not distinguish between primary and secondary outcomes. Outcomes include: symptoms, recovery, QoL, patient willingness to enroll, patient engagement, and patient satisfaction

Author	Title	Study Duration	# of Patients	Project Overview	mHealth Intervention	Outcomes
Fiscella, K. https://www.pcori.org/research-results/2013/helping-people-living-hiv-learn-skills-manage-their-care	Addressing HIV Treatment Disparities Using a Self-Management Program and Interactive Personal Health Record	4/1/2014-1/31/2018	360	Use of iPod for self-management, educational app for PLWH coupled with health coaching and clinician encouragement of patients to utilize iPod app	Web-enabled hand-held device customized for HIV patients	<i>Primary Patient Outcomes:</i> Pre- post-changes in patient activation measure score <i>Secondary Patient Outcomes:</i> eHealth literacy; patient involvement in decision-making & care, medication adherence; preventive care; HIV Viral Load
Green, L./Rivers, B. https://www.pcori.org/research-results/2013/navigator-guided-e-psychoeducational-intervention-prostate-cancer-patients-and	Navigator Guided e-Psychoeducational Intervention for Prostate Cancer Patients and Their Caregivers	7/1/2013-4/30/2018	391	Using an app: Personalized Health Information Navigator (PHIN); an interactive psycho-educational intervention delivered via mobile tablet technology	Personalized Health Information Navigator mobile application for patient-centered education	<i>Primary Patient Outcomes:</i> NR
Greer, J. https://www.pcori.org/research-results/2013/does-smartphone-app-help-patients-cancer-take-oral-chemotherapy-planned	Mobile Application for Improving Symptoms and Adherence to Oral Chemotherapy in Patients with Cancer	3/1/2014-11/30/17	100	Examine impact of mobile application (eCARE-AD), which offers tailored feedback to cancer patients in real-time based on PROs, on outcomes such as medication adherence, symptoms, and QoL. PRO data triaged to oncologists.	Mobile application to assesses symptoms and adherence concerns for patients taking oral cancer chemotherapy	<i>Primary Outcomes:</i> Adherence to oral chemotherapy <i>Secondary Outcomes:</i> Symptoms and side effects of treatment; Patient QoL; Satisfaction with care; Urgent care clinic visits; ED visits
Katz, R. https://www.pcori.org/research-results/2013/changing-healthcare-delivery-model-community-health-workermobile-chronic-care	Changing the Healthcare Delivery Model: A Community Health Worker/Mobile Chronic Care Team Strategy	10/1/2013-10/31/17	166	3 arm comparison of mHealth system plus CHW vs. mHealth system alone vs. CHW alone to improve diabetes self-management and achieve better wellness behaviors and clinical outcomes	Mobile application (mHealth disease management system) to increase wellness behaviors in patients with diabetes	<i>Primary Patient Outcomes:</i> Change from baseline in the unmet behaviors/goals that were not achieved at Year 1 <i>Secondary Patient Outcomes:</i> Change in distress from baseline as measured with Fisher Brief Diabetes Distress; Change in hemoglobin A1C; Change in medication adherence

Author	Title	Study Duration	# of Patients	Project Overview	mHealth Intervention	Outcomes
Laudenslager, M. https://www.pcori.org/research-results/2013/quality-life-allogeneic-hematopoietic-stem-cell-transplant-patients-improved	Quality of life in allogeneic hematopoietic stem cell transplant patients is improved when their caregiver's distress is reduced	10/1/2013 -1/31/18	159	Smartphone technology enables video chats between caregivers and their providers (supporting caregiver self-management and relaxation strategy learning), so that they can attend appointments even when unable to be physically present in an outpatient setting	Smartphone technology for reducing distress & enhancing quality of life for both the patient and caregiver	<i>Primary Patient Outcomes:</i> Change in patient QoL over time; Change in caregiver distress over time <i>Secondary Patient Outcomes:</i> Change in the following over time: <ul style="list-style-type: none"> • Perceived Stress • Depression • Anxiety • Adrenal Activity • Caregiver telomere length • Caregiver telomerase activity • Caregiver burden
Ma, G. https://www.pcori.org/research-results/2014/comparative-trial-improving-care-underserved-asian-americans-infected-hbv	A Comparative Trial of Improving Care for Underserved Asian Americans Infected with HBV (PNMI)	1/01/2015 -1/30/19	500	Assessing the effect of the PNMI intervention that includes patient-navigator driven sessions and clinical support + CHB patient-designed text messages (v. usual care) in helping to increase education, self-management, and monitoring/adherence re: chronic HBV among Asian Americans	Patient navigator-led plus mobile phone text messaging intervention (PNMI) for improving adherence to HBV monitoring guidelines	<i>Primary Patients Outcomes:</i> Patients receiving the PNMI intervention will have increased adherence rate to the recommended clinical care and getting doctor-recommended tests at 6 and 12-months compared to the Standard Care. <i>Secondary Patient Outcomes:</i> Patients receiving the PNMI intervention will report greater increases in HBV knowledge, coping skills, social support, benefit finding, QoL, and greater reductions in anxiety compared to patients receiving standard care.
Margolis, K. https://www.pcori.org/research-results/2016/pragmatic-trial-comparing-telehealth-care-and-optimized-clinic-based-care	Pragmatic Trial Comparing Telehealth Care and Optimized Clinic-Based Care for Uncontrolled High Blood Pressure	7/1/2016-6/30/2021	2000	Comparison of two organizational models for team-based care (face-to-face clinic care with physician-medical assistant dyad vs. telehealth care coordinated by pharmacist or nurse practitioner with home BP monitoring and strong self-management)	Systematic home blood pressure tele monitoring, between visit care by telephone and e-mail	<i>Primary Patient Outcomes and Measurements:</i> Systolic Blood Pressure – over 12 months <i>Secondary Patient Outcomes and Measurements:</i> Self-reported side effects of antihypertensive medications; Patient experience/satisfaction with care; Confidence in self-management of blood pressure

Author	Title	Study Duration	# of Patients	Project Overview	mHealth Intervention	Outcomes
McDermott, M. https://www.pcori.org/research-results/2014/patient-centered-home-exercise-program-peripheral-artery-disease	Patient Centered Home Exercise Program for Peripheral Artery Disease	9/1/2014-8/31/2018	210	Use of Fitbit activity monitor and telephone/in-person coach to assist patients with peripheral artery disease in a home-based exercise program	Fitbit to monitor exercise behavior	<i>Primary Outcomes:</i> Six minute walk time at baseline and 9-month follow-up <i>Secondary Outcomes:</i> Walking Impairment Questionnaire – changes in distance/speed scores; Patient-Reported Outcomes Measurement Information System (PROMIS) Questionnaires
Nkoy, F. https://www.pcori.org/research-results/2013/redesigning-ambulatory-care-delivery-enhance-asthma-control-children	Redesigning Ambulatory Care Delivery to Enhance Asthma Control in Children	08/2013 – 5/30/2018	327	Web-based portal enables PCPs to have real-time access to patient asthma symptom data, and encourages patients/caregivers to take a more proactive role in self-management and other care-related activities	Web-based tool & application (AsthmaTracker) used track asthma symptoms regularly & act before an asthma attack happens	<i>Primary Patient Outcomes and Measurements:</i> Change of Child/Parent quality of life – QOL at baseline, 3 month, 6 months and 12 months. <i>Secondary Patient Outcomes and Measurements:</i> <ul style="list-style-type: none"> • Child asthma control – use of e-AT • Child interrupted/missed school days • Parent satisfaction • Parent interrupted/missed work days • Use of oral steroid • ED/hospital admissions
Poole, J https://www.pcori.org/research-results/2014/taking-charge-systemic-sclerosis-improving-patient-outcomes-through-self	Taking Charge of Systemic Sclerosis: Improving Patient Outcomes Through Self-Management	9/1/2014 - 5/1/2018	250	Internet-based program (self-management and exercise) requires self-guided learning and provides downloadable resources, exercise routines, worksheets, etc. in the form of 1) several learning modules accessible each week via a secured website, and 2) weekly posts/facilitated online discussions	Web-based Self Management Program: includes educational videos (1–2 posted weekly), and a discussion board	<i>Primary Outcomes:</i> Improved self efficacy <i>Secondary Outcomes:</i> <ul style="list-style-type: none"> • Health knowledge • Patient Activation • QoL • Health Utilization and health log

Author	Title	Study Duration	# of Patients	Project Overview	mHealth Intervention	Outcomes
Rubin, D. https://www.pcori.org/research-results/2017/community-health-workers-and-mobile-health-emerging-adults-transitioning	Community Health Workers and Mobile Health for Emerging Adults Transitioning Sickle Cell Disease Care (COMETS Trial)	8/1/2017-7/31/2022	450	Compares the effectiveness of two self-management support interventions (CHWs and mobile health) vs. enhanced usual care to improve health-related quality of life and acute care use for transitioning youth with SCD	mHealth application to improve self-management, stay connected with physicians, avoid acute care use, & maximize patient QoL during the transition	<p><i>Primary Patient Outcomes:</i></p> <ul style="list-style-type: none"> Higher quality of care in the CHW arm or mHealth arm at 6, 12, and 18 months Lower acute care in the CHW arm or mHealth arm at 6, 12, and 18 months <p><i>Secondary Patient Outcomes:</i></p> <ul style="list-style-type: none"> Greater patient activation and self-management behaviors in the CHW arm or mHealth arm at 6 months Patients with greater patient activation and self-management behaviors will have better treatment outcomes compared to those in usual care at 6, 12, and 18 months Patients in the CHW arm and mHealth arm will affect the total number of adult hematology visits and magnitude of biologic markers compared to those in usual care at 18 months Patients with greater adult hematology visits or higher biologic markers will have better outcomes compared to those in usual care at 18 months
Sadasivam, R. https://www.pcori.org/research-results/2016/smoker-smokers2s-peer-marketing-and-messaging-disseminate-tobacco	Optimizing Patient Engagement in a Novel Pain Management Initiative (OPEN)	3/13/2017-3/13/20	1,200	Dissemination of an effective, evidence-based digital intervention for smoking cessation – Decide2Quit- via methods that are widely used outside of health care but not tested for health interventions	Digital Intervention for Smoking Cessation (DISCs) (readily accessible health communication programs via Internet & smart phones)	<p><i>Primary Outcome Measures:</i></p> <ul style="list-style-type: none"> Smoking Cessation Reduction in number of cigarettes smoked <p><i>Secondary Outcome Measures:</i></p> <ul style="list-style-type: none"> Repeated use of Decide2Quit functions Recruitment of African Americans Recruitment time

Author	Title	Study Duration	# of Patients	Project Overview	mHealth Intervention	Outcomes
Taveras, E. https://www.pcori.org/research-results/2013/do-weight-management-programs-involving-health-coaches-improve-body-mass-index	Improving Childhood Obesity Outcomes: Testing Best Practices of Positive Outliers	11/1/2013 -5/31/17	750	Childhood obesity intervention with decision support tools in the EHR to improve screening and referral followed by use of health coaches delivering support and counseling via phone, email, and/or other social media	Automated, personalized text messages or e-mails addressing patient goals & providing skills training or educational "tips" about one of the targeted behaviors	<p><i>Primary Patient Outcomes:</i></p> <ul style="list-style-type: none"> Improvement in BMI Parent and child-reported child health related quality of life <p><i>Secondary Outcomes:</i></p> <ul style="list-style-type: none"> Parent's sense of empowerment Patient and Family Centeredness of Pediatric Care Behavioral change
Wade, S. https://www.pcori.org/research-results/2013/comparative-effectiveness-family-problem-solving-therapy-adolescent-traumatic	Comparative Effectiveness of Family Problem-Solving Therapy for Adolescent Traumatic Brain Injury	8/01/2014 -10/31/18	120	Compare the effectiveness, feasibility and acceptability of three formats of family problem-solving therapy for improving functional outcomes following TBI in adolescents, including face-to-face, web-based with therapist involvement, and self-guided web-based treatment	Family Problem Solving Treatment (F-PST) used to improve/ameliorate patient-identified behavioral & caregiver outcomes for traumatic brain injury; used via computer & Internet connection & SMS text messaging	<p><i>Primary Patient Outcomes:</i></p> <ul style="list-style-type: none"> Participants in the therapist-guided, online F-PST compared to the self-guided and face-to-face groups will report the greatest improvements in patient-reported outcomes in terms of child functioning and quality of life. <p><i>Secondary Patient Outcomes:</i></p> <ul style="list-style-type: none"> Participants in the therapist-guided, online F-PST compared to the self-guided and face-to-face groups will report the greatest improvements in parent-reported outcomes in terms of caregiver and family functioning, distress, and quality of life.
Wysocki, T. https://www.pcori.org/research-results/2012/shared-medical-decision-making-pediatric-diabetes	Shared Medical Decision Making in Pediatric Diabetes	3/1/2013-8/31/2018	166	Decision aid tool via iPad / internet for families of and adolescents with type 1 diabetes. After using decision aid tool, family and adolescent join a video-conference with an educator to discuss questions / comments from which a summary is developed and shared with the provider for discussion at the next clinic visit.	iPad & video-conferencing used to access multimedia decision & websites to facilitate adolescent & parent decision making for diabetes management	<p><i>Primary Patient Outcomes:</i></p> <ul style="list-style-type: none"> Device utilization/Engagement with pertinent technology <p><i>Secondary Patient Outcomes:</i></p> <ul style="list-style-type: none"> Glycated A1c Hypoglycemia Diary Decision quality Knowledge of insulin pump or glucose monitor Diabetes self-management self report

Author	Title	Study Duration	# of Patients	Project Overview	mHealth Intervention	Outcomes
Young, H. https://www.pcori.org/research-results/2014/patient-and-provider-engagement-and-empowerment-through-technology-p2e2t2	Patient and Provider Engagement and Empowerment Through Technology (P2E2T2) Program to Improve Health in Diabetes	9/1/2014-12/31/18	300	Enhance self-management of diabetes by offering timely, tailored nurse coaching feedback to facilitate behavior change using mHealth technology with bidirectional exchange of meaningful information between patient and provider	mHealth platform/dashboard, fitBit; patients receive timely, tailored nurse coaching feedback to facilitate behavior change via mHealth	<i>Primary Patient Outcomes:</i> <ul style="list-style-type: none"> • Changes in Self-Efficacy • Changes in QoL • Changes in HbA1C • Changes in Readiness to Change

QoL = quality of life

Appendix C: Evidence Gaps and Future Research Recommendations

Table 3. Evidence Gaps and Future Research Recommendations for mHealth Interventions for Self-management of Chronic Diseases

Chronic Disease/ Disorder	Number of SRs	Evidence Gaps	Future Research Recommendations
Diabetes ⁷⁻²¹	15	<ul style="list-style-type: none"> • Many mHealth studies had poor methodological quality (i.e., small sample sizes, poor study design, and no power calculations) and were poorly reported • Most measures of adherence were subjective self-report • Few studies assessed glycemic control • Apps and texting were frequently part of multicomponent interventions so discerning individual effects was not always possible. • There is a concern that the studies are not generalizable with regard to the patients and providers participating in the studies and the practices used • "Many studies excluded patients who failed to engage with the devices from the analysis; this implies they assessed intervention efficacy and not effectiveness." [Baron¹⁶] 	<ul style="list-style-type: none"> • "Further research in well-designed trials with large sample size is needed to further demonstrate how mobile phone intervention can enhance diabetes self-management support and examine its cost-effectiveness." [Liang¹⁷] • Better designed and reported RCTs with longer follow-up are needed to conclusively determine the effectiveness of mobile devices on HbA1c levels in patients with diabetes. • "Future research should focus on which components effectively promote physical activity and enhance adherence to deliver sustainable outcomes." [Connelly¹⁵] • In areas like diabetes where "interventions have shown small benefits of borderline or no clinical importance, future research should focus on improving interventions, drawing on existing guidance for the development of complex interventions, prior to considering further evaluation by randomised controlled trial."²² • Use of technologies for improving frequency of contact, clinical assessment and early intervention to avoid adverse events need to be studied further. • Future research is needed in addressing safety issues and adverse events when using mobile apps in the self-management of diabetes. • "We recommend that HCP [health care professional] feedback should be central in all future app designs and supplemented with dynamic automated feedback. Future technology should also be underpinned by behavior change theories and gamification elements to achieve a larger effect on BG control and improve compliance of patients in using diabetes apps. Finally, future technology should also consider the needs of older patients." [Hou¹³] • Studies need to be generalized to developing countries.

Chronic Disease/ Disorder	Number of SRs	Evidence Gaps	Future Research Recommendations
Obesity ²³⁻³⁹	17	<ul style="list-style-type: none"> • Very few RCTs evaluated mobile apps for weight loss/ few RCTs had weight loss as an outcome • Although we identified studies that evaluated change in body weight, fewer studies looked at change in BMI and waist circumference. • Many studies had small sample sizes and short follow-up • RCTs had high risk of bias and most RCTs were underpowered to detect a between-group difference in BMI or weight loss. • Few studies evaluated wearable devices • mHealth components were often embedded as part of a multicomponent intervention (e.g., larger weight loss programs), making it difficult to determine their true effect • Few RCTs used mobile devices in the treatment of pediatric obesity • Most study enrollees were healthy volunteers which limits generalizability of findings 	<ul style="list-style-type: none"> • More research needed on specific factors of mHealth interventions that may influence outcomes • Measurement and reporting of diet and physical activity outcomes and analysis of their effect on weight maintenance are needed • Better-designed and powered RCTs with larger sample sizes and longer follow-up are needed to: <ul style="list-style-type: none"> ○ compare mHealth weight loss interventions to traditional modes of treatment delivery (face-to-face delivery) ○ determine whether weight loss can be maintained • RCTs that detail behavior change techniques within existing devices are needed to insure internal and external validity; clear reporting needed on their behavior change techniques employed in the interventions [Job³⁷] • Development of systematic monitoring procedures that record and assess not just a weight loss outcome but message type and content, intensity and duration, as well as message adherence and acceptability [Wickham³⁵] • Weight loss or BMI should be reported "in percentage terms to enable meta-analyses and the clinical standard of 5–10% weight loss to be assessed and to report the percentage of participants in the recruited study arms who achieved clinically useful weight loss." [Bacigalupo³⁶] • Studies are needed to assess cost-effectiveness of mobile phone interventions. • Future studies need to assess effectiveness of activity trackers on men (only 15% of study population) and the use of trackable devices alone.

Chronic Disease/ Disorder	Number of SRs	Evidence Gaps	Future Research Recommendations
Mental disorders ⁴⁰⁻⁵⁸	19	<ul style="list-style-type: none"> • Few studies evaluated individual features of mobile devices, most studies have high risk of bias, short duration and small sample sizes • Very small non-randomized studies with 1 to 9 patients in each study • Some studies used a handheld device that is now considered obsolete • Few studies compared devices • Few studies have investigated verbal behavior beyond acquisition of a mand (requesting) repertoire, only devices used were iPad or iPod Touch and the Proloqu2Go software was used in nearly all studies. • Most studies were feasibility or pilot studies without control or comparison groups • Many studies did not report on clinical outcomes • Must studies used self-reported outcome measures • Some studies used apps specifically designed for the study and not accessible to the general public • “No conclusive results are available regarding the sustainability of the beneficial effects, the efficacy compared to regular care control groups, and the efficacy in patients with clinically diagnosed PTSD. Major challenges are to reduce the high attrition rates, to demonstrate cost-effectiveness and to develop quality assessment procedures for eMental health interventions.” [Gaebel⁴⁷] 	<ul style="list-style-type: none"> • RCTs needed with larger sample sized and longer followup. • Ethical issues need to be considered when using continuous monitoring with mental health mHealth interventions, particularly mood-monitoring apps. • "Future trials should employ well-standardised ICT-based interventions with clear definitions of the content of interventions. Methodology should also be well-described and the use of CONSORT should be obligatory." [Kauppi⁵²] • Future studies should incorporate robust intervention designs and appropriate behavior change theories to inform future implementation strategies • Challenges in this area include confidentiality, cost, access, and user attitudes, which need to be considered in the future • "Future studies which directly test alternative approaches against each other in non-inferiority controlled trials, while assessing outcome variation between subsamples of participants, would add great value to our understanding of what would constitute the optimal smartphone app for depressive symptoms, and in which populations these methods may be most effective." "the extent to which the observed effects on depressive symptoms arise from using the device itself, rather than the psychotherapeutic components of the intervention, should be examined and quantified in future research, to further explore the notion of a "digital placebo" influencing findings" [Firth⁴⁴] • Substance use – "...future research using collateral informants or drug screens would enhance confidence in the observed outcomes" [Kazemi⁴⁶] • “While this review shows that tablets can be generally effective tools for behavior change, a more specific analysis is needed to determine effects of treatment comparisons across different displays or application features” [Watson⁴⁸].

Chronic Disease/ Disorder	Number of SRs	Evidence Gaps	Future Research Recommendations
Respiratory disorders ^{4,59-66}	9	<ul style="list-style-type: none"> • Few RCTs, most with short-term followup, which could potentially influence results • Most studies had small sample sizes and were underpowered to detect between-group differences • "No two studies tested the same text messaging intervention in the same way using the same outcome measure(s) and for the same period of time." [DiBello⁶²] This makes it difficult to generalize to a broader population. • "There is little evidence and the low methodological quality hinders any robust conclusions about its effectiveness." [Martinez-Garcia⁶³] • Studies sometimes combined smartphones with education and exercise training, making it difficult to determine the effect of the smartphone 	<ul style="list-style-type: none"> • "Future studies should aim specifically at patients who are unintentionally non-adherent in examining the effects of electronic reminders on adherence." [Vervloet⁶⁷] • Future studies should focus more on special populations, including adolescents and pregnant women with asthma. No studies assessed the effectiveness of mHealth apps on children and healthcare providers, and only two studies were conducted on patients with uncontrolled asthma. [Farzandipour⁴] • "Further high-quality experimental research recommended, focusing on outcomes relevant to different stages of COPD. Researchers should clearly convey how self-management is assessed and should give greater consideration to consistency in outcomes measured, particularly cost, and should include longitudinal measures for a minimum of one year to comment on behavioural change and impact of treatment." [McCabe⁶⁴] • Larger RCTs with longer follow-up are needed to evaluate the effectiveness, cost-effectiveness, and safety issues of these devices. • Comorbidities in older patients with asthma need to be addressed • Future research needs to include mixed methods design and use smartphones as the main intervention
Smoking ⁶⁸⁻⁷³	6	<ul style="list-style-type: none"> • Lack of evidence from low-income populations, no RCTs of smartphone app-based interventions, little research into different functional components, message content, mediators and moderators of mobile phone programs • Few RCTs evaluated mobile interventions (SMS) for smoking cessation in young adults • Few studies evaluated the additive effect of SMS plus the standard intervention (e.g. cessation medications) • Scarcity of research of technology-based interventions aimed at improving quit rates in disadvantaged populations 	<ul style="list-style-type: none"> • More RCTs are needed to determine efficacy of this intervention in indigenous populations. Future trials should "appropriately sample minority and indigenous groups to enable an analysis of the consistency of effect of interventions for indigenous and nonindigenous participants." [Johnston⁷⁰] • "Adequately powered high quality trials of optimised interventions are required in areas of health behaviour change and self-management of diseases where there is currently suggestive evidence of benefit." [Free²²] • More RCTs with longer followup • Future research should examine the additive effect of SMS plus the intervention. • Studies should address for whom and under what circumstances SMS interventions are optimized, along with the duration of effect. • "more information is also needed on what combinations of text message factors (dose, duration, complimentary technologies, etc.) produce the best results..." [Cole-Lewis⁷⁴]

Chronic Disease/ Disorder	Number of SRs	Evidence Gaps	Future Research Recommendations
Cardiovascular disorders ⁷⁵⁻⁷⁸	4	<ul style="list-style-type: none"> • The evidence base is small, several studies had inadequate sample size, and some used quasi-experimental design • With so few studies, it is difficult to determine which mHealth features are most effective. • Reduction in CVD morbidity and all-cause mortality was only seen in secondary CVD prevention and heart failure groups. Primary prevention populations showed a benefit in weight loss, BMI, SBP, and cholesterol levels, but not for CVD outcomes. The observed heterogeneity in findings precludes definitive conclusions regarding specific digital health interventions that are most effective for CVD prevention [Widmer⁷⁷] • Findings were mixed for clinical outcomes and quality of life. Most studies were underpowered to detect between-group differences • Women, elderly, and low socioeconomic status subgroups are underrepresented in the studies [Pfaeffli Dale⁷⁸] • In some studies, mHealth device only part of a multicomponent intervention, so the efficacy of the mHealth device could not be separated from the overall intervention. • Use of the technology as an intervention and the tool to measure adherence is a limitation in some studies. 	<ul style="list-style-type: none"> • Larger, better-designed studies are needed to determine the effectiveness of mHealth interventions for heart failure and to determine sustainability of behavior changes • Higher-quality RCTs with larger sample sizes and longer follow-up are needed to evaluate the efficacy of electronic reminders for improving medication adherence in patients with chronic diseases • Future research is necessary to address the variables that determine success of mHealth interventions that are most effective for CVD prevention
Infectious diseases ⁷⁹⁻⁸²	4	<ul style="list-style-type: none"> • Few RCTs evaluated text messages and even fewer evaluated mobile apps. • Most studies evaluated adherence rather than clinical or other outcomes. • Majority of studies were small pilots and not all evaluated an mHealth intervention (cell phones and computers included in some studies) 	<ul style="list-style-type: none"> • "There is a need to develop, implement and evaluate more comprehensive mHealth interventions in order to address the self-management needs of people living with HIV." • More RCTs with longer-term follow-up are needed. • More RCTs needed particularly in pediatric populations • "Outcome measures for adherence intervention research should be standardised to improve comparability of studies." [Kanters⁷⁹] • Patients' needs/perspectives need to be considered in tailoring future interventions to reduce risky behaviors • Exploring reasons for differential losses to followup could inform future studies • Need to improve quality of studies (RCTs & non-RCTs) • Need to explore feasibility and efficacy by sub-populations (age, race, gender, sexual orientation) in future work

Chronic Disease/ Disorder	Number of SRs	Evidence Gaps	Future Research Recommendations
Neurologic disorders ^{83,84}	2	<ul style="list-style-type: none"> • Only 1 RCT and a few non-randomized controlled studies were identified. Most studies had no control group, and very few studies did a follow-up assessment • Many studies lacked health outcomes as part of their evaluation process and there was no consensus as to which outcomes to measure 	<ul style="list-style-type: none"> • Large RCTs that assess long-term function are needed to evaluate mobile devices compared to usual care for use as memory aids in patients with cognitive deficits. Outcomes measured should include valid measures of cognitive and social functioning. • More RCTs with a larger number of enrollees needed • Future RCTs testing mHealth need to engage the FDA & other government agencies with the widest jurisdiction over regulation. • Privacy issues need to be considered in addition to efficacy and safety
Chronic kidney disease ^{85,86}	2	<ul style="list-style-type: none"> • Studies had small sample sizes and were underpowered to detect between-group differences. 	<ul style="list-style-type: none"> • "Further research is needed on the effects of IT-based interventions on self-management outcomes in CKD patients living in developing countries, patients undergoing peritoneal dialysis, and those in early stages of CKD." [Jeddi⁸⁵] • "There is a need for additional rigorous trials with larger sample sizes and subgroup analysis to determine whether dietary mobile app interventions are beneficial in the different age, socio-economic, literacy and educational subgroups with chronic renal disease." [Campbell and Porter⁸⁶]
Cancer ⁸⁷	1	<ul style="list-style-type: none"> • Although the studies were rated as high quality/low risk of bias by reviewers, the studies looked at different outcomes, were underpowered to detect significant between-group differences and two of the four studies had inconsistent findings for the same outcome. 	<ul style="list-style-type: none"> • More adequately powered RCTs using mHealth interventions for cancer care follow-up are needed.
Chronic pain ⁸⁸	1	<ul style="list-style-type: none"> • Few RCTs evaluated mobile devices and few studies evaluated text messaging. 	<ul style="list-style-type: none"> • More RCTs needed • "Effects of technology on practitioners and patients outcomes remain understudied, and their promise to increase self-care and accurate monitoring remains mostly untested. In addition, data integration raises several concerns and challenges to the design, development and application of monitoring systems applied to pain." [Pombo⁸⁸]

Chronic Disease/ Disorder	Number of SRs	Evidence Gaps	Future Research Recommendations
SRs that addressed multiple chronic conditions ^{22,67,74,89-102}	18	<ul style="list-style-type: none"> • Very few RCTs. Most had small sample sizes, no detailed descriptions of content and app components, some did not do statistical analysis • Most studies used only one method of measuring adherence, there were a variety of direct and indirect methods. • The definition and rate of adherence are not uniform across studies. • Many studies did not report details of implementation and message delivery • Mobile application was only one component of the intervention, which included a multi-component medication reminder device. The effectiveness of the separate components was not evaluated. • Study limitations: small study size, imprecision of results, inadequate controls, and the use of the technology as an intervention & the tool to measure adherence. • Many studies were pilot studies and provided incentive to participants (money or device) to encourage adherence. Studies with more rigorous designs & interventions with large sample sizes & longer followup needed. 	<ul style="list-style-type: none"> • More RCTs are needed to confirm findings for many chronic diseases • RCTs with larger sample sizes and longer followup comparing mobile apps to controls are needed • More RCTS evaluating the efficacy of electronic reminders for improving medication adherence in patients with chronic diseases are needed • Future research should include other smartphone health promotion interventions • "Future research on the benefit of different features of text message interventions, the longevity of the effect, and the influence on objective clinical measures of outcomes are needed to help better identify the role of text message interventions to improve medication adherence in chronic disease care." [Thakkar⁹⁵] • Well-designed RCTs with larger sample sizes and longer follow-up are needed to evaluate mobile apps for management of chronic diseases in adolescents since most mobile apps for adolescents have no clinical evidence. • Further evaluation of short- and long-term efficacy and cost-effectiveness of interventions are needed • A better understanding of the barriers to adherence may help inform new mHealth interventions to improve adherence & health outcomes. • Long-term effectiveness of significance of apps need to be studied