The Use of Data Collected from mHealth apps to inform Evidence-based Quality Improvement: An Integrative Review

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<th>Worldviews on Evidence-Based Nursing</th>
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Descriptive Title: The Use of Data Collected from mHealth apps to inform Evidence-based Quality Improvement: An Integrative Review.

Short title: Using data from mHealth apps to inform Evidence-based Quality Improvement

ABSTRACT

Background: The global acceptance and use of technology in healthcare has resulted in an abundance of mobile health (mHealth) applications (apps) available for use in the delivery and improvement of care. With so many apps available to patients and clinicians, it is important to understand how data from apps is being used to inform quality improvement in practice.

Aim: The aim of this integrative review is to establish current knowledge of how mHealth apps are used to produce data to inform quality improvement in healthcare.

Method: Scopus, Web of Science, CINAHL and Medline Plus Full Text databases were searched for peer-reviewed papers written in English. The inclusion criteria comprised full text, empirical research studies relating to mobile health application use (not development) in clinical care.
Results: 19 studies met inclusion criteria. The functions of the apps outlined in the studies can be summarised into four different categories; communication, illness management, clinical management and education/information. The types of data collected by the apps included numerical, textual, photographic, and graphical with several apps able to collect a variety of data types. Analysis of the studies showed that although data collection is rarely outlined as the explicit purpose of mHealth apps, data collected through such technology is and can be used to inform practice change both in real-time and retrospectively.

Linking Evidence to Action: This review highlights while this is an emerging area, data obtained from mHealth apps can and is being used to inform quality improvement in healthcare. Further research is required in this area to adequately understand how data from mHealth apps can be used to produce quality improvement, specifically in relation to nursing. This review also highlights a need for the development of apps that aim to capture data to inform quality improvement, particularly from the patient perspective.

Keywords: mHealth, app, data (or data collection), quality improvement, healthcare, integrative review
BACKGROUND

The ubiquitous nature of mobile phones and other portable information technology (IT) devices has seen the rapid development and acceptance of mobile health (mHealth) application (app) use in healthcare. The World Health Organisation (WHO) acknowledge that there is no global consensus on the definition of mHealth and offer a definition of mHealth as “medical and public health practice supported by mobile devices, personal digital assistants (PDA’s) and other wireless devices” (WHO, 2011, p. 6). Informed by this definition, this review defines mHealth as ‘the use of mobile technologies to support health information, medical practices and the achievement of health objectives’.

As a number of definitions of quality improvement in healthcare exist it is essential to also outline how quality improvement is defined in this review. This review draws its definition of quality improvement from the globally recognised Institute for Healthcare Improvement (IHI). The IHI definition/understanding of quality improvement stems from the science of improvement approach. This approach views quality improvement as “an applied science that emphasizes innovation, rapid-cycle testing in the field, and spread in order to generate learning about what changes, in which contexts, produce improvements. It is characterized by the combination of expert subject knowledge with improvement methods and tools. It is multidisciplinary — drawing on clinical science, systems theory, psychology, statistics, and other fields” (reprinted from www.IHI.org with permission of the Institute of Healthcare Improvement (IHI), ©2018). This definition of quality
improvement in healthcare is relevant to healthcare clinicians at all levels of practice from management to clinical care. However, the focus of this article is on those involved in direct clinical care.

In clinical practice, mHealth apps can be used to assist in delivering effective patient care, facilitate research and inform quality improvement by examining data about both illness management and patient experience. Use of mHealth applications in healthcare deliver several benefits over traditional methods by providing convenient, real-time, portable access to health information services and enabling the collection and storage of large amounts of data (World Health Organization (WHO), 2016). Historically, data has been fundamental in supporting and informing change in healthcare. This capacity to support healthcare and collect data results in mHealth apps holding great potential to play a pivotal role in health care delivery and quality improvement.

mHealth apps have been developed to collect and deliver health related information for both patients and clinicians for a variety of purposes including (but not limited to): communication, patient management, medication compliance, diagnostic tools, education, behavioural prompts, reminder purposes, self-management, post-op care, personal health records, and reference information. There are large amounts of evidence available relating to the development and implementation of such apps. However, despite the sizeable number of apps available for both healthcare providers and patients, there is limited evidence available on how the data
generated from these apps is used, particularly in relation to using that data to inform quality improvement.

**AIM**

As outlined above, data collected from mHealth apps holds potential to be used to inform sustainable quality improvement in healthcare. As such, the aim of this integrative review is to establish current knowledge of how mHealth apps are used to produce data to inform quality improvement in practice.

**METHOD**

This integrative review was performed in accordance with guidelines for integrative reviews by Whittemore & Knafl (2005) and Hopia, Latvala & Liimatainen (2016).

**Search Strategy**

In October 2017, a comprehensive search of the Scopus, Web of Science, CINAHL and MEDLINE Plus Full Text databases was performed (see Figure i) to identify current evidence suitable to answer the PICO question ‘how are apps used to produce data in healthcare to inform quality improvement?’

Key words used in the search strategy included apps OR app OR “mobile application”, healthcare OR “healthcare” OR hospital OR nursing OR “quality improvement” OR “quality*” OR “practice improvement”. Each search string was combined with the boolean operator AND to obtain focused results. Each search string was searched in both title and topic to ensure comprehensive coverage of the
topic of interest and was altered to search each database’s individual requirements.

Full details of the electronic search strategy used in the Web of Science database can be seen in Table 1.

**Study Selection and Data Extraction**

One reviewer independently evaluated the search results based on an agreed inclusion criteria of a) full text, b) empirical research studies, c) relating to mobile health application use (not development) d) in clinical care. Excluded from the review were research protocols, manuscripts, editorials, conference papers and non-English publications, apps that provided education/information and didn’t collect data, or papers on app development. Data was then extracted from the 19 studies that met the inclusion criteria and collated in an electronic table (Table 2). This process and its results were then critiqued by the other investigators.

**Quality Assessment**

To assess the validity of the results and relevance of the studies identified, quality assessment of the articles included in the review was completed using the Critical Appraisal Skills Programme (CASP) checklists for critical appraisal of qualitative research (CASP, 2017), randomised controlled trials (CASP, 2017a) and systematic review (CASP, 2017b). These tools were selected, as they are well-recognised tools in critical appraisal of research and provide a variety of checklists to systematically assess the varying study designs found in the research studies included. Risk of bias within the studies was assessed using The Cochrane Risk of Bias Tool (Higgins et al., 2011).
RESULTS

The search strategy yielded a total of 710 articles from across all four databases, which reduced to 634 once duplicate articles were removed. It is important to note that CINAHL and Medline Plus Full Text yielded many results for each individual search string, however when combined with ‘AND’ nil results were obtained. The 634 articles identified from the database searches were screened by title and abstract and 563 records were excluded based on the inclusion/exclusion criteria (of which a large number were research protocols). The 71 remaining articles identified were then located in full text and reviewed in more depth to assess for eligibility. Further screening of the reference lists of these articles also identified 4 additional articles. After reviewing these articles in relation to the exclusion criteria, a total of 56 articles were excluded and 19 articles were selected for evidence synthesis.

Study Characteristics

The years of studies yielded in the initial database searches spanned from 1991-2017. However, the articles that met the inclusion criteria for evidence synthesis spanned from 2012-2017 indicating the emergence and developing nature of this topic in healthcare over the last five years. Studies were conducted in 17 different countries including seven in the United States of America, four in Canada, two in the United Kingdom, Sweden, China and Korea, and one in Turkey, New Zealand, Germany, India, Iran, Japan, Democratic Republic of Congo, Spain, Czech Republic, Italy, and Australia. One study reported by Holmen, Wahl, Smastuen & Ribu (2017) was conducted across three countries.
Studies varied greatly in their aims, methodologies and sample sizes. A variety of study designs were selected for analysis, including 4 systematic reviews (Holmen et al., 2017; Kitsiou, Pare, Jaana & Gerber, 2017; Lee et al., 2015; Peiris, Praveen, Johnson & Mogulluru, 2014), 4 randomised control trials (Armstrong, Coyte, Brown, Beber & Semple, 2017; Cingi et al., 2015; Lakshminarayana et al., 2017; Wolf et al., 2016), 1 non-randomised control trial (Sundberg et al., 2017), 3 retrospective cohort studies (Dickson, Sumathipala & Reeves, 2016; Khanna, Sambandam, Gul & Mounasamy, 2015; Twichell et al., 2017), 6 pilot studies (Foo et al., 2015; Gunter et al., 2016; Jakel et al., 2016; Macpherson et al., 2014; Patel, Siegler, Stromberg, Ravitz & Hanson, 2016; Semple, Sharpe, Murnaghan, Theodoropoulos & Metcalfe 2015) and 1 case report (Gernart et al., 2017).

**Populations of Interest**

Eleven out of the nineteen studies reviewed involved patients and medical clinicians and three involved medical clinicians alone (with 3/19 studies not specifying population of interest for the apps). Only two studies involved nursing staff (Jakel et al., 2016; Patel et al., 2016). The aim of the study by Jakel et al (2016) was to examine if use of a Provider Resilience mobile application would improve professional quality of life for a cohort of oncology nurses. This app collected data to evaluate healthcare providers level of compassion fatigue, burnout and compassion satisfaction, however, the results of using the application were not statistically significant. The aim of the study by Patel et al (2016) was to evaluate the impact of using a smartphone-based communication app to improve communication between
healthcare clinicians including clinical teams, doctors, nurses, social workers, pharmacists and secretaries. The outcome of this study was that nurses and doctors both reported texting on a smart device was more efficient and less disruptive than making phone calls or using pagers with statistical significance of <0.0001 in responses relating to efficiency and workflow.

All studies selected involved mHealth apps used in a hospital/clinical care context. The predominant population of interest were patients (8 adult and 1 paediatric) with two studies looking at both adult and paediatric patients (Lee et al., 2015; Macpherson et al., 2014) and three studies not explicitly stating the age of the population impacted by the app (Cingi et al., 2015; Dickson et al., 2016; Lee et al., 2015). Five studies reviewed apps relating to healthcare clinicians including medical, nursing, social work, pharmacists, and clerical staff (Foo et al., 2015; Jakel et al., 2016; Khanna et al., 2015; Lee et al., 2015; Patel et al., 2016).

**Functions of Apps**

The functions of the apps outlined in the studies were discussed and themed by the authors until consensus was reached on four different categories; communication, illness management, clinical management and education/information. Despite the different functions, data from all mHealth apps provided support whether that was relating to the patient experience, decision-making or treatment delivery. See Table 3 for a detailed breakdown of app functions.
Data Collected Using mHealth Apps

The types of data collected by the apps included numerical data e.g. numbers, survey scores, vital signs (Cingi et al., 2015; Dickson et al., 2016; Foo et al., 2015; Gernart et al., 2017; Jakel et al., 2016; Sundberg et al., 2017), textual data e.g. using words, phrases or more in depth descriptions (Cingi et al., 2015; Gernart et al., 2017), photographic data e.g. photos of wounds (Khanna et al., 2015; Semple et al., 2015), graphic data where graphs or scales were generated as a result of patient/physician input or where images were selected by users to express symptoms (Foo et al., 2015), with a number of apps able to collect a variety of data types.

As well as the ability to collect an assortment of data types, the apps reviewed were at times able to collect large amounts of data, for example a study on communication (Patel et al., 2016) reviewed 708, 456 text messages whilst another looked at over 6800 abnormal blood pressure measurements (Twichell et al., 2017). There was also considerable variance in study participants ranging from eight orthopaedic residents in a study about the use of smart phone technology in India (Gunter et al., 2016) to over 1450 in a communication study (Patel et al., 2016).

Data collected through apps was used both in real-time to deliver healthcare, inform healthcare decision-making and create self-awareness (Armstrong et al., 2017; Cingi et al., 2015; Dickson et al., 2016; Foo et al., 2015; Gunter et al., 2016; Jakel et al., 2016; Khanna et al., 2015; Macpherson et al., 2014; Semple et al., 2015; Sundberg et
al., 2017; Twichell et al., 2017), and retrospectively to inform healthcare management (Gernart et al., 2017; Lakshminarayana et al., 2017; Semple et al., 2015; Wolf et al., 2016), communication strategies (Khanna et al., 2015; Patel et al., 2016) and healthcare delivery changes (Foo et al., 2015).

Quality Improvements as a Result of mHealth App Use

Whilst not the main focus of the apps, a number of quality improvements and outcomes were reported in the studies reviewed. These included improvements to: clinical outcomes (Cingi et al., 2015), disease control and management (Kitsiou et al., 2017; Lakshminarayana et al., 2017), quality of life (Cingi et al., 2015; Sundberg et al., 2017), time to treatment (Dickson et al., 2016; Twichell et al., 2017), communication (Foo et al., 2015; Khanna et al., 2015; Macpherson et al., 2014), awareness of patient information (Khanna et al., 2015; Lee et al., 2015), symptom burden (Sundberg et al., 2017), emotional functioning (Sundberg et al., 2017), medication adherence (Lakshminarayana et al., 2017), time efficiency (Foo et al., 2015; Khanna et al., 2015; Lee et al., 2015; Patel et al., 2016; Semple et al., 2015), disease management (Holmen et al., 2017), follow up time (Armstrong et al., 2017; Semple et al., 2015) and patient management (Foo et al., 2015; Lakshminarayana et al., 2017). Of the nineteen studies reviewed, only one article (Foo et al., 2015) made explicit links outlining that data collected from the app was used to inform quality improvement. The quality improvements outlined by the other eighteen studies were related directly to using the app itself with some articles indicating the potential for future quality improvement based on study results.
DISCUSSION

The findings of this review confirm the global interest and potential international impact of mHealth applications to assist in both the delivery and development of healthcare with seventeen countries being represented in the nineteen studies reviewed. As can be seen from the year of publication of included studies (2012-2017), the use of mHealth apps to produce data that informs quality improvement is an emerging area in healthcare. This is congruent with the findings from Peiris et al (2014) who found a large number of grey literature outlining studies in progress or randomised control trials with findings yet to be reported. This is further reflected in the findings of this review where twelve out of the fifty-six articles excluded were relating to mHealth app development (see Figure 1).

It was interesting to note that only two out of nineteen studies involved nursing staff (of which only one had statistically significant results), compared to fifteen involving medical staff. This finding highlights the limited evidence available and subsequent need for further research relating to data collection through mHealth apps in the discipline of nursing. This finding is congruent with Foo et al.(2015), who outlined that further research focussing on nursing teams in relation to the use of mHealth apps used to track patient journey and clinical task management is key to improving the functionality of current apps. The findings of this review also confirm this as the functions of the apps used by nursing staff in this review were relating to education/information and communication not illness or clinical management.

Nurses are an integral part of the healthcare team and play a significant role in the delivery of front line patient care. This proximity to patients places them in a key
position for collection of data that could be used to inform quality improvement, particularly in relation to clinical or illness management.

As mentioned above, the four types of data collected by the mHealth apps in the articles reviewed included numerical, textual, imaged or graphical data with numerical and textual data being the most common form of data collected. However, whilst data collection was possible from all the apps utilised in the studies, review of these studies revealed that data collection was often not the purpose of the apps themselves. The main functions of the apps were to improve communication, illness and clinical management and provide education/information. Although the purpose of the apps was improvement focussed, it was the data collected by the mHealth apps that informed these changes. The data from these apps was used for a variety of purposes resulting in quality improvement e.g. faster identification of changes in patient condition (Semple et al., 2015; Twichell et al., 2017), improving communication processes (Foo et al., 2015; Khanna et al., 2015; Patel et al., 2016), enhancing understanding of quality of life (Cingi et al., 2015; Lakshminarayana et al., 2017; Sundberg et al., 2017), increasing patient compliance (Cingi et al., 2015; Gernart et al., 2017; Ktsiou et al., 2017; Wolf et al., 2016) and improving access to and satisfaction with healthcare (Dickson et al., 2016; Lakshminarayana et al., 2017).

This review outlines that data is collected through mHealth apps both in real-time and retrospectively, with benefits to both approaches. Benefits of utilising real-time data include (but are not limited to) timely interventions and decision-making
relating to clinical care and illness management and improved accuracy of
information collected. The increasing accessibility and portable nature of mHealth
devices enables the data collection process to be more efficient and effective due to
shorter time spent collecting and collating data when using a mHealth app. It also
provides greater access for patients to be involved in data collection from the
convenience of their hospital beds or homes. Having data stored in an app rather
than paper, and having it accessible in real time also improves the time taken for
clinicians/researchers to access this data and make appropriate data-informed
changes to practice. Using an app to collect data in real-time reduces the risk of
missing data sets; as it is all stored in a central online, secure space and cannot be
misplaced after collection. Collecting and using data from mHealth apps
retrospectively also equips clinicians with information on healthcare processes over
time, which can be used to inform sustainable healthcare change and provide
evidence for both clinicians and patients e.g. reviewing effectiveness of interventions
(Khanna et al., 2015; Patel et al., 2016), patient treatment compliance via mHealth
app diaries (Gernart et al., 2017; Wolf et al., 2016), understanding quality of life
(Cingi et al., 2015; Gernart et al., 2017; Wolf et al., 2016), reviewing time to
treatment (Dickson et al., 2016) and using data captured on the app as a memory aid
when attending follow up appointments (Lakshminarayana et al., 2017).

The most common focus of data collection related to communication and illness
management. Collection of data from the patient perspective in relation to the care
experience provides key information on the quality of care and its effect on the
patient (McCance, Wilson & Kornman 2016). This data provides a platform for the
delivery of person-centred care, identification of gaps in care delivery and quality improvement. However only five out of nineteen studies used mHealth apps to explore the patients experience in healthcare and the impact of illness on quality of life (Cingi et al., 2015; Gernart et al., 2017; Lakshminarayana et al., 2017; Macpherson et al., 2014; Sundberg et al., 2017). These studies predominantly provided data for the medical clinician/s caring for these patients with only two studies mentioning providing this information to nurses. This indicates the need for further research where data collected from mHealth apps is provided to healthcare clinicians, in particular, nursing staff.

This review highlights that data from mHealth apps is used for the benefit of both patients and clinicians in healthcare. For patients this includes recognition of abnormal results (Semple et al., 2015; Twichell et al., 2017), improved illness management (Cingi et al., 2015; Kitsiou et al., 2017; Lakshminarayana et al., 2017; Peiris et al., 2014; Semple et al., 2015; Wolf et al., 2016), improved accuracy of electronic health records and health data (Lakshminarayana et al., 2017; Wolf et al., 2016), real time communication and feedback (Peiris et al., 2014; Sundberg et al., 2017), faster treatment time (Armstrong et al., 2017; Dickson et al., 2016; Semple et al., 2015), enhanced patient experience (Armstrong et al., 2017; Lakshminarayana et al., 2017; Semple et al., 2015; Sundberg et al., 2017), access to health and health system information (Lakshminarayana et al., 2017; Lee et al., 2015), and self-awareness and education (Holmen et al., 2017; Kitsiou et al., 2017; Lakshminarayana et al., 2017). For healthcare providers (predominantly medical), this includes the improvement of communication between healthcare teams (Foo et al., 2015;
Khanna et al., 2015), improvement of patient management pathways (Dickson et al., 2016; Foo et al., 2015; Twichell et al., 2017), time and cost efficient healthcare delivery (Gunter et al., 2016; Lee et al., 2015; Semple et al., 2015), greater understanding of patient compliance (Kitsiou et al., 2017; Lakshminarayana et al., 2017; Wolf et al., 2016) and the impact of work and illness on emotional well-being and quality of life (Gernart et al., 2017; Jakel et al., 2016; Lakshminarayana et al., 2017; Macpherson et al., 2014).

Whilst the studies reviewed attributed several benefits from utilising mHealth apps, it was interesting to note that only one study’s focus was the collection of data through an mHealth app for the purpose of informing quality improvement (Foo et al., 2015). This indicates that the use of mHealth apps to produce data to inform quality improvement is more of an innate outcome rather than an explicit focus within healthcare, highlighting the need for further research and development in this area.

Limitations

The limitations of this review include having a single reviewer screen and appraise the articles selected, under guidance from supervisors. While every effort was made to retrieve all relevant articles as a result of a rigorous search strategy, it is acknowledged that this search was undertaken at a point in time in what is a rapidly evolving field.

IMPLICATIONS FOR FUTURE RESEARCH
This review highlights how data obtained from mHealth apps can and is being used to inform quality improvement in healthcare. The emerging nature of this topic, evidenced by the recent studies published and low number of high quality evidence of studies available, indicate that further research is required in this area to adequately understand how data from mHealth apps can and is being used to produce quality improvement, specifically in relation to nursing. This review also highlights a need for the evaluation of data produced by existing mHealth apps and the development of apps that specifically aim to capture data to inform quality improvement, particularly from the patient perspective.

CONCLUSIONS

In conclusion, this review highlights the emerging nature of using data collected from mHealth apps to inform quality improvement in healthcare. Analysis of the included studies showed that although data collection is rarely outlined as the explicit purpose of mHealth apps, when collected through such technology, is used to inform practice change both in real-time and retrospectively. These improvements include benefits for both patients and clinicians such as improved disease control and management, quality of life, communication and time efficiency.

Acknowledgements

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This work was supported by the Australian Federal Government Research Training Program Scholarship.

**LINKING EVIDENCE TO ACTION**

- Data from mHealth apps can be used to inform improvements for both patients and clinicians such as improved disease control and management, quality of life, communication and time efficiency.
- Evaluation and use of data from existing mHealth apps used in practice to inform quality improvement is needed.
- Further research is required to adequately understand how data from mHealth apps can be used to produce quality improvement, specifically in relation to nursing.
- This review also highlights a need for the development of apps that aim to capture data to inform quality improvement, particularly from the patient perspective.
- There is a need for increased publication of high quality evidence relating to data collection through mHealth apps used in nursing, particularly from countries in the Southern Hemisphere.
References


Critical Appraisal Skills Programme (CASP), (2017). Qualitative Research Checklist Retrieved from [http://docs.wixstatic.com/ugd/dded87_25658615020e427da194a325e7773d42.pdf](http://docs.wixstatic.com/ugd/dded87_25658615020e427da194a325e7773d42.pdf)


Figure i) Literature search flow diagram

Identification

- Records identified through database searching (n = 710)
- Additional records identified through other sources (n = 0)

Records after duplicates removed (n = 634)

Screening

- Title & abstracts of records screened (n = 634)
- Records excluded (n = 563)

Eligibility

- Full-text articles assessed for eligibility (n = 75)
- Additional references identified through searching the references of retrieved articles (n = 4)
- Full-text articles excluded based on criteria (n = 56)
  - 23: Not relating to clinical context
  - 12: Not relating to mHealth app use
  - 12: Relating to app development
  - 4: Apps not for information not data collection
  - 2: Editorials
  - 1: Conference paper
  - 1: Research protocol
  - 1: No full text available

Included

- Studies included in qualitative synthesis (n = 19)
### Table 1. Web of Science Search strategy

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<tr>
<td>#3</td>
<td>TOPIC healthcare OR “healthcare” OR hospital OR nursing</td>
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<tr>
<td>#4</td>
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### Table 2. Characteristics of included studies.

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<th>Population</th>
<th>Study Aim</th>
<th>Study Design</th>
<th>App name &amp; function</th>
<th>Data Collected</th>
<th>Results/Quality Improvement</th>
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<tr>
<td>Armstrong et al., 2017</td>
<td>Canada</td>
<td>Ambulatory adult patients undergoing breast reconstruction</td>
<td>To determine whether follow-up care delivered via a mobile app can be used to avert in-person follow-up care visits compared with conventional, in person follow-up care in the first 30 days post ambulatory surgery</td>
<td>Randomised control trial</td>
<td>Sixty-five participants</td>
<td>Textual</td>
<td>Participants using the app reported greater level of convenience in follow up care compared to in-person group</td>
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<td></td>
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<td>QoC Health Inc Mobile App Allows patients to: submit photographs, answer a validated quality of recovery questionnaire and a pain visual analogue scale using a mobile device for the first 30 days after the operation Surgeons can follow patient reports on a web portal</td>
<td>Image</td>
<td>minimal difference between satisfaction scores between app group vs in-person group</td>
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<td></td>
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<td>neither satisfaction or convenience scores were statistically significant</td>
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<tr>
<td>Cingi et al., 2015</td>
<td>Turkey</td>
<td>Patients with allergic rhinitis and asthma (no age group specified)</td>
<td>Impact of mobile patient engagement app on health outcomes and quality of life</td>
<td>Randomized control trial</td>
<td>Three hundred and seventy-five participants</td>
<td>Numerical</td>
<td>Improved quality of life and clinical outcomes. Rhinitis group Clinical improvement, improvement in rhinitis quality of life, activity (statistical significance p=0.05)</td>
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<td></td>
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<td></td>
<td>POPET (Physician On-Call Patient Engagement Trial) Communication, health management, medication compliance</td>
<td>Textual</td>
<td>Asthma group improved number of well controlled asthma score</td>
</tr>
<tr>
<td>Dickson, Sumathipala &amp;</td>
<td>United States of</td>
<td>Patients with Acute Ischaemic Stroke (AIS) (no age specified)</td>
<td>Evaluate effect of app on door-to-needle (DTN) time in patients presenting to Emergency Departments with AIS</td>
<td>Retrospective cohort study</td>
<td>Eighty-five activations over 18-month period</td>
<td>Numerical</td>
<td>App use resulted in reduction in door-to-needle time by 46% (p=0.001)</td>
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<td>Reeves, 2016</td>
<td>America</td>
<td></td>
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<td></td>
<td>Pulsara StopStroke Medical app aimed at enhancing rapid assessment and care of patients suffering from AIS</td>
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<tr>
<td>Authors</td>
<td>Country</td>
<td>Target Population</td>
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<td>Data Representation</td>
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<tr>
<td>Foo et al., 2015</td>
<td>New Zealand</td>
<td>Healthcare clinicians</td>
<td>Assess impact of mobile task management tool on clinical workflow within an acute general surgical service</td>
<td>Pilot study</td>
<td>Numerical and Graphical</td>
<td>Faster decision making improved team communication capture of data re: patient journey and workflow which was not previously available</td>
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<tr>
<td>Gemart et al., 2017</td>
<td>Germany</td>
<td>Adult patients with chronic pruritus</td>
<td>To validate ItchApp as a novel instrument</td>
<td>Validation study and Randomised, double-blind placebo-controlled trial using the app</td>
<td>Numerical and Textual</td>
<td>-94% level of patient compliance</td>
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<tr>
<td>Gunter et al., 2016</td>
<td>United States of America</td>
<td>Adult patients &gt;18 years in the vascular or general surgery service of a large tertiary hospital</td>
<td>1) develop a novel image-based smartphone app for post discharge surgical wound monitoring 2) rigorously user test it with a representative population of vascular and general surgery patients</td>
<td>Descriptive study</td>
<td>Imaged Textual</td>
<td>Above average overall usability score 83.3</td>
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<tr>
<td>Holmen et al., 2017</td>
<td>Studies from Japan</td>
<td>Patients &gt;16 years with</td>
<td>Systematically review studies that aimed to</td>
<td>Systematic literature review</td>
<td>Numerical Textual</td>
<td>Unclear methodological quality of studies,</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Research Participants</td>
<td>Research Design</td>
<td>Intervention</td>
<td>Outcome Measures</td>
<td>Findings</td>
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<tr>
<td>For Peer Review</td>
<td>China, Korea, Democratic Republic of Congo, Canada, Spain, and Czech Republic</td>
<td>Diabetes (type 1 and type 2)</td>
<td>Evaluate integrated communication within mobile apps for tailored feedback between patients with diabetes and health care personnel in terms of study characteristics, functions, study outcomes, effects, and methodological quality</td>
<td>Communication e.g., SMS interaction, reminders, texting of blood glucose levels, feedback from health care professional and therapeutic advice. Small number of apps transmitting blood glucose level and dietary intake. Others relating to self-management &amp; education.</td>
<td>Implications for need for more controlled trials of higher methodological quality. Outcome measures of app related to disease management but did not mention outcomes relating to quality improvement. 1/6 measured therapy satisfaction.</td>
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<tr>
<td>Jakel et al., 2016</td>
<td>United States of America</td>
<td>Adult oncology nurses</td>
<td>Examine if the use of the app will improve oncology nurses’ professional quality of life.</td>
<td>Prospective quasi-experimental pilot study.</td>
<td>PRMA (Provider Resilience Mobile Application) tool to increase provider resilience. It includes psychoeducation, methods to evaluate level of burnout, compassion fatigue, compassion satisfaction and secondary trauma stress using a visual analogue scale, questionnaire, and r&amp;r clock to remind participants time since the user took a day off.</td>
<td>Numerical Textual Graphic</td>
<td>No change seen in the pre- and post-test scores of the intervention group, control group or sample as a whole.</td>
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<tr>
<td>Khanna, Sambandam, Gul &amp; Mounasamy 2015</td>
<td>India</td>
<td>Adult clinicians (8 orthopaedic residents)</td>
<td>Report the impact of the introduction of a smartphone application as an intradepartmental</td>
<td>Retrospective study</td>
<td>WhatsApp – cross platform mobile messaging app allowing the exchange of</td>
<td>Textual images numerical</td>
<td>High scores indicating improved awareness of patient information statistically significant (p=</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Participants</td>
<td>Purpose of the Overview</td>
<td>Study Design</td>
<td>Type of Evidence</td>
<td>Results</td>
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<tr>
<td>Kitsiou et al., 2017</td>
<td>United States of America, UK, CHN, CAN, IRN</td>
<td>Patients with type 1 and type 2 diabetes</td>
<td>Purpose of the overview is to critically appraise and consolidate evidence from multiple systematic reviews on the effectiveness of mHealth interventions for patients with diabetes to inform policy makers, practitioners and researchers</td>
<td>Systematic review</td>
<td>Textual, Numerical</td>
<td>All residents found WhatsApp helpful in improving the efficiency of handovers and standard of patient care. Statistically significant reduction in the time of written handovers in the morning from 25 minutes to 14 minutes (p=0.003)</td>
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<tr>
<td>Lakshminarayana et al., 2017</td>
<td>UK</td>
<td>Patients with Parkinson’s Disease</td>
<td>To assess if patients with Parkinson’s disease who use a Parkinson’s tracker app (PTA) for 16 weeks in addition to treatment as usual (TAU) show improved self-reported quality of life</td>
<td>Randomized control trial</td>
<td>Numerical, Textual</td>
<td>Statistically significant result indicating use of app to produce quality improvement for patients with Parkinson’s disease over 16-week period. -Improved patients’ perception of quality of life</td>
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</table>
medication adherence. Secondary objectives were to investigate whether patients who receive the PTA and those who receive TAU differ in terms of quality of life, quality of clinical consultation and symptom control.

patients to set up for alerts to track medication
-Option to generated a report of data entered by the patient over the trial period as an aid at their 16 week follow up appointment
-Games to track physical responsiveness
-Information about Parkinson's disease

Lee et al., 2015
Korea
Not specified
Apps for both adult and paediatric patients & healthcare clinicians
To evaluate the mobile health applications with focus on quality and patient safety developed by a single tertiary hospital in Korea.

Evaluation/ Systematic Review of twenty three studies in Korea.

Apps evaluated re: 6 aims for quality improvement suggested by US Institute of Medicine (patient centredness, effectiveness, patient safety, timeliness, efficiency, equity)

23 different apps
- my medications
- my chart in my hand
- pharm consult
- wild plants in Korea
- pediatric cancer diary
- injini
- quality of life
- my cancer diary
- pediatric cancer information
- pit-a-pat
- emergency in ordinary life
- HEALTHCARE PROVIDERS
- ASAN phonebook
- CPCR drugs
- toxicology
- mAMIS

Textual numerical
Several apps provided information rather than collect data
8/23 apps

consultation (p=0.0110)
- Improved medication adherence compared to treatment as usual (p= 0.0304)

Apps designed between 2010-2014
- Only 2 apps met all 6 aims for quality improvement
- Most of the apps designed for patients provide health information or patient medical information (7/10 apps)
- 1 app for patients collected survey data
- 4/23 apps were personal health record
- 3/13 healthcare provider apps focussed on communication
<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Country</th>
<th>Population</th>
<th>Methodology</th>
<th>Tools</th>
<th>Feasibility/Acceptability</th>
<th>Findings</th>
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</thead>
<tbody>
<tr>
<td>Macpherson et al., 2014</td>
<td>United States of America</td>
<td>72 adolescents and young adults 13-29 years of age with cancer at 5 institutions across the USA</td>
<td>Aim of the study was to evaluate the feasibility and acceptability of a computer based symptom cluster heuristics tool designed to explore symptom clusters experienced by adolescents and young adults with cancer</td>
<td>Computerized symptom capture tool (C-SCAT) Features 30 symptoms commonly experienced by adolescents and young adults with cancer, combines graphical images and free text responses in an innovative heuristics approach to gain the perspectives of AYA’s on their symptoms and symptom clusters</td>
<td>All 72 participants completed the C-SCAT with 74% of participants reported that the final image was an accurate or very accurate representation of their symptom experience</td>
<td>C-SCAT demonstrated feasibility and acceptability app has potential to empower adolescents and young adults to 1) communicate symptom experience and partner with providers in their care 2) improve symptom management and ameliorate distress 3) translate to use with other highly symptomatic populations</td>
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<tr>
<td>Patel et al., 2016</td>
<td>United States of America</td>
<td>Healthcare clinicians (clinical teams, doctors, nurses, social</td>
<td>To determine if a commercially available smartphone based secured messaging</td>
<td>Cureatr- Health Insurance Portability and Accountability Act (HIPAA)-complaint</td>
<td>Different number of respondents in pre-and post evaluation study and inability to link responses</td>
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<tr>
<td>Study</td>
<td>Country</td>
<td>Participants</td>
<td>Methodology</td>
<td>Findings</td>
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<tr>
<td>Peiris et al 2014</td>
<td>Australia</td>
<td>Adults (patients and volunteers) with non-communicable diseases (cardiovascular disease, diabetes, cancer,)</td>
<td>Asses the impact of mHealth interventions on health care quality. Characterise the spectrum of mobile health interventions that have been used for non-communicable diseases</td>
<td>Systematic Literature Review 48 studies across Brazil, Turkey, China, Honduras, India, Malaysia, Cameroon, Thailand, Iran, Argentina &amp; Mexico. Apps focussed on: Textual Numerical mHealth for non-communicable diseases is under-explored, however several study protocols indicating future growth in this area. Despite mHealth having a</td>
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<tr>
<td>Study Reference</td>
<td>Country</td>
<td>Setting</td>
<td>Objective</td>
<td>Methodology</td>
<td>App Features</td>
<td>Key Findings</td>
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| Semple et al., 2015 | Canada | Ambulatory care patients undergoing breast reconstruction or orthopaedic arthroscopic anterior cruciate ligament repair | To assess the feasibility of using a mobile app for the monitoring or post-operative quality of recovery at home following surgery in an ambulatory setting | Prospective cohort study (pilot study) | - Sensors and point of care diagnostics  
- Communication  
- Decision support  
- Client education  
- Telecare intervention  
- Disease management  
- SMS reminder system  
- Interactive voice system  
- Disease monitoring  
- Electronic health record  
- Medication adherence  
- Data collection | Effective Mobile app monitoring is feasible and acceptable to both patients and surgeons  
Patient satisfaction very high 3.9/4 satisfaction score  
2 potential post op complications identified prior to scheduled follow up resulting in better patient outcome due to faster time of identification  
Cost and time effective benefit also highlighted by surgeons. |
<table>
<thead>
<tr>
<th>Study</th>
<th>Country</th>
<th>Participants</th>
<th>Intervention</th>
<th>Control Description</th>
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<tbody>
<tr>
<td>Sundberg et al., 2017</td>
<td>Sweden</td>
<td>Male patients mean age 69 years with prostate cancer</td>
<td>Evaluate the effect on symptom burden and quality of life when using the application for real-time symptom assessment and management during radiotherapy for localised prostate cancer</td>
<td>Non-randomized control trial&lt;br&gt;One hundred and thirty participants&lt;br&gt;Sixty-four participants in control group&lt;br&gt;Sixty-six participants in intervention group</td>
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<td><strong>Interaktor</strong>&lt;br&gt;An app for smartphones and tablets for early detection, reporting and management of symptoms and concerns during treatment for prostate cancer. Allows real time communication and rapid management of symptoms when detected early</td>
<td>Textual and numerical&lt;br&gt;Reporting symptoms via the application had positive effect on symptom burden and quality of life&lt;br&gt;Statistically significant results for intervention group in emotional functioning&lt;br&gt;Control group also had statistically significant lower levels of quality of life</td>
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<tr>
<td>Twichell et al., 2017</td>
<td>United States of America</td>
<td>Paediatric patients 3-18 years of age with one BP above the 90th age-sex-height referenced percentile</td>
<td>Examine change in abnormal blood pressure recognition before vs. after the introduction of an electronic health record app designed to calculate BP percentiles with a training lecture</td>
<td>Retrospective cohort study&lt;br&gt;78, 768 clinical encounters reviewed.&lt;br&gt;Three thousand five hundred and twenty-one had abnormal BP's pre-app use&lt;br&gt;Three thousand, three hundred and fifty-eight had abnormal BP's post app use</td>
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<td><strong>Substitutable Medical Applications &amp; Reusable Technology (SMART) BP Centiles App</strong>&lt;br&gt;Free, substitutable, open-source, open access BP calculator and longitudinal tracking tool capable of running within any Electronic Health Record that supports the SMART Health IT Platform. The app displays the BP percentile with an ambulatory blood pressure measurement, as well as historic blood pressure percentiles allowing providers to determine if an elevated BP was detected early</td>
<td>Numerical&lt;br&gt;Data generated by app allowed medical staff to track trends for patient and not only improve recognition of elevated BP, but observe statistically significant higher recognition of abnormal BP 4.9% pre-app and 7.1% post app (p=0.0001)</td>
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</table>

As app use was voluntary and not mandated or included in workflow, it was only used in 13% of clinical encounters when the BP was elevated, = 5% use in overall clinical encounters = small sample.
<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Setting</th>
<th>Objective</th>
<th>Design</th>
<th>Key Findings</th>
</tr>
</thead>
</table>
| Wolf et al., 2016   | Sweden            | Hospital, outpatients’ clinics and primary care patients <75yrs, English speaking | Investigate the effect of a web and mobile based eHealth diary and symptom tracking tool combined with a person-centred care intervention in patients hospitalised for an acute coronary syndrome event | Sub study of a randomized control trial Person-centred care after Acute Coronary Syndrome (PACS) | Numerical Textual Graphical  
Self-efficacy scale results indicate that use of the app improved patient self-efficacy.  
Small sample size only 37/90 patients participated (40% of patients included in intervention)  
All results classified as eHealth so unable to determine effect of the app vs. webpage  
Patients who used the eHealth tool in combination with person-centred care intervention had 4-fold improvement compared to the control group. |
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<th>Used the General Self Efficacy Scale (GSES) to evaluate patient-reported scores at baseline, 4 weeks, 8 weeks and 6 months</th>
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<tbody>
<tr>
<td>Communication</td>
<td>Illness management</td>
<td>Clinical management</td>
<td>Education/information</td>
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<tr>
<td>Messaging</td>
<td>Medication compliance (Lakshminarayana et al., 2017; Peiris et al., 2014)</td>
<td>Patient assessment (Dickson et al., 2016)</td>
<td>Disease information (Lakshminarayana et al., 2017; Lee et al., 2015; Peiris et al., 2014)</td>
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<td>(Cingi et al., 2015; Holmen et al., 2017; Khanna et al., 2015; Kitsiou et al., 2017; Lee et al., 2015; Patel et al., 2016; Peiris et al., 2014; Sundberg et al., 2017)</td>
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<td>Image exchange (Armstrong et al., 2017; Gunter et al., 2016)</td>
<td>Symptom tracking (Holmen et al., 2017; Kitsiou et al., 2017; Wolf et al., 2016)</td>
<td>Decision making (Dickson et al., 2016) (Foo et al., 2015; Peiris et al., 2014)</td>
<td>Treatment information (Holmen et al., 2017; Jakel et al., 2016; Lee et al., 2015)</td>
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<tr>
<td>Discussion (Khanna et al., 2015)</td>
<td>Diet and activity (Kitsiou et al., 2017) (Wolf et al., 2016)</td>
<td>Symptom recognition (Christiansen, Fjell, &amp; Sundberg, 2017; Sundberg et al., 2017; Twichell et al., 2017)</td>
<td>Illness management (Holmen et al., 2017; Kitsiou et al., 2017; Peiris et al., 2014)</td>
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<td>Real-time feedback/advice (Holmen et al., 2017) (Kitsiou et al., 2017; Semple et al., 2015; Sundberg et al., 2017)</td>
<td>Post op recovery (Armstrong et al., 2017; Gunter et al., 2016; Semple et al., 2015; Sundberg et al., 2017)</td>
<td>Diagnosis (Twichell et al., 2017)</td>
<td>Data collection (Peiris et al., 2014)</td>
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<tr>
<td>Diary function (Cingi et al., 2015) (Gernart et al., 2017; Lee et al., 2015; Wolf et al., 2016)</td>
<td>Symptom burden (Macpherson et al., 2014; Sundberg et al., 2017)</td>
<td>Electronic health record (Lee et al., 2015; Peiris et al., 2014)</td>
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<tr>
<td>Electronic health record (Lee et al., 2015; Peiris et al., 2014)</td>
<td>Quality of life (Cingi et al., 2015; Gernart et al., 2017; Jakel et al., 2016; Lee et al., 2015; Sundberg et al., 2017)</td>
<td>Handover (Khanna et al., 2015)</td>
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<td>Self-monitoring (Jakel et al., 2016; Kitsiou et al., 2017; Lakshminarayana et al., 2017; Peiris et al., 2014; Wolf et al., 2016)</td>
<td>Digitisation of patient journey (Foo et al., 2015)</td>
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<td>Reminders (Holmen et al., 2017; Jakel et al., 2016; Kitsiou et al., 2017; Lakshminarayana et al., 2017; Peiris et al., 2014)</td>
<td>Task performance (Foo et al., 2015)</td>
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<td>Pain assessment (Semple et al., 2015)</td>
<td>Follow up (Armstrong et al., 2017; Gunter et al., 2016; Semple et al., 2015)</td>
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<tr>
<td>Diary function (Gernart et al., 2017) (Wolf et al., 2016)</td>
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Note: The reference in Table 3 are of the 19 studies included in this review