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Evidence Check

mHealth technologies for chronic disease prevention and management

An **Evidence Check** rapid review brokered by the Sax Institute for Healthdirect Australia. December 2015.

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This report was prepared by:
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1 Executive summary

Aims and background

- The aim of this rapid review is to examine the evidence relating to the benefits, uptake and operationalisation of mHealth technologies for chronic disease management and prevention.
- In a context of rapidly emerging technologies, it is important to understand what evidence is available to inform policy interventions designed to integrate technology for health service delivery, especially for services that are accessed by people of varying socio-economic status (SES).
- For the purpose of this review, mHealth technologies refer to Short Message Service (SMS)/Multimedia Message Service (MMS), mobile devices (e.g. Personal Digital Assistant [PDA]), mobile apps, wearable devices and sensors. Excluded from this review are telehealth and telephone-based services.
- The literature from 2005 was reviewed, with a focus on developed countries.

Key findings

- The majority of studies included in this review were published after 2010, indicating the relative infancy of this technology and the need for further evaluation of its long-term effectiveness.
- Of all the mHealth technologies, SMS is the most commonly evaluated in the literature, and that with the strongest evidence of effectiveness.
- Evidence for interventions containing more innovative technologies, such as those involving smartphone apps and/or wearable devices, has been generated predominately from feasibility and usability studies, with few published randomised controlled trials (RCTs) evaluating effectiveness.
- For studies focusing on benefits for self-management, diabetes was the most common chronic disease studied. Significant improvements were found in glycaemic control through the use of mobile phones, SMS, internet, and/or wireless devices.
- For studies focusing on behaviour change, significant improvements were found in physical activity measures, weight loss outcomes, and smoking cessation, among others.
- The evidence regarding socio-economic and demographic factors of mHealth, as well regarding implementation aspects of mHealth interventions, were generally of lower quality.

Concluding remarks

- SMS is the most commonly studied mHealth technology, with the strongest evidence of effectiveness.
- mHealth interventions can promote significant improvements in glycaemic control (for diabetes patients), as well as in physical activity, weight loss, and smoking cessation, among other outcomes. However, benefits appear dependent upon the characteristics of the intervention (e.g. bundle of features, use of behaviour change theories) and the specific patient population (e.g. age, digital literacy).
- One important marker of the success of an mHealth intervention is its integration into healthcare as part of a service (and not as a standalone system). One of the greatest barriers to mHealth uptake in healthcare is the existence of competing health system priorities, combined with a lack of evaluation studies and cost-effectiveness analysis to guide decisions.
- Improving the uptake and impact of an mHealth service will require the following elements: i) integration into a health service, ii) bundles of features to facilitate action (e.g. decision support, followed by task support), iii) application of appropriate use of theories and behavioural change strategies underpinning program design, iv) strategies employed to maintain participant interest and minimise dropout, and v) ensuring mHealth service fidelity (i.e. the accurate delivery, receipt, and enactment of the service).
- Strategies to increase uptake of mHealth should address the main barriers for each stakeholder as part of this process: payers, providers and, most importantly, patients.
- Relevant to Healthdirect Australia, opportunities may arise in providing personalisation and tailoring offered by these emerging mHealth technologies, situating these technologies in the existing ecosystem of Healthdirect Australia, and identifying bundles of mHealth and eHealth features that function together as a service in this ecosystem.

2 Background and introduction

Chronic diseases are the leading cause of mortality and morbidity worldwide.[1,2] Patients with a chronic condition spend on average one hour per year with their physician, leaving around 10,000 hours where they have to manage their health and illnesses by themselves.[3] Self-management activities involve managing symptoms to prevent complications, adhering to treatment regimes, initiating and maintaining lifestyle changes and coping with the physical and psychosocial consequences of the disease. All of these activities combined have been demonstrated to minimise the deleterious impact of the condition on health.

Further, self-management programs aim to improve the knowledge, skills, and confidence that are important for both self-care as well as for increasing linkages with clinical care and improving health outcomes.[4-11] Elements commonly involved in successful self-management and behavioural change programs include: education; collaborative problem definition; self-management training and support; targeting, goal setting, planning, skill development, and problem solving; and follow-up. [5,8,9,12]

The advent of the internet and other technologies in recent times has allowed patients access to greater amounts of information in order to guide decision making about healthcare.[13-16] Therefore, interest in the use of eHealth to facilitate self-management and promote patient empowerment is rapidly increasing.[17-20] Among the diversity of eHealth interventions now emerging, mHealth shows particular promise.

Mobile health, or mHealth, may be defined as *"the use of mobile telecommunication technologies for the delivery of healthcare and in support of wellness"*.[21] Mobile technologies such as mobile phones and wireless monitoring devices have many clear benefits that can supplement or extend beyond that provided by traditional healthcare delivery platforms: they are popular, readily available, easily portable, have high capacity and can be used to suit different needs.[22]

In October 2014, the number of active mobile devices surpassed the world population: 7.22 billion devices.[23] In Australia, December 2014 data reveal that 5.2 million adults use only their mobile phone to make calls (i.e. they do not have a fixed-line telephone service); 3.9 million adult Australians are mobile-only internet users; and 2.1 million are exclusively mobile in their phone and internet communications.[24] Additionally, the Australian Mobile Phone Lifestyle Index survey, carried out at the end of 2014, found that 89% of respondents owned a smartphone, and that between 59–80% were high-level users of the mobile phone; voice calls, SMS, sending/receiving emails, information gathering, visiting websites and/or browsing and/or searching the internet were all enacted via mobile phone.[25] Furthermore, almost one in five reported accessing health and wellbeing information on their mobile phone regularly (at least once a month), and 27% reported having used 'health & wellbeing' apps in the last six months.[25] These figures are rapidly increasing. A Deloitte report revealed the number of mobile device users who downloaded at least one mHealth application onto their smartphone doubled between 2011 and 2012 alone.[26]

Given the growing burden of chronic diseases coupled with the increasing popularity of mobile technologies, the application of mHealth in their self-management and primary prevention seems promising. mHealth may improve the monitoring and tracking of health behaviours, the collection of health information (e.g. weight, blood pressure), communication between patient and health care provider and adherence to treatment regimes; all of which have the potential to empower patients with respect to self-care, as well as to increase personalisation and convenience of care provided by clinicians.[21,22]

Aims and questions addressed

The aim of this rapid review was to examine the evidence relating to the benefits, uptake and operationalisation of mHealth technologies for chronic disease management and prevention. The following four questions were explicitly addressed in this review:

- Question 1: What is the evidence regarding the **benefits** of using mHealth technologies to support **chronic disease management**?
- Question 2: What is the evidence regarding the **benefits** of using mHealth technologies to **track health behaviours** for **prevention** purposes?
- Question 3: What is the evidence regarding how **demographic** and **socio-economic** factors affect the **benefits** of mHealth?
- Question 4: What is the evidence regarding **strategies** that can be used to **operationalise** the use of mHealth technologies for chronic disease management and prevention purposes?

3 Methods

Search strategy

A search of the literature from 2005 onwards was performed from September to October 2015 using Pubmed, Embase, Scopus, CINAHL and Cochrane library. Search terms included mHealth, chronic diseases, and self-management (complete search strategy available in Appendix A).

The reference lists of relevant articles were also screened to ensure all eligible studies were captured. To capture grey literature, publications and reports from several institutions (e.g. World Health Organization [WHO], Pew Research Centre, IMS Institute for Healthcare Informatics, PricewaterhouseCoopers, The Economist) were searched. Key opinion leaders with international standing in the field of mHealth, chronic disease management and prevention, and underserved populations were contacted regarding possible additional studies that met the inclusion criteria.

To ensure mobile apps from the Australian setting were included in the review, those that were listed by the government and non-profit chronic disease groups at the federal and state level were examined. Mobile apps developed by non-profit consumer groups in Australia were identified for each chronic disease, as indicated by the Australian Institute of Health and Welfare (www.aihw.gov.au/chronic-diseases/). Health-related apps developed by the Australian government on the federal and state level were also retrieved (www.australia.gov.au/about-government/apps). A full list of these apps is outlined in Appendix B. No evaluation studies of these apps were identified at the time of writing.

Study selection criteria

Studies were included in this review if they: 1) focused on patients or consumers; 2) involved a mobile health intervention, either isolated or as part of a multi-component intervention; 3) were qualitative or quantitative, cross-sectional or prospective in design (however, for aspects pertaining to effectiveness, only experimental studies and systematic reviews/meta-analyses were considered); 4) were focused on the self-management of a chronic condition, or focused on tracking/promoting health behaviours (e.g. physical activity, diet) or reducing behavioural risk factors (e.g. smoking, alcohol/other substances abuse).

Studies were excluded if they: 1) focused exclusively on telemedicine or on the remote management of a condition by providers (not involving a self-management component); 2) focused on acute rather than chronic conditions; 3) involved a medical intervention (diagnosis or treatment) instead of self-management; 4) were opinion articles or editorials; 5) were duplicates or were not in English.

Additionally, literature regarding low-income countries was only considered for Question 3, as advised by the Commissioning Agency (Questions 1, 2 and 4 focused on middle- and high-income countries). Furthermore, for SMS-focused papers, only reviews were included (primary research was excluded, as advised by the Commissioning Agency), unless the intervention was deemed innovative in any sense. Finally, primary studies were excluded if they were found to have been already included in any of the reviews meeting inclusion criteria.

Initial screening of studies was based on the information contained in their titles and abstracts and was conducted by four investigators. Full-paper screening was conducted individually by the same four investigators. When there were doubts regarding inclusion or exclusion, another investigator (LL or AL) was involved in the decision.

The scope of each question was defined by the Commissioning Agency as follows:

Research Question 1: What is the evidence regarding the benefits of using mHealth technologies to support chronic disease management?

Scope of question 1:

- Benefits include not only direct and measurable benefits to the consumers, such as reduction in excess weight or cholesterol levels, but also health literacy, the ability to self-manage, awareness and other factors that may indirectly lead to better health. Include also evidence regarding benefits that may accrue to parties other than the consumer, if any (for example, a better estimate of the prevalence of a certain condition in a specific area would benefit society as a whole).

- Chronic disease management is defined broadly. However, this review does not include the management of end stage chronic conditions, such as end stage renal disease (ESRD) that may require extensive treatment and/or interaction with the hospital/provider system.

- Include evidence showing the cost-effectiveness of the application, highlighting whichever perspective has been used (societal or the perspective of some other stakeholder).

- Include any evidence related to mHealth improving self-reporting by adding actual observations.

Research Question 2: What is the evidence regarding the benefits of using mHealth technologies to track health behaviours for prevention purposes?

Scope of question 2:

- 'Tracking health behaviours' may be achieved through the collection information provided by a device/biomedical sensor or by allowing users to enter information themselves.

- Include evidence regarding preventive activities related to reduction of behavioural risk factors. Natural targets for prevention include, but are not limited to:
    - Physical activity/reduction of sedentary lifestyle
    - Smoking
    - Diet
    - Obesity reduction
    - Alcohol consumption.

- Include evidence regarding whether mHealth applications geared to reduce behavioural risk factors (such as those listed above) capture the pattern of risky activities early enough to allow a preventive strategy to be effective.

- Include evidence regarding the prevention of health events that can be avoided if caught early enough. Healthdirect Australia already provides an online service called 'Symptom Checker' (www.healthdirect.gov.au/symptom-checker) that allows individuals to input information about their symptoms, receive personalised information and/or possibly be recommended to seek medical attention. Include evidence of how mHealth technologies can be used by such a service to receive better and more timely information.

- Include evidence showing the cost-effectiveness of the application, highlighting whichever perspective has been used (societal or the perspective of some other stakeholder).

Research Question 3: What is the evidence regarding how demographic and socio-economic factors affect the benefits of mHealth?

Scope of question 3:

- Include evidence of the benefits of mHealth, as well as barriers to its use, for Aboriginal and Torres Strait Islanders and Culturally and Linguistically Diverse (CALD) populations.

- Include evidence on the effect of health literacy.

- Factors to be considered include, but are not limited to, age, gender, ethnicity, education and remoteness/geography.

- Different sub-populations may benefit differently from mHealth because their adoption rates are different and/or they respond differently to the intervention. Both perspectives should be included in the analysis.

- Highlight what are the documented barriers to the use/adoption of mHealth technologies across different sub-populations.

Research Question 4: What is the evidence regarding strategies that can be used to operationalise the use of mHealth technologies for chronic disease management and prevention purposes?

Scope of question 4:

- Assuming that some mHealth technologies with significant benefits have been identified and appropriate platforms are in place, how can the technology be brought to consumers and how can uptake be increased? What are the next operational steps that need to be taken in order to roll out an application? Note that this question is not about the development of an application, which is not in the scope of Healthdirect Australia, but rather about the strategies that lead to successfully implementing a successful service.

- Include evidence regarding past failures. For example, if an application had been developed and was never taken up by consumers, what went wrong? What could have been done differently? What lessons were learned?
- Include evidence regarding past successes. For example, if an application had been developed and was widely adopted, what were the reasons? What worked? What lessons were learned?

- Include evidence regarding factors that can influence the adoption of mHealth technologies and what strategies can be used to incentivise and promote adoption.

- Include evidence regarding barriers to the adoption of mHealth, such as privacy concerns, conservative culture in healthcare, regulations and other institutional constraints.

Data extraction strategy and synthesis procedures

Four investigators extracted information from the included studies into a standardised computer-based form. The following data were collected for each study: first author, year, study type, mHealth mode, intervention task, participants and setting, health domain, main findings, and quality assessment. Results were grouped by question. When papers covered topics pertaining to more than one question, they were included (and data were abstracted) for each of the covered questions. Two investigators (LL and AL) reviewed the complete abstraction form for consistency. A narrative synthesis was conducted for the included studies. Effect sizes, such as standardised or weighted mean differences, relative risks, odds ratios, and z scores, were extracted from meta-analysis.

For the purposes of this analysis, we classified the 'mHealth mode' into four main categories: SMS; phone plus software or application; phone plus specific instrument (medical device connected to phone via a cord); or phone plus wireless or Bluetooth-compatible device. The specific function of the mobile device utilised in the intervention was also abstracted, when mentioned by the authors of the study (e.g. GPS/camera/scanner/voice recorder).

The 'task' that the mHealth intervention was designed to support was coded according to a predefined classification scheme[27]:

- Inform: provide information in a variety of formats (text, photo, video, audio)
- Instruct: provide instructions to the user
- Record/Track: capture user-entered data
- Display: graphically display user-entered data/output user entered data
- Guide: provide guidance based on user-entered information, and may further offer a diagnosis, or recommend a consultation with a physician/a course of treatment
- Remind/Alert: provide reminders to the user
- Communicate: provide communication with Healthcare Professionals (HCP) (email/SMS)/patients and/or provide links to social networks.

Assessment of evidence quality

The quality of the included studies was assessed in terms of their design.

Literature reviews were classified into:

- **Systematic reviews with a meta-analysis** component were considered 'very high' on the Grade of Quality
- **Systematic reviews without a meta-analysis** were generally considered 'high'
- **Narrative or other forms of reviews** that were not conducted with high levels of rigour were considered 'moderate/low'.

Empirical studies were classified into:

- **Technical feasibility or pilot studies**. These studies tested the technical feasibility of the mHealth interventions, such as algorithm accuracy and efficiency. They are not clinical studies, and may be tested on simulated data. Often no human participants are involved in these studies. These studies may be conducted with high levels of technical rigour. However, for the purpose of this review, these studies were considered 'low' on the Grade of Quality as they do not inform how human participants would use or benefit from the technology.

- **Descriptive/qualitative studies**. These studies used focus groups or interviews on usually small samples and were generally considered 'low' quality.

- **Cross-sectional surveys**. These studies undertook surveys that prospectively asked patients and consumers about factors influencing their use of mHealth, or their attitudes, intentions or perceptions of use. Most of these studies were conducted in relation to specific health topics. These studies were generally considered to be of 'low' quality.

  Those studies that conducted multivariate analysis in an attempt to focus on the strongest associations with mHealth use were of higher quality, and thus were considered 'moderate/low' quality in this review. Risk of bias in these studies was assessed by whether the study had discussed representativeness of the survey.

- **Experimental studies**. These studies described and evaluated the effects of an intervention. Generally, intervention studies are of higher quality than descriptive/qualitative studies and cross-sectional surveys. Of these studies, before and after studies, quasi-experimental, or cross-sectional comparisons were the weakest design, and thus considered of 'moderate' quality.

  Randomised controlled trials (RCTs) were the strongest design, and considered of 'moderate/high' quality in this review. Higher-quality studies also examined actual changes in health outcome and behaviours rather than attitudes or intentions as primary outcomes. Risk of bias was assessed in terms of the presence and characteristics of a control group and selection bias, as many studies involved the patients or consumers choosing to participate in a program or intervention.

4 Results

The database search retrieved 4222 citations (Figure 1). After removing duplicates (N=2078), 1894 articles were excluded based on their title and abstract, and 250 full-text papers were reviewed. A total of 72 papers were included in this review. Several articles covered aspects related to more than one of the four questions: 21 papers were included in Question 1, 20 in Question 2, 15 in Question 3, and 29 in Question 4. Grey literature search revealed six additional documents relevant for Question 4.[26-31]

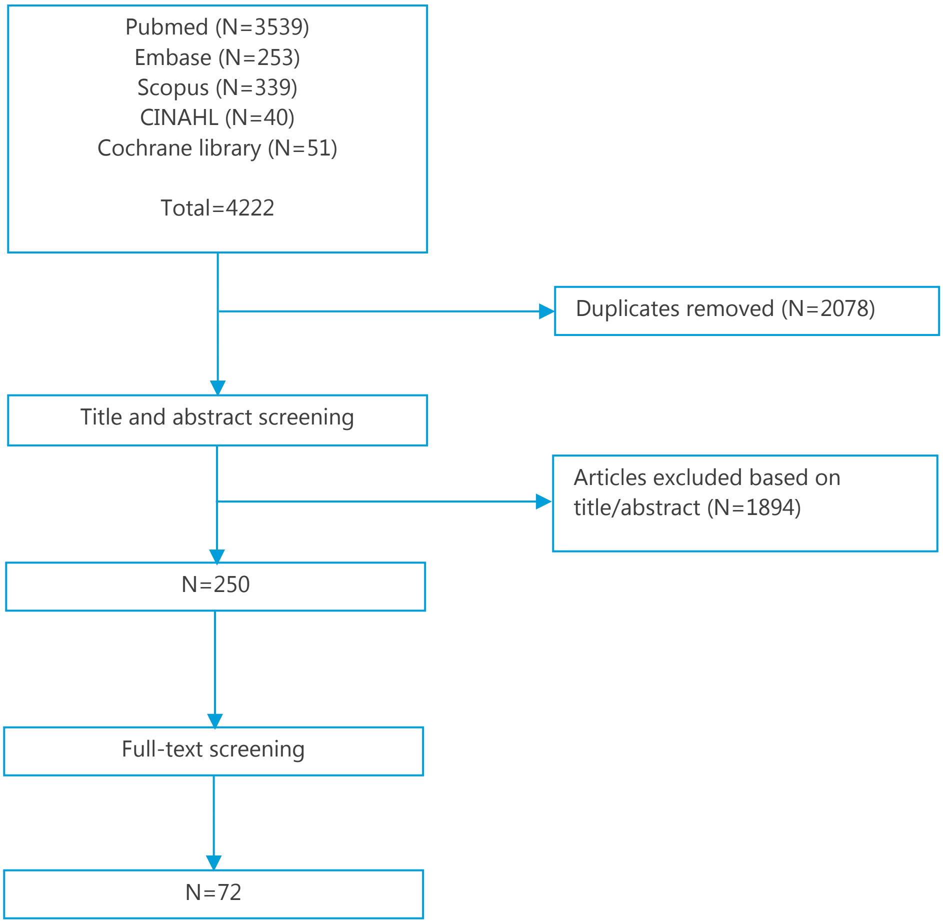

Figure 1: Flow diagram of included studies

Table 1: Papers included for this review (2005 to current)

Question	References	Grade of Evidence
Q1. Benefits of mHealth for chronic disease self-management	31 studies: • 22 systematic reviews (5 meta-analysis) • 1 scoping review • 4 RCTs • 3 quasi-experimental • 1 feasibility	• High for SMS • Moderate for mobile apps and devices • Low for wearable and sensors
Q2. Benefits of mHealth to track health behaviours for primary prevention purposes	16 studies: • 13 systematic reviews (6 meta-analysis) • 1 scoping review • 2 RCTs	• High for SMS • Moderate for mobile apps and devices • Low for wearable and sensors
Q3. Socio-economic and demographic factors affecting mHealth uptake and benefits	15 studies: • 4 systematic reviews (2 meta-analysis) • 2 scoping reviews • 2 RCTs • 1 qualitative • 1 mixed-methods • 5 feasibility	Moderate to Low
Q4. Operationalisation of mHealth	6 grey literature reports 28 studies: • 7 systematic reviews • 1 scoping review • 2 RCTs • 3 quasi-experimental • 8 feasibility • 1 qualitative • 1 survey • 1 case-control • 4 cross-sectional	Low (primarily grey literature)

Question 1: What is the evidence regarding the benefits of using mHealth technologies to support chronic disease management?

Summary points:

- In order to evaluate the evidence regarding the benefits of using mHealth technologies to support chronic disease management, 21 papers were analysed (published between 2008 and 2015).
- In the analysed publications, the health domains where these mHealth technologies have been tested to support chronic disease management were: diabetes, cardiovascular, chronic lung diseases (i.e. Chronic Obstructive Pulmonary Disease [COPD], asthma), mental health, and osteoarthritis.
- Several mHealth technologies were used: SMSs, mobile or smartphone (with or without internet access), PDAs, tablets, handheld computers, apps, blood sugar monitors, blood pressure monitors, pedometers, accelerometers, and sensors. The most commonly used mode of delivery was SMS.
- The majority of mHealth interventions to support chronic disease management seem to involve a great variety of functions/tasks, such as to inform, instruct, record, display, guide, remind/alert, and communicate.
- The majority of studies focused on diabetes (three meta-analyses and 10 systematic reviews). The three meta-analyses in patients with diabetes showed improvements in glycaemic control through the use of mobile phones, SMS, internet, and/or wireless devices, with moderate effect sizes (-0.60, -0.51, and -0.27). The ten systematic reviews of mHealth interventions for diabetes self-management showed mixed results for the various outcomes assessed (e.g. Body Mass Index (BMI), weight, glycaemic control, cholesterol, self-management behaviours, self-efficacy, and exercise).
- The remaining studies, mostly systematic reviews, showed inconsistent results for a variety of outcomes across several health conditions.
- The majority of the analysed studies did not take into account the costs associated with intervention provision. Only two studies mentioned cost issues; one concluded that the particular intervention being provided was not cost-effective (yet this was not based on formal economic evaluation).

1.1. Benefits of using mHealth technologies to support chronic disease management:

1.1.1 Diabetes (type 1 and 2)

Three meta-analyses[32-34] on mHealth interventions for type 1 diabetes (T1DM) and/or type 2 diabetes (T2DM) self-management were identified, showing significant improvements in glycaemic control for patients in the intervention groups compared with controls, with moderate effect sizes (-0.60, -0.51, and -0.27) (Table 2).

Interestingly, Saffari et al. 2014[32] reviewed six studies which used SMS to send and receive data (interactive approach) relating to Blood Glucose, diet, physical activity, and medication adherence[35] and showed that these interactive approaches for gathering and providing data reduced HbA1c more than studies with unidirectional (only data collection) approaches, as did those using SMS and the internet. Furthermore, mHealth technologies for type 2 diabetes were most effective when combined with health care professional feedback.

Table 2: Summary effects from meta-analysis of mHealth in diabetes

Study author, year	Number, type and intervention duration of included studies	Summary effect* (standard difference in means) [95% prediction interval]
Saffari et al., 2014[32]	10 RCTs (3–12 months)	-0.60 [-0.83; -0.36]
Liang et al., 2011[33]	22 experimental studies (11 RCTs) (3–12 months)	-0.51 [-0.69; -0.33]
Free et al., 2013[34]	5 RCTs (3–12 months)	-0.27 [-0.48, -0.06]

* Effect sizes smaller than zero represent a decrease in the intermediate outcome (e.g. HbA1c), meaning an improvement as a result of the intervention.

Ten **systematic reviews** of mHealth interventions for diabetes self-management showed inconsistent results for the various outcomes assessed (e.g. BMI, weight, glycaemic control, cholesterol, self-management behaviours, self-efficacy, and exercise).

- Connelly et al. 2013[36] reviewed 15 studies on T2DM involving eHealth. Among the three studies particularly concerning mHealth, there were no significant differences between intervention and control groups regarding physical activity or glycaemic control.

- Holtz et al. 2012[37] reviewed 21 experimental studies on mHealth interventions for T1DM and/or T2DM self-management and found that the outcomes assessed varied considerably across studies, with few significant findings being reported (three studies reported significant improvements in glycaemic control and two studies in knowledge about diabetes).

- Baron et al. 2012[38] reviewed 24 papers corresponding to 20 experimental studies (13 studies on T2DM and seven on T1DM), finding that poor reporting and methodological weaknesses were frequent, and that study variability and mixed results hampered an objective assessment of benefits. Few statistically significant results were reported.

- Krishna et al. 2008[39] reviewed 18 papers on diabetes self-management with the use of cell phone technology and found that nine out of 10 studies that measured haemoglobin A1c showed a significant improvement, but there were mixed results regarding other outcomes.

- Russell-Minda et al. 2009[40] reviewed 18 trials on cell phone and wireless technologies for diabetes self-management and found limited to moderate evidence that interventions using mobile phones and wireless devices may improve glycaemic control.

- Hamine et al. 2015[22] reviewed 107 studies focusing on several health domains and found significant improvements in clinical outcomes in 11 out of 26 diabetes-related studies

- Buhi et al. 2012[41] reviewed 34 studies focusing on several health domains and identified six out of 17 diabetes-related studies where glycaemic control was improved when SMS was utilised.

- De Jongh et al. 2012[42] reviewed experimental studies focusing on several health domains, including diabetes, and found little evidence of benefit.

- Krishna et al. 2009[43] reviewed 25 studies focusing on several health domains and found significant improvements in diabetes-related health outcomes in eight out of nine studies involving diabetes patients.

- Allet et al. 2010[44] found mixed results in the 10 diabetes studies reviewed.

1.1.2 Cardiovascular disease

Five **systematic reviews** of mHealth interventions for cardiovascular disease (CVD) showed mixed results for the various outcomes assessed (e.g. BMI, weight, lipid profile).

- Hamine et al. 2015[22] reviewed 107 studies focusing on several health domains and found significant improvements in outcomes such as blood pressure (BP), weight, and lipid profile in seven out of 13 CVD-related studies. Four interventions were designed to improve outcomes for patients with both Diabetes Mellitus (DM) and CVD, with half showing significant improvements in clinical outcomes, including HbA1c and BP control.

- De Jongh et al. 2012[42] reviewed one study involving hypertensive patients, which did not find a difference in the proportion of patients who achieved blood pressure control, but showed a statistically significant difference in adherence to medication.

- Krishna et al. 2009[43] reviewed one study in hypertensive patients, which did not find statistically significant differences in outcomes between intervention and control groups.

- Allet et al. 2010[44] found mixed results for the five cardiovascular disease studies reviewed.

- Free et al. 2013[34] reviewed three CVD-related papers: one with unclear/high risk of bias reported an improvement in cardiovascular risk profiles for patients receiving telemonitoring via mobile phone with text message-based advice; another trial with unclear risk of bias reported a statistically significant reduction in systolic and diastolic blood pressure compared to baseline in an intervention group receiving monitoring of salt excretion; finally, one trial demonstrated improved quality of life for patients with heart failure receiving a mobile phone-based telemonitoring intervention.

- Chow et al. 2015[45] conducted an RCT where patients with coronary heart disease received four semi-personalised SMSs per week for six months. At six months, levels of LDL-C were significantly lower in intervention participants, with concurrent reductions in systolic blood pressure and BMI, significant increases in physical activity, and a significant reduction in smoking.

1.1.3 Chronic lung disease

Seven **systematic reviews** and one **RCT** of mHealth interventions for chronic lung disease (CLD) patients showed mixed results for the various outcomes assessed:

- Hamine et al. 2015[22] reviewed 107 studies focusing on several health domains and found mixed results in CLD clinical outcomes – three out of six RCTs reported statistically significant improvements in lung function parameters.

- Buhi et al. 2012[41] reviewed one study focusing on asthma which found significant improvements between groups.

- De Jongh et al. 2012[42] reviewed one study involving asthma patients receiving a text messaging intervention that showed greater improvements on peak expiratory flow variability (mean difference (MD) -11.12, 95% confidence interval (CI) -19.56 to -2.68) and pooled symptom score comprising four items (cough, night symptoms, sleep quality, and maximum tolerated activity) (MD -0.36, 95% CI -0.56 to -0.17) compared with the control group.

- Krishna et al. 2009[43] found one asthma study where results showed significantly greater improvements in asthma cough and night-time symptoms in intervention patients.

- Allet et al. 2010[44] found mixed results in four COPD studies.

- Belisario et al. 2013[46] reviewed two studies on mHealth interventions for asthma self-management. One study found no statistically significant differences on asthma symptom scores, asthma-related quality of life, visits no the ED or hospital admissions. The other study found statistically significant improvements in asthma-related quality of life, lung function, and number of visits to the Emergency Department (ED).

- Free et al. 2013[34] reviewed six studies focusing on asthma control: two trials reported no statistically significant beneficial effects of either a text message-based intervention or a mobile phone-based monitoring and feedback intervention on asthma control; one trial providing asthma patients with alerts regarding health-risk weather forecast had no statistically significant benefits on reducing exacerbations of asthma; one trial reported improved quality of life with a mobile phone-based asthma self-care system; and another trial reported increases in self-reported adherence to asthma medication.

- One multi-centre RCT on mHealth monitoring did not find significant improvement in asthma control. Among 288 adolescents and adults with poorly controlled asthma, the mobile technology did not improve asthma control or increase self-efficacy compared with paper-based monitoring when both groups received clinical care to guidelines standards.[47]

- Finally, an appraisal of available apps for asthma self-management conducted in 2012 found that 32 out of 72 apps made recommendations that were not supported by current evidence.[48]

1.1.4 Mental health

Four studies (three **systematic reviews** and one **RCT**) on mHealth interventions for mental health patients found mixed results for a variety of outcomes:

- Ehrenreich et al. 2011[49] reviewed three studies that used handheld computers targeting anxiety, finding significant improvements in anxiety in only one study.

- Donker at al. 2013[50] reviewed eight papers describing five apps targeting depression, anxiety, and substance abuse. No statistically significant differences between intervention and control groups regarding depressive symptoms, stress, anxiety, and substance use. Few significant results at follow-up within the intervention group in several of the studies.

- Free et al. 2013[34] evaluated four trials focusing on mental health, with mixed results: two trials reported increases in emotional self-awareness in young people receiving risk assessment and management of youth mental health problems; another trial reported that delivering cognitive behavioural therapy messages by mobile phone was feasible and acceptable; finally, one trial reported improved recall of goals in interventions delivering text messages to patients undergoing brain rehabilitation.

- Depp et al. 2015[51] conducted an RCT with 82 patients with bipolar disorder. They found that patients receiving psychoeducation in intervention group (smartphone) reduced depressive symptoms at 12 weeks compared to control group (paper-and-pencil). However, the effect was not maintained at 24 weeks.

1.1.5 Medication adherence

Two **meta-analyses**[34,52] found statistically significant results for vaccine attendance and medication adherence, respectively (Table 3).

Table 3: Summary effect from meta-analysis of mHealth interventions for medication adherence

Study author, year	Number of studies combined, type and intervention duration	Summary effect (RR) [95% prediction interval]
Free et al., 2013[34]	2 RCTs (9–28 days)	1 [0.77, 1.3] (Medication adherence)
	3 RCTs (4 months)	1.36 [1.27, 1.47] (Vaccine attendance)
Finitsis et al., 2014[52]	9 RCTs (14 days to 12 months)	1.39 [1.18, 1.64] (Medication adherence)

* Effect sizes higher than one represent an improvement as a result of the intervention

Six **systematic reviews** found mixed results for medication adherence, and one **RCT** did not find a statistically significant difference:

- Park et al. 2014[53] reviewed 29 papers and found that 18 showed improvements in medication adherence rates after interventions involving the use of text messages ($p < 0.05$).

- Anglada-Martinez et al. 2015[54] found improvements in medication adherence in four of the five studies on HIV-infected patients, in eight of the studies on patients with other chronic diseases, and in one study performed in healthy individuals.

- Nglazi et al. 2013[55] found mixed results on the effectiveness of SMS interventions for improving patients' adherence to tuberculosis treatment.

- Mbuagbaw et al. 2015[56] found mixed results but concluded that there appears to be some benefit of using text messaging as a tool to improve adherence to medication and attendance at scheduled appointments.

- Hamine et al. 2015[22] found that of the 27 RCTs that measured the effect of mHealth on adherence behaviours, a significant difference between intervention and control groups was observed in 15 studies.

- Free et al. 2013[34] reviewed three trials which reported statistically significant increases in adherence to antiretroviral medication with text message reminders, and one trial which reported increases in adherence that were not statistically significant.

- Cocosila et al. 2009[57] conducted an RCT on improving adherence to vitamin C with a mobile phone intervention and did not find a statistically significant difference between intervention and control groups in medication adherence.

1.1.6. Other health domains

- Allet et al. 2010[44] reviewed two studies in arthritis patients which showed significant improvements in daily step counts between intervention and control groups.

- Heron et al. 2010[58] evaluated the effectiveness of momentary ecological interventions and found mixed results from moderate-low quality studies on the effectiveness of ambulatory treatment for smoking cessation, weight loss, anxiety, diabetes management, eating disorders, alcohol use, and healthy eating and physical activity.

1.2 Cost-effectiveness

Three studies (one RCT, one quasi-experiment, and one feasibility study) have incorporated a quantitative approach to analyse costs of mHealth for chronic disease management:

- In an RCT of mobile monitoring that did not find a significant improvement in asthma control, the mean cost of providing respiratory care (including the nurse monitoring reviews) was £246 (standard deviation [SD] £226) in the mobile group compared with £245 (SD £201) in the paper group (mean difference -£1.26 (-£51.47 to £48.95). The mobile technology was not cost-effective.[47]

- A quasi-experiment examined the fees patients with COPD would be willing to pay for a ubiquitous healthcare service. The average acceptable fees (in USD) of the service system are as follows: u-health device, $421.28; home visit, $21.53/visit; tele-education, $0.53/min or $26.57/month; and total service fee, $44.26/month.[59]

- A feasibility study estimated T1DM patients would need to pay €10 per month for a data bundle on their mobile phone contract in order to use a mobile-enabled application to enter diabetes-related data for healthcare professionals to view on a web portal.[60]

Other cost issues were mentioned in the following contexts:

- There is lack of cost-effectiveness analyses with respect to mobile technology as a modality for health promotion or risk reduction.[41]

- Few studies take seriously the issue of cost. In many of the small pilot studies, expensive devices or vouchers were given to study participants. When implemented at scale, interventions that use patients' existing mobile devices rather than relying on gifted devices will go further toward explaining feasibility and improving adherence.[22]

- Rigorous cost-effectiveness analyses will be necessary to demonstrate not only the health impact but also the value of investing in these innovations now.[22]

1.3 mHealth and self-reporting

Three experimental studies evaluated the potential of mHealth to improve self-reporting in chronic disease patients, showing positive results:

- Berke EM et al. 2011[61] conducted a quasi-experimental study with eight participants on self-tracking using wearable device with sensors to assess sociability and physical activity (e.g. steps taken, time spent with others). They found that mobile sensing of sociability and activity was well correlated with traditional measures (surveys).

- Garcia-Palacios et al. 2014[62] conducted an RCT with 47 patients with chronic pain/fibromyalgia and found that those with access to a smartphone diary reported more accurate and complete pain ratings compared to paper diary.

- Palmier-Claus J et al. 2012[63] conducted a quasi-experimental study with 44 participants with schizophrenia and related disorders for assessment of psychosis. They found that use of a smartphone achieved a compliance of 82% in self-reporting of psychotic symptoms. These ambulant ratings showed excellent test-retest reliability scores.

Question 2: What is the evidence regarding the benefits of using mHealth technologies to track health behaviours for prevention purposes?

Summary points:

- Evidence on the efficacy of mHealth interventions to track and promote healthy lifestyle behaviours is growing. Three meta-analysis of interventions involving SMS, mobile apps, PDAs, and remote or web 2.0 technologies showed significant improvements in physical activity measures and/or weight loss outcomes. Two meta-analyses evaluated the effectiveness of mobile phone interventions for smoking cessation and found significant results. One meta-analysis combined studies for separate outcomes, namely two RCTs for medication adherence and three RCTs for vaccine attendance, having found statistically significant results for the latter.

- mHealth technologies utilised for prevention purposes include (in descending order of frequency): SMS, apps, self-tracking devices, wearable devices, then sensors.

- Use of SMS to improve health behaviour may be divided into three categories: sending information to people (e.g. educating, notifying reminding); gathering information from people; communication and interaction.

- Bundle of features is important to achieve behaviour change (e.g. self-monitoring, followed by personalised feedback, etc). Most interventions employ feature bundles, not reliant on only one feature, which makes the evaluation of their effect more complex.

- Seven systematic reviews included studies where behaviours were tracked with the use of sensors and other wireless self-tracking devices (Free, Fanning, Lyzwinski, O'Reilly, Bacigalupo, Bort-Roig, Buhi). However, it is not easy to objectively assess the effect of these technologies, for two main reasons: most interventions involved several other aspects in addition to wireless self-tracking; most systematic reviews did not provide separate analysis for primary studies involving these kinds of technologies.

- Behaviour change techniques/theories are not consistently applied in these mHealth interventions. There is little integration with clinical care. Drop-off in use over time is common.

- Features in an mHealth intervention that are important for uptake and impact include: tailoring and personalisation, being integrated in a health system (and not a standalone system), interactive, offering a bundle of features that facilitate behaviour change, use of theories or proven behavioural change strategies, and consideration of mHealth treatment fidelity strategies.

- There is paucity of evidence on cost-effectiveness.

Weight and physical activity

Three **meta-analyses**[64-66] of interventions involving SMS, mobile apps, PDAs, and remote or web 2.0 technologies showed significant improvements in physical activity measures and/or weight loss (e.g. step counts, duration of moderate to vigorous physical activity, accelerometer counts per minute, self-reported physical activity), as well as mixed results for various other outcomes (Table 4). Another **meta-analysis**[34] found no statistically or clinically significant changes in weight for trials using SMS messages to reduce calorie intake and increase physical activity (standard mean difference [SMD] 22.14 [95% CI 27.05 to 2.77] kg) or for trials using application software to reduce calorie intake (SMD 20.10 [95% CI 20.49 to 0.69] kg) (Table 4). There were mixed results for other outcomes in these studies. Finally, one other meta-analysis[67] analysing activity monitor-based interventions in patients with type 2 diabetes found statistically significant improvements in physical activity, HbA1c, BMI and systolic blood pressure, with small to moderate effect sizes (Table 4).

Table 4: Summary effects from meta-analyses of mHealth interventions for physical activity (PA) and/or weight loss

Study author, year	Number of studies combined, type and duration	Summary effect (standard difference in means [SDM]) [95% prediction interval]
Fanning al., 2012[64]	11 RCTs (2–52 weeks)	0.54 [0.17, 0.91] (physical activity)
Foster et al., 2013[65]	9 RCTs (12 months)	0.2 [0.11, 0.28] (physical activity)
Lyzwinski et al., 2014[66]	11 RCTs	0.43 [0.25, 0.61] (weight change)
Free et al., 2013[34]	2 RCTs (4 weeks) [SMS to reduce calorie intake and increase physical activity]	-2.14 [-7.05, 2.77] (weight change)
	2 RCTs (4–12 months) (apps to reduce calorie intake)	0.10 [-0.49, 0.69] (weight change)
Vaes et al., 2013[67] (activity monitor-based interventions in patients with type 2 diabetes)	8 RCTs	0.81 [0.46, 1.17] (physical activity)
	16 RCTs	-0.23 [-0.41, -0.05] (HbA1c)
	10 RCTs	-0.24 [-0.48, -0.01] (BMI)
	11 RCTs	-0.18 [-0.34, -0.01] (systolic blood pressure)

* Effect sizes smaller than zero for weight change, HbA1c, BMI and systolic blood pressure represent an improvement as a result of the intervention. Effect sizes above zero for physical activity represent an improvement as a result of the intervention.

Seven **systematic reviews** analysed physical activity and/or weight loss outcomes, having found mixed results:

- O'Reilly et al. (2013)[68] reported that of the 12 included studies that used mobile technologies to influence physical activity behaviour, nine reported significant changes in either physical activity or sedentary behaviour.
- Bacigalupo et al. (2012)[69] reviewed 21 RCTs and found consistent evidence that weight loss occurs in the short-term as a result of mobile technological-based interventions in overweight and obese individuals, with moderate evidence for the medium-term.
- Shaw et al. 2012[70] found that of the 14 interventions included in the review, 11 showed a statistically significant effect on weight loss, diet or exercise, and one study showed a statistically significant effect on BP. There were mixed results regarding self-efficacy and social support.
- Stephens et al. 2013[71] found that five out of the seven studies reported statistically significant results in at least one outcome. However, studies were low to moderate in quality and the majority of significant findings were not between intervention and control groups and not in the primary outcome.
- Bort-Roig et al. 2014[72] reviewed 17 studies, of which five assessed physical activity intervention effects, showing mixed results. Four studies (three pre–post and one comparative) reported physical activity increases.
- Buhi et al. 2012[41] reviewed four studies focusing on weight loss, where three found statistically significant results favouring the intervention; mixed results for physical activity.
- Krishna et al. 2009[43] reviewed one study focusing on physical activity and found a statistically significant difference in percentage of body fat lost.
- One RCT[73] using mobile phone and sensors showed positive results for weight loss in the intervention group at 24 weeks.

Smoking cessation and substance use

Two **meta-analyses** evaluated the effectiveness of mobile phone interventions for smoking cessation (one of the included studies was pooled in both) (Table 5). One meta-analysis[34] found that SMS-based smoking cessation interventions more than doubled biochemically-verified smoking cessation at six months (pooled effect estimate relative risk [RR] 2.16 [95% CI 1.77 to 2.62, p<0.0001]). Another meta-analysis was conducted by the Cochrane group and studies were pooled in two different analysis, both showing statistically significant improvements: one including studies where interventions were delivered solely by mobile phone, and another with interventions delivered equally by mobile phone and internet.

Table 5: Summary effect from meta-analysis of mHealth interventions for smoking cessation

Study author, year	Number of studies combined, type and duration	Summary effect (RR) [95% prediction interval]
Free et al., 2013[34]	2 RCTs (6 months)	2.16 [1.77, 2.62] (smoking cessation)
Whittaker et al., 2009[74]	2 RCTs (4–6 weeks) (mobile phone-only intervention)	2.18 [1.8, 2.65] (abstinence)
	2 RCTs (12 months) (mobile phone and internet intervention)	2.03 [1.4, 2.94] (smoking cessation)

* Effect sizes higher than one for smoking cessation and abstinence represent an improvement as a result of the intervention.

Two **systematic reviews** and one **RCT** also focused on smoking cessation outcomes, finding good-quality evidence of the effectiveness of mHealth intervention.

- Buhi et al. 2012[41] found that seven out of eight studies focusing on smoking cessation revealed statistically significant differences in smoking cessation.
- Krishna et al. 2009[43] reviewed four smoking cessation studies which reported significantly greater success in behaviour change among the intervention group participants who received a smoking cessation–related educational intervention delivered to their cell phones.
- Vidrine et al. 2006[75] conducted an RCT with HIV patients that showed that participants who received the cellular telephone intervention were 3.6 times (95% confidence interval, 1.3-9.9) more likely to quit smoking compared with participants who received usual care (P>0.0059).

Other health behaviours

- Heron et al. 2010[58] evaluated the effectiveness of momentary ecological interventions and found mixed results from moderate-low quality studies on the effectiveness of ambulatory treatment for smoking cessation, weight loss, anxiety, diabetes management, eating disorders, alcohol use, and healthy eating and physical activity.

Question 3: What is the evidence regarding how demographic and socio-economic factors affect the benefits of mHealth?

Summary points:

- Few studies have assessed the benefits of mHealth interventions for specific sub-populations. We found four studies in diabetes and one in hypertension where this issue was considered. Although it seems that younger type 2 diabetes patients, with shorter diabetes duration, may benefit more from mHealth interventions, more studies are needed for definitive conclusions to be drawn.

- The most common aspects influencing adoption and use of mHealth technologies reported in the literature, include the following: cost, access to the technology/internet, ease of use, perceived benefit, computer/mobile phone experience, literacy, level of personalisation/tailoring of the intervention, presence of feedback from healthcare providers, convenience, technical problems, and security issues.

- Studies in Australian sub-populations, although few, seem to suggest high acceptability and usage of the technologies.

- It appears that mHealth tools are acceptable and feasible for most sub-populations as long as they are personalised and suited to their different needs, and sufficient training and support are provided.

- Adoption and usage may be improved when the design of the intervention takes into consideration the particular characteristics and needs of the target population. For instance, to facilitate usage by low literacy populations, mobile tools that are based on alternative input mechanisms such as photographs and voice can be used instead. Likewise, larger device screens could make mHealth tools easier to be used by the elderly.

3.1 Benefits for different sub-populations

Few studies have assessed the benefits of mHealth interventions for specific sub-populations. We found four studies in diabetes and one in hypertension where this issue was considered.

Diabetes

In patients with diabetes, higher effect sizes were found for younger versus older patients (>55 years old), shorter duration of disease, and for type 2 versus type 1 diabetes:

- Saffari et al.[32] reviewed 10 RCTs on T2DM self-management and showed that the effect size found in younger patients [SDM -0.65; Standard Error (SE) 0.119] indicates a higher reduction in HbA1c than in patients over age 55 years (SDM -0.42; SE 0.08; p=0.006]. As a possible explanation, at the initial stages of risk recognition the person may be more likely to adopt preventive measures to avoid complications and negative outcomes related to the risk.

- Baron et al.[38] reviewed 24 experimental studies and found one where a significant reduction in HbA1c occurred only in the group with shorter diabetes duration.

- Liang et al.[33] showed in a subgroup analysis that the pooled reduction in HbA1c from 10 studies of patients with T2DM was 0.8% [9 mmol⁄mol; 95% confidence interval, 0.5–1.1% (6–12 mmol⁄mol)] and the pooled result from nine studies of patients with T1DM was 0.3% (3 mmol⁄mol; 95% confidence interval, 0–0.5% (0–6 mmol⁄mol); p for difference = 0.02).

Furthermore, the efficacy of mHealth interventions on diabetes management may be affected by **gender**, as suggested by a qualitative study where men and women differed in regards to self-efficacy, knowledge gained, and desired content in future mHealth interventions.[76]

Hypertension

In the subgroup of intervention patients with low literacy or high information needs there was an 8.8mm Hg reduction in average systolic blood pressure, and a significantly greater proportion of intervention than control patients having BPs in the acceptable range.[77]

3.2 Australian studies

We found three studies conducted in Australia:

- In a study on Aboriginal children with chronic otitis media, it was found that phone multimedia messages (MMS) did not have any significant increase in clinical attendance and ear health.[78] However, 84% in the control group and 70% in the intervention group were happy to receive phone MMS health messages in the future. So, although the difference was not significant, results show that MMS is an acceptable and culturally appropriate form of health promotion for these Indigenous families.

- One study investigated the acceptability of mHealth interventions by mental health patients, for self-management of their conditions. Attitudes toward the use of mobile phones for the monitoring and self-management of depression, anxiety, and stress appear to be positive as long as privacy and security provisions are assured, and as long as the intervention is not intrusive and is easy to use, providing feedback to users.[79]

- One other study evaluated the feasibility of using an mHealth intervention for cardiac rehabilitation patients in Australia, having found high usage and acceptance of the technology.[80]

Furthermore, one additional study reviewed the evidence regarding the use of social media and mobile apps for health promotion in Australian Indigenous populations, having found little evidence pertaining to their effectiveness, with current interventions being very limited in scope and not widely adopted.[81]

3.3 Barriers to adoption and use by different sub-populations

The most common aspects influencing adoption and use of mHealth technologies reported in the literature, include the following[22,31,79,82-85]: cost, access to the technology/internet, ease of use, perceived benefit, computer/mobile phone experience, literacy, level of personalisation/tailoring of the intervention, presence of feedback from healthcare providers, convenience, technical problems, and security issues.

The adoption of mHealth technologies requires some level of literacy that needs to be considered especially when the interventions are targeting elderly or individuals with lower technical skills.[86] For instance, in one study, less engagement in an mHealth intervention was observed in racial/ethnic minorities, older adults, and people with lower health literacy or more depressive symptoms.[83]

Nevertheless, studies focusing on use of mHealth tools by vulnerable, hard-to-reach, or high-risk patient populations (elderly patients, members of minority ethnic and racial groups and low-income adults) found that these tools could lessen the burden of traveling to the healthcare provider's office.[22] Also, these patients report good comprehension and satisfaction in mHealth feasibility and acceptability studies.[22]

One review of mHealth interventions for elderly patients found that mHealth is being increasingly used as a way to support health management and self-monitoring in this population, but elderly people still face some barriers to their current use[84]. Indeed some studies suggest that using specific designs such as larger device screens could make mAdherence tools easier to be used by the elderly[22].

In conclusion, mHealth may help reduce barriers to care and reduce health disparities among different groups if inequalities are taken into account in the design of interventions. Further research is needed to better understand differences in usability between diverse patient groups and to encourage development of mHealth tools to address users' needs.[22]

Question 4: What is the evidence regarding strategies that can be used to operationalise the use of mHealth technologies for chronic disease management and prevention purposes?

Summary points:

- Strategies to increase uptake of mHealth will likely need to address the main barriers for each of the stakeholders in this process: payers, providers and, most importantly, patients.
- Regarding apps, several aspects will be important to facilitate their uptake: payer and provider recognition of the potential role of apps in healthcare; creation of security/privacy guidelines and policies that protect personal health information; reimbursement and supporting policies; integration of apps with other health IT systems; curation and evaluation of healthcare apps to guide both patients and clinicians and an infrastructure for app prescribing (i.e. an 'app formulary').
- Intervention features associated with increased satisfaction and/or adherence include: interactive approaches, user-friendliness, time required to use the application, automatic and wireless transmission of data from wearables and other devices, variety of educational and motivational content with tailored or personalised SMS, automated reminders, and SMSs with educational and motivational content.
- The 'stickiness of the app' is an important factor in keeping interest over time and in avoiding the decay in adherence.

4.1. Operational steps and strategies to increase uptake

A survey conducted in 2009 by the World Health Organization's (WHO) Global Observatory for eHealth assessed the status of mHealth in Member States, namely the adoption, types of initiatives, status of evaluation, and barriers to implementation.[31] In this survey, completed by 114 Member States, 'competing health system priorities' was consistently rated as the greatest barrier to mHealth adoption.[31] Given the growing challenges and limited budgets in healthcare today, the selection of interventions is increasingly based on evidence of efficacy and cost-effectiveness. However, evaluation studies of mHealth interventions are still sparse, and often lack a cost-effectiveness analysis. Indeed, the same 2009 WHO survey found that only 12% of Member States reported evaluating mHealth services.[31] Other barriers to mHealth implementation mentioned in the WHO survey included the lack of knowledge concerning the impact on health outcomes, lack of supporting policy, and legal issues.[31]

For physicians, additional barriers have been mentioned in the literature, such as lack of compatibility with workflow, competing demands, existing reimbursement structure, lack of evidence, cost, and lack of necessary technology.[28,29,87-89]

For patients, barriers for mHealth uptake include cost, lack of relevant applications, providers' unwillingness to use mHealth tools, privacy or security concerns, lack of knowledge about services, and undue anxiety if technology fails.[22 28,29,87,89]

On the other hand, drivers for mHealth uptake for patients involve aspects like reducing own healthcare costs, convenient access to provider, ability to obtain information, and greater control over own health.[28] For physicians, drivers for uptake include: lower overall cost of care for patients, easier access of patients to care, reaching previously unreachable patients, improved quality of care, and more efficient care processes.[28] Strategies to increase uptake of mHealth will likely need to address the main barriers for each of the stakeholders in this process: payers, providers and, most importantly, patients. Importantly, these strategies should also stem from the main drivers for mHealth uptake, identified in the literature.

Key steps for implementing an mHealth project have been described as follows[30]: 1) identifying a clinical champion and project team; 2) engaging key decision makers early in the project; 3) developing a project outline (including scope, target patient population and target patient volume for the project; key metrics and success criteria; product requirements; approval processes; and timeline); 4) mapping the workflow and planning the implementation; 5) gathering patient feedback; 6) community building and staff training; 7) going live; 8) iterating and monitoring success; and 9) transitioning to long term adoption.

Within mHealth, apps are gaining particular interest, despite their recent appearance. The app maturity process will probably be driven by several factors[27-29,90]: payer and provider recognition of the potential role of apps in healthcare; creation of security/privacy guidelines and policies that protect personal health information; reimbursement and supporting policies; integration of apps with other health IT systems; curation and evaluation of healthcare apps to guide both patients and clinicians and an infrastructure for app prescribing. This infrastructure, or 'app formulary', could facilitate app selection and uptake by grouping apps by type and by having ratings of functionality, ease of use, and quality of the content. Three examples of this type of infrastructure already exist:

- In 2013 the National Health Service (NHS) Commissioning Board in the UK launched a library of NHS-reviewed health apps for consumers (e.g. apps providing advice on specific medical conditions or allowing users to book repeat prescriptions, access test results, and find the most appropriate NHS service).[27] This library is a response to the overwhelming number of health apps that are available nowadays, and is intended to guide users and help them know which ones are safe.

- Companies like HealthTap in the US are also getting involved in the app evaluation market, with a product called AppRx, which enables physicians in the network to review health and medical apps based on three questions: 1) Is the app medically sound?; 2) Is the app useful?; and 3) Is the app easy to use and understand?[27]

4.2. Features influencing adoption

Intervention features influencing adoption varied across studies and health domains.

In general, features such as automated reminders, SMSs with educational and motivational content, and wireless transmission of data seem to contribute to increased self-care awareness and knowledge about chronic diseases.[22]

One systematic review found that mHealth studies reporting negative results in adherence were using more basic and repetitive content; while the successful studies use several educational and motivational strategies to engage users (i.e., tailored or personalised messages).[53]

Diabetes

Saffari et al. 2014[32] found that interactive approaches were more effective in improving glycaemic control, showing a higher effect size (SDM -0.60; SE 0.08) than unidirectional (data collection-only) approaches (SDM -0.31 SE 0.1; p=0.001). Similarly, SMS plus internet interventions were more effective (SDM -0.87; SE 0.29) than SMS-only approaches (SDM -0.44 SE 0.12; p=0.01).

Chomutare et al. 2011[91] found that although the evidence-based recommendations and requirements suggest the use of personalised education and decision-support features in mHealth, most of the diabetes mobile apps do not have it integrated.

Liang et al. 2011[33] found that studies where the intervention used both mobile phone and internet showed a greater reduction in HbA1c than the studies with only mobile phone [0.7% (7 mmol/mol) vs. 0.4% (4 mmol/mol)], and studies with daily intervention frequency reported greater reduction in HbA1c than those with weekly intervention frequency [0.6% (7 mmol/mol) vs. 0.2% (2 mmol/mol)], but the differences were not statistically significant.

Connelly et al. 2013[36] found that use of additional components within the technology, such as email and log books, seemed to increase engagement with the intervention.

Other authors have mentioned 'ease of use' and 'data presentation' as important aspects for intervention adoption, as well as 'time required to use the application' and automatic and wireless transmission of blood glucose data.[92]

Finally, a review of available apps for diabetes self-management was conducted in 2011, where 137 apps were assessed for their functionalities and adherence to evidence-based guidelines, with its results showing that personalised education was an unrepresented feature in diabetes mobile apps.[91]

Fitness

Bracelets for activity monitoring seem to be unobtrusive and easy to use.[93]

An analysis of wireless devices (electronic activity monitors) found that all monitors provided tools for self-monitoring, feedback, and environmental change. Other prevalent techniques were goal-setting and emphasizing the discrepancy between current and goal behaviour.[94]

Another study has mentioned that the five recommended key components for effective technology-based weight loss interventions are self-monitoring, counsellor feedback and communication, social support, use of a structured program, and use of an individually tailored program.[95]

Fanning et al. 2012[64] found significant moderate to large effect for pedometer steps (g=1.05, 95% CI 0.75 to 1.35, P<0.01). When examining intervention components specifically, those delivered via mobile phone yielded a significant moderate effect (g=0.52, 95% CI 0.11 to 0.94, P=0.01).

Foster et al. 2013[65] found that the most effective interventions applied a tailored approach to the type of PA and used telephone contact to provide feedback and to support changes in PA levels. There were no differences in effectiveness between studies using different types of professionals delivering the intervention (for example health professional, exercise specialist). There was no difference in pooled estimates between studies that generated the prescribed PA using an automated computer program versus a human, neither between studies that used pedometers as part of their intervention compared to studies that did not.

O'Reilly et al. 2013[68] found that responses for usability were mixed, varying from 58% of participants agreeing that a mobile journal was easy to use to all participants agreeing that an on-body sensing system was easy to use. The studies that reported acceptability assessment outcomes revealed that on-body sensing systems, mobile journals, and SMS messaging, received positive acceptability ratings from participants. Additionally, one study that used a mobile journal and three studies that used SMS messaging determined that these mobile technologies are feasible ways to deliver PA interventions. None of the studies that employed on-body sensing systems assessed feasibility, so the literature does not provide evidence of the feasibility of on-body systems for PA measurement or interventions. Text messaging or smartphone applications are well accepted by participants. Of the 12 studies that used mobile technologies to influence PA behaviour, nine (75%) reported significant changes in PA or sedentary behaviour. These studies employed SMS communication to promote PA, PA self-monitoring through mobile journaling, or both SMS and journaling.

Lyzwinski et al. 2014[66] concluded that mobile devices appear to induce positive changes in the behavioural determinants of weight and subsequently are associated with weight loss. Mobile device interventions were heavily informed by theory and behaviour change techniques. All studies included goal setting, self-monitoring, and feedback. Feedback was provided through different sources of media such as web groups, social networking sites, app feedback on the smartphone dashboard, and phone call feedback. Self-monitoring of diet and physical activity was also employed using various mediums including the use of mobile apps, PDAs, the web, sending text messages, and using pedometers and accelerometers.

Shaw et al. 2012[70] reviewed seven studies which measured feasibility and acceptability of SMS as a mode for weight loss interventions. Feasibility was defined as the ability to transmit data via SMS to participants, the receipt of information by participants and the ability to communicate back to the researchers. SMS was found feasible and acceptable in all seven studies. They also concluded that one SMS per day may be appropriate in helping motivate people to engage in weight loss behaviours without generating a considerable burden.

De Leon et al. 2014[96] found that periodic messaging has positive short-term effects across a number of health behaviours and across media and frequency. Given that the included interventions varied by many factors, including behaviour, prompt, use of feedback, goal-setting, and theoretical models, it was difficult to form a conclusive judgment regarding which combination of elements is most effective.

Carter et al. 2013[97] achieved high trial retention (93%) in the smartphone group, 19 out of 42 (55%) in the website group, and 20 out of 43 (53%) in the diary group at six months. Adherence was statistically significantly higher in the smartphone group with a mean of 92 days (SD 67) of dietary recording compared with 35 days (SD 44) in the website group and 29 days (SD 39) in the diary group ($P<0.001$).

Medication adherence

Hamine et al. found that use of daily SMS reminders for medication intake showed significant improvements in medication adherence rates.[22] Text messaging providing education and motivational support were associated with improved adherence to medication, namely in patients with diabetes.[22] One study demonstrated the dual benefits of both better access to patient data and mobile coaching.22 One of the studies reviewed by the same authors involved the use of an electronic blister pack with SMS communication and showed a significant improvement in adherence to DM medication.[22]

Other reviews have found that positive studies seem to deliver a variety of educational and motivational content with tailored or personalised SMS.[53]

Ecological momentary intervention (EMI) sessions seem to be viewed by patients as helpful, user-friendly, and engaging. Patients report satisfaction with the timing and burden of sessions, as well as the method of delivery. In the same study, adherence was high (on average, participants completed 92% of EMI sessions).[98]

Asthma

In one study, patients rated mHealth positively and considered that it may help clinicians to provide care, especially during acute attacks. Although rated similarly, professionals were more sceptical about benefits. Both professionals and patients had concerns about the time and cost implications.[47] Also, participants considered that mobile phone-based monitoring systems can facilitate guided self-management although, paradoxically, may engender dependence on professional/technological support.[47]

Smoking cessation and substance abuse

A review of 47 iPhone apps available for smoking cessation showed that most apps were found to have low levels of adherence to evidence-based practices for smoking cessation and rarely adhere to established guidelines.[99]

Dulin et al. (2014)[100] evaluated the effect of a smartphone program for self-management of alcohol usage. The program was found to be useful in managing alcohol intake and reduced number of drinks per day by 52%.

Elderly

One important step in improving healthcare for elderly patients using mHealth will be not only to increase smartphone penetration in this group, but also to consider family and caregivers of the elderly and the role they can play in managing care.[27] For example, some apps for medication adherence serve not only as pill reminders, but also allow the patient to nominate a "support network" who will also receive notifications if a medication dose has been missed.[27]

Furthermore, older patients with multimorbidity may benefit more from broader apps, not focused on single diseases or medical problems.[27]

Other health domains

Three studies were identified using wearables to detect and prevent accidents related to living with chronic diseases. These included fall detection, apnoea detection, and assessing balance for people with Parkinson's disease in their home setting.[101-103] These pilot studies demonstrated the feasibility of these interventions.

4.3. Past failures

- A study evaluated smartphone apps claiming to detect skin cancer based on pictures of moles and found out that three of the apps missed melanoma between 30% and 90% of the time, while only one of the apps sent the picture of a suspected mole to a dermatologist.[27,104,105]

4.4. Past successes

- Although apps are currently available across the full spectrum of the patient journey, wellness apps predominate, whereas self-diagnosis, filling prescriptions and medication compliance seem to have the lowest numbers of apps developed to date.[27] IMS report found that only 159 apps linked to sensors, most of them were fitness and weight apps; Fewer than 50 of those 159 apps were related to actual condition management.[27]

- One of the most advanced apps for chronic disease management and remote monitoring, approved by the FDA, is the WellDoc Diabetes Manager software. In the initial clinical trial of WellDoc the intervention group showed improved self-care in diet, medication, and exercise compared to the control group receiving usual care. Furthermore, 84% patients in the intervention group had medications titrated or changed by their healthcare provider compared to controls.[106] A following trial of WellDoc showed a statistically significant decrease in A1c values for intervention patients compared to the standard care control group.[106] The study therefore demonstrates that it is possible to improve treatment outcomes with mobile phone and web portal communications when used by both patients and their HCPs.

- WellDoc Diabetes Manager exemplifies several success principles[28]: it is integrated into existing healthcare plans, personal lifestyles, clinical processes, and multiple technologies; it is interoperable with the Electronic Health Record (EHR); it provides intelligent guidance for users and real time alerts based on data inputted; it is clinician-friendly, providing clinicians with clear actionable data that they can use as a basis for recommendations; it is socialised and interactive, providing personal coaching, direct physician support, and caregiver linkage; it is outcome-oriented and cost-effective, as demonstrated in trials; it is engaging, enabling patients to configure settings, messaging, tonality, and interaction modes.

- The University of Auckland conducted a randomised smoking cessation clinical trial with 1700 smokers and found that those who received the supportive text messages successfully quit smoking at more than twice the rate (28% compared with 13%) of those in the control group. New Zealand's health authorities built on that success with a free national smoking cessation service.[29]

- Bayer has developed a tool that multiple sclerosis patients can use to track their medications, and Novartis has built apps for cystic fibrosis and cancer, among other diseases.[29]

- 'My Health Matters', an app from Merck for HIV patients to chart symptoms and adherence to their prescribed drug regimens, has won an award from Medical Marketing & Media.[29]

4.5 Mobile apps endorsed by government and non-profit chronic disease groups in Australia

A summary of mobile apps available specifically for Australians is presented in Appendix B.

- There were six mobile apps from the Federal level government (www.australia.gov.au/about-government/apps). One was to keep track of medicines (Medicine List+); one was to access, add and view information about a child's health records (My Child's eHealth Record); one was for management of post-traumatic stress disorder (PTSD) and prevention of further stress (PTSD Coach Australia); two were to encourage smoking cessation (NoSmoke and Quit for You-Quit for Two); one was to locate and find information about health providers and hospitals (NHSD – Find a Health Service); and one was to educate parents about otitis media.

- From the State government, three apps concerned fitness and exercise promotion (Daily PA, Health & Fitness Age Challenge Application, and Walk to School). Two apps were to provide information about harmful effects of UV light and promote prevention behaviours such as wearing sunscreen (Sun Effects Booth, SunSmart). Better Health Channel provides medical and health information, such as first aid procedures. It also provides health and nutritious recipes and personalised health alerts and notifications for heat, UV, smog and pollen.

- From the non-profit chronic disease groups as indicated by the Australian Institute of Health and Welfare (www.aihw.gov.au/chronic-diseases/), we retrieved 13 health mobile apps.

- Below is a summary of the apps for each chronic disease:
    - Cardiovascular disease (one app to manage medicines, blood pressure and cholesterol. Also possible to learn about heart attack warning signs and what to do)
    - Cancer (one app from Cancer Council to inform and promote protection against sun exposure. One app from Lung Foundation Australia that provides information and contacts easily)

- Diabetes (two apps retrieved. One provides resources and information for meal planning and health articles, as well as contact details for healthcare professionals. The other app allows recording of blood glucose levels, daily diet, exercise and medication lists and reminders)
- Mental health (there were six mindfulness apps. These apps provide meditation, and give information and resources about how to control everyday stress and anxiety, as well as how to recognise the physical symptoms of stress. One app was designed for management of Alzheimer's disease; it provides a guide about healthy lifestyle and better self-care behaviours)
- Respiratory diseases (one app was for management of Asthma. It also included information about what to do in case of an emergency by providing easy access to First Aid for asthma instructions in the phone app)
- No apps were found for chronic kidney diseases, musculoskeletal conditions and oral health.

We did not find any evaluation studies for these apps.

5 Discussion

There is a growing body of evidence regarding the feasibility and efficacy of mHealth interventions in the prevention and self-management of chronic diseases.

Question 1: Benefits of using mHealth technologies to support chronic disease management

Studies involving the use of mHealth technologies to support **chronic disease management** have been conducted in several health domains: diabetes, cardiovascular diseases, chronic lung diseases (i.e. COPD, asthma), mental health, and osteoarthritis. Although SMS was the most common mode of delivery in earlier mhealth studies, the most recent ones involved the use of more innovative platforms, such as mobile applications, sensors, and wireless devices.

The majority of mHealth interventions to support chronic disease management seem to involve a great variety of tasks, such as inform, instruct, record, display, guide, remind/alert, and communicate.
The majority of studies regarding mHealth for chronic disease management focused on diabetes (two meta-analysis and 10 systematic reviews). The two meta-analyses in patients with diabetes showed improvements in glycaemic control through the use of mobile phones, SMS, internet, and/or wireless devices. The 10 systematic reviews of mHealth interventions for diabetes self-management showed mixed results for the various outcomes assessed (e.g. BMI, weight, glycaemic control, cholesterol, self-management behaviours, self-efficacy, and exercise). The remaining studies, mostly systematic reviews, showed mixed results for a variety of outcomes in several health domains.

Finally, the majority of the analysed studies did not take into account the costs associated with providing the intervention. Only two studies mentioned cost issues; one concluded that the particular intervention being provided was not cost-effective.

Question 2: Benefits of using mHealth technologies to track health behaviours for prevention purposes

Evidence on the efficacy of mHealth interventions to **track and promote healthy lifestyle behaviours** is growing. Three meta-analyses of interventions involving SMS, mobile apps, PDAs, and remote or web 2.0 technologies showed significant improvements in physical activity measures and/or weight loss outcomes. Two meta-analyses evaluated the effectiveness of mobile phone interventions for smoking cessation and found significant results. One meta-analysis combined studies for separate outcomes, namely two RCTs for medication adherence and three RCTs for vaccine attendance, having found statistically significant results for the latter.

The mHealth technologies utilised for behaviour change included (in descending order of frequency): SMS, apps, self-tracking devices, wearable devices and sensors. There was little integration of these interventions with clinical care.

Seven systematic reviews included studies where behaviours were tracked with the use of sensors and other wireless self-tracking devices (Free, Fanning, Lyzwinski, O'Reilly, Bacigalupo, Bort-Roig, Buhi). However, it is not easy to objectively assess the effect of these technologies, for two main reasons: most interventions involved several other aspects in addition to wireless self-tracking; and most systematic reviews did not provide separate analysis for primary studies involving these kinds of technologies. Indeed, bundle of features seems to be important to achieve behaviour change (e.g. self-monitoring followed by personalised feedback), and most interventions employ feature bundles, making an objective evaluation of their effect more complex.

Features in an mHealth intervention that are important for uptake and impact include: tailoring and personalisation, being integrated in a health system (and not a standalone system), offering a bundle of features that facilitate behaviour change, use of theories or proven behavioural change strategies, and consideration of mHealth treatment fidelity strategies.

There is a paucity of evidence regarding cost-effectiveness.

Question 3: Influence of demographic and socio-economic factors on the benefits of mHealth

Demographic and socio-economic factors seem to influence both the adoption and the effectiveness of mHealth interventions. The most common aspects influencing adoption and use of mHealth technologies include the following: cost, access to the technology/internet, ease of use, perceived benefit, computer/mobile phone experience, literacy, level of personalisation/tailoring of the intervention, presence of feedback from healthcare providers, convenience, technical problems, and security issues.

Low literacy levels can significantly influence the impact of mHealth, especially when the technology/intervention is not tailored to the specific needs of the population. One example is the use of alternative mechanisms for information input in order to avoid the use of written text in populations with low levels of literacy. Additionally, there is evidence that training and support in using the technology may increase its uptake and use.

Question 4: Strategies to operationalise the use of mHealth technologies for chronic disease management and prevention purposes

There is a paucity of evidence regarding strategies to **operationalise the use of mHealth technologies** for chronic disease management and prevention, and the majority of information in this area comes from grey literature.

One of the greatest barriers to mHealth uptake in healthcare seems to be the existence of competing health system priorities, combined with the lack of evaluation studies and cost-effectiveness analysis to guide decisions. Strategies to increase uptake of mHealth will likely need to address the main barriers for each of the stakeholders in this process: payers, providers and, most importantly, patients.

Intervention features associated with increased satisfaction and/or adherence include: interactive approaches, user-friendliness, time required to use the application, automatic and wireless transmission of data from wearables and other devices, variety of educational and motivational content with tailored or personalised SMS, automated reminders, and SMSs with educational and motivational content.

Regarding apps, many authors consider that several aspects will be important to facilitate their uptake, namely: payer and provider recognition of the potential role of apps in healthcare; creation of security/privacy guidelines and policies that protect personal health information; reimbursement and supporting policies; integration of apps with other health IT systems; curation and evaluation of healthcare apps to guide both patients and clinicians and an infrastructure for app prescribing (i.e. an 'app formulary').

Future studies should aim at incorporating the RE-AIM framework (Reach, Effectiveness, Adoption, Implementation, Maintenance)[107,108] to better plan and evaluate their interventions, aiming at the future translation of research to practice.

6 Conclusions

Mobile phones have several characteristics that make them an attractive tool for the prevention and self-management of chronic conditions: they are **portable** and **ubiquitous**; they are **personal**, making it possible to target interventions to specific individuals; they are **connected**, being able to provide direct access to a wide range of external resources; and they are increasingly **intelligent** and have many capabilities.[109]

Of all the mHealth technologies, SMS is the most prevalent in the literature, and the one with the strongest evidence of effectiveness. Furthermore, interventions based on SMS are generally the simplest and lowest cost to develop and have the potential for reaching the largest possible audience.

Although a dose-response for SMS-interventions cannot be identified from the present literature, interventions using as little as four text-messages per week have been shown to be effective in improving a variety of outcomes.[45] Additionally, personally tailored and interactive interventions seem to be more efficacious, especially when the users are able to choose when to receive messages.[109] Indeed, a meta-analysis of text messaging interventions to promote antiretroviral therapy adherence showed that larger effects were present when interventions: 1) had SMS sent less frequently than daily, 2) supported bidirectional communication, 3) included personalised message content, and 4) were matched to participants' therapy dosing schedule.[52]

Interventions with more innovative technologies, such as those involving smartphone apps and/or wearable devices, remain mostly seen in feasibility and usability studies, with few published randomised controlled trials evaluating their effectiveness. However, these interventions seem promising in promoting long-term engagement, especially when involving three key components: 1) habit formation; 2) social aspects (e.g. support, comparison, competition); and 3) goal setting and feedback.[110]

Overall, mHealth interventions seem to be able to promote significant improvements in glycaemic control (for diabetes patients), as well as in physical activity, weight loss, and smoking cessation, among other outcomes. However, the benefits seem to be dependent on the characteristics of the intervention (e.g. bundle of features, use of behaviour change theories, 'stickiness') and the specific patient population (e.g. age, digital literacy).

One important aspect for the success of mHealth interventions is their integration in healthcare, whereby they are able to function as part of a service (and not as a standalone system). Nevertheless, one of the greatest barriers to mHealth uptake in healthcare seems to be the existence of competing health system priorities, combined with the lack of evaluation studies and cost-effectiveness analysis to guide decisions.

Therefore, in order to improve the uptake and impact of an mHealth service, the following elements are important for consideration: 1) the mHealth component is integrated into a health service (and not as a standalone system); 2) there is a bundle of features to facilitate action (e.g. decision support, followed by task support); 3) the design incorporates appropriate use of theories and behavioural change strategies; 4) there are strategies in place to maintain participant interest and minimise dropout; and 5) there are plans to ensure mHealth service fidelity (i.e. the accurate delivery, receipt, and enactment of the service).[111,112]

In the end, strategies to increase uptake of mHealth will likely need to address the main barriers for each of the stakeholders in this process: payers, providers and, most importantly, patients.

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8 Appendices

Appendix A: Systematic search of mHealth literature across five databases

Databases: Pubmed, Embase, Scopus, CINAHL, Cochrane Library

Time period: From 2005 to current

Limits: English and Humans

("Chronic Disease"[Mesh] OR "Self Care"[Mesh] OR "Diabetes Mellitus"[Mesh] OR "Mental Health"[Mesh] OR "Risk Reduction Behavior"[Mesh] OR "Sedentary Lifestyle"[Mesh] OR "Asthma"[Mesh] OR "Obesity"[Mesh] OR "Exercise"[Mesh] OR "Cardiovascular diseases"[Mesh]) **AND** ("Mobile Health" OR "Text Messaging"[Mesh] OR mHealth* OR m-health* OR mobile* OR wearable* OR pervasive OR "Mobile applications"[Mesh] OR "Cell Phones"[Mesh])

MeSH terms: "**Mobile applications**" includes: Application, Mobile; Applications, Mobile; Mobile Application; Mobile Apps; App, Mobile; Apps, Mobile; Mobile App; Portable Electronic Apps; App, Portable Electronic; Apps, Portable Electronic; Electronic App, Portable; Electronic Apps, Portable; Portable Electronic App; Portable Electronic Applications; Application, Portable Electronic; Applications, Portable Electronic; Electronic Application, Portable; Electronic Applications, Portable; Portable Electronic Application; Portable Software Apps; App, Portable Software; Apps, Portable Software; Portable Software App; Software App, Portable; Software Apps, Portable; Portable Software Applications; Application, Portable Software; Applications, Portable Software; Portable Software Application; Software Application, Portable; Software Applications, Portable

"**Cell phones**" includes: Phone, Cell; Phones, Cell; Cellular Phone; Cellular Phones; Phone, Cellular; Phones, Cellular; Telephone, Cellular; Cellular Telephone; Cellular Telephones; Telephones, Cellular; Cell Phone; Transportable Cellular Phone; Cellular Phone, Transportable; Cellular Phones, Transportable; Transportable Cellular Phones; Smartphone; Smartphones; Smart Phones; Smart Phone; Phone, Smart; Phones, Smart; Mobile Phone; Mobile Phones; Phone, Mobile; Phones, Mobile; Mobile Telephone; Mobile Telephones; Telephone, Mobile; Telephones, Mobile; Car Phone; Car Phones; Phone, Car; Phones, Car; Portable Cellular Phone; Cellular Phone, Portable; Cellular Phones, Portable; Portable Cellular Phones

Appendix B: Mobile apps endorsed by government and non-profit chronic disease groups in Australia

1. Federal level government

Name	Government department	Description
Medicine List +	National Prescribing Service Ltd	The more medicines you take, the more difficult it can be to remember important information about them. A medicines list can be a useful way to keep all the information about your medicines together Keeping an up-to-date list of all the medicines you take will help you to get to know your medicines, get better results from your medicines and enjoy better health App features: • Barcode scan your medicines or select from a pick list • Follow links to more medicine and health information on the NPS MedicineWise website • Edit, update and print an easy-to-read 'Medicines List' • Set alerts for medicine doses and for refilling prescriptions • Add details about your health conditions • Record details about your medical tests and results, and have your results graphed • Save your information as a PDF, and email the PDF to any email address
My Child's eHealth Record	National E-Health Transition Authority	This app is for Australian healthcare consumers with children under the age of 14 years. It allows parents and authorised representatives to access the child's personally controlled electronic health (eHealth) record to add and view information about the child's development The app lets you add and view a range of information, such as growth charts and reminders about health checks and immunisations
PTSD Coach Australia	Department of Veterans' Affairs	Helps you understand and manage the symptoms of post-traumatic stress disorder, or PTSD. It is not designed as a stand-alone treatment – ideally, it is a tool to use as part of your treatment PTSD Coach Australia is an app that helps people understand and manage the symptoms of post-traumatic stress disorder, or PTSD

		The app is based on the latest scientific understandings of PTSD, and was modified from the US Department of Veterans' Affairs PTSD Coach app
Quit for You – Quit for Two	Australian National Preventive Health Agency	Provides support and encouragement to help you give up smoking if you are pregnant or planning to be Part of government advertising campaign intended to encourage mothers from a 'diverse background' to quit smoking Includes tracker/educational component for baby progress and money saved, etc. Includes Quitline connection and other support options
NHSD – Find a Health Service	Healthdirect Australia	The National Health Services Directory (NHSD) helps you find location and opening hours for GPs, pharmacies, emergency departments and hospitals, when and where you need them
Talking book/ Care for Kids' Ears	Commonwealth Department of Health	Basic ear health information presented in style of an interactive children's book, read in English or many Indigenous languages
NoSmokes.com.au	Menzies School of Health Research	Designed for use by Aboriginal and Torres Strait Islander people, including mobile software, videos, and online games. Hosted from dedicated website, Facebook page, and YouTube channel

2. Australian state government health apps

Name	Government department/category	Description
Daily Physical Activity	Department of National Parks Recreation Sport and Racing	• Tool for teachers and coaches who lead PA and sport sessions whether these be in the classroom, schoolyard or local sporting club • The aim of this resource is to get school children active, and to instil in them a positive attitude towards an active lifestyle
Health & Fitness Age Challenge Application	The State of Queensland (Department of Health) Health & Fitness	• Everyday things to improve the way you look and feel • Get reminders, tips and facts about the areas you need to focus on • Track your progress over the four weeks and beyond
Sun Effects Booth	Queensland Health	• Shows how your current behaviour in the sun can damage your face in the future • Allows users to check the daily UV Index forecast for their local area to see how strong the sun is and when the UV Index reaches 3 and sun protection is required
VacciDate	The State of Queensland (Department of Health)	• Tool to help you manage your child's vaccination schedule in Queensland for children up to four years of age • Enter appointment dates for vaccinations; receive reminders at one month, one week, one day and one hour before the next vaccination is due or next appointment is scheduled; and store a record of vaccinations received for each child
Better Health Channel – Health Information and Services	Department of Health (Victoria)	• Providing easy to understand and reliable information • First aid procedures for a wide range of common injuries • Healthy and nutritious recipes • Urgent medical help and advice contacts • Personalised health alerts and notifications for heat, temperature, UV, smog and pollen
SunSmart	Department of Health (Victoria) Cancer Council	• The SunSmart app lets you know when you do and don't need sun protection and when it's safe to get some sun for vitamin D, making it easier than ever to be smart about your sun exposure all year

Teen Drinking Law	Department of Health (Victoria)	• Provides information about risks and decisions associated with under-age drinking
Walk to School	Department of Health (Victoria)	• Encourage regular walking not only in the lead up to the day, but beyond, such as: being able to track kilometres travelled to and from school, time spent walking and the average walking speed in a bid to make walking to school more fun and enjoyable for everyone involved

3. Mobile apps endorsed by non-profit chronic disease groups in Australia

Chronic disease	Organisation name	App available? (Y/N)	App name	App details
Cardiovascular disease	Heart Foundation	Yes	My heart, my life	• Manage medicines • Manage blood pressure and cholesterol • Educate about heart attack
Cancer	Cancer Council	Yes	SunSmart	• Education about sun protection
	Lung Foundation Australia	Yes	Lung Foundation Australia	• Information and contacts for Lung Foundation Australia easily accessible
	Leukemia Foundation	No		
	National Breast Cancer Foundation	No		
	Ovarian Cancer Australia	No		
	Prostate Cancer Foundation Australia	No		
Chronic kidney disease	Kidney Health Australia	No		
Diabetes	Diabetes Australia	Yes	Diabetes Australia app	• Meal planning, latest news and health articles • Easy access to contact details for healthcare professionals • Recipes, yoga
	Diabetes Australia AMA Queensland Foundation	Yes	myDiabetes	• Record blood glucose levels (BGLs) • Record daily diet and exercises • Inbuilt food, exercise and medication lists • Add food, exercise and medications to the lists • View graphs of BGLs, Glycaemic Load and calories burned over time • Send graphs via email • Save doctors' prescriptions and add new medications • Set reminders for medication

	Diabetes SA	No		
	Diabetes NSW	No		
	Diabetes Victoria	No		
Mental health	*beyondblue* Smiling Mind	Yes	Mind the Bump	• Free Mindfulness Meditation App to help individuals and couples support their mental and emotional wellbeing in preparation for having a baby and becoming new parents
	beyondblue	Yes	The Check-in	• Helps build a conversation plan to support a friend, including where the conversation will happen, what to ask, what you have noticed and what you can do to support • Provides links to a range of online and phone services appropriate for young people in Australia • Provides tips and advice from young people who have been through these conversations with friends
	ReachOut	Yes	ReachOut WorryTim e	• Control everyday stress and anxiety by acting as a place to store daily worries – *"Choose a time in the day that works best for you, and WorryTime will send you an alert when it's time to think about what's been stressing you out"*
	ReachOut	Yes	ReachOut Breathe	• Helps control breath and measures heart rate in real-time using the phone camera • Helps address the onset of physical symptoms of stress, like shortness of breath, increased heart rate and tightening of the chest

	ReachOut	Yes	Recharge	• Personalised six-week program that helps improve general health and wellbeing by focusing on four key areas: 1. A regular wake and sleep time each day achieved gradually over six weeks 2. An alarm clock that triggers fun activities designed to get people up and out of bed 3. Increasing exposure to daylight early in the day, to help reset the body clock 4. Encouraging increased physical activity, especially within two hours of waking up
	Alzheimer's Australia	Yes	BrainyApp	• Guide on how to live a brain-healthy lifestyle
	Department of Veterans' Affairs (DVA)	Yes	High Res	• Manage immediate responses to stress and help build resilience.
Musculoskeletal conditions	Arthritis Australia	No		
Oral health	National Oral Health Plan	No		
	Australian Dental Association	No		
Respiratory diseases (asthma and COPD)	Asthma Australia	No		
	Asthma Council	Yes	Asthma Buddy	• Record a prevention and relief medication plan and reference peak flow values • Know what to do in case of an emergency including easy access to the First Aid for Asthma instructions • Email a PDF copy of your action plan (e.g. to the doctor)

Appendix 1: Papers included for Question 1 – What is the evidence regarding the benefits of using mHealth technologies to support chronic disease management?

1.1 Benefits of using mHealth technologies to support chronic disease management

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings* (only statistically significant results are reported)	Grade of evidence
Saffari et al., 2014[32]	Meta-analysis	SMS +/- internet	Inform, instruct, record, display, guide, remind/alert, communicate	10 RCTs (2005–2013) (N=960)	Diabetes (type 2)	Combined results show improvements in glycaemic control for the intervention, compared with controls	Very high
Liang et al., 2011[33]	Meta-analysis	Mobile phone +/- internet, wireless devices	Inform, instruct, record, display, guide, remind/alert, communicate	22 experimental studies (2004–2010) (N=1657)	Diabetes (type 1 and 2)	Combined results show improvements in glycaemic control for the intervention, compared with controls	Very high
Free, 2013[34]	Meta-analysis	SMS, mobile phone, MP3/4, PDA	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. feedback, goal setting; tailoring; prompt self-monitoring of behaviour; identify barriers to behaviour/problem solving/identify ways of	49 disease management studies and 27 health behaviour studies	Disease management (e.g. diabetes) Behaviour change	Combined results show improvements in glycaemic control for the intervention, compared with controls Mixed results for CVD and chronic lung disease management, as well as for mental health interventions	Very high

			overcoming barriers)				
Connelly et al., 2013[36]	Systematic review	15 studies/eHealth interventions: 9 web-based, 3 with mobile phones, 2 with CD-ROMs and 1 computer-based	Inform, instruct, record, display, guide, remind/alert, communicate	3 studies concerning mHealth (2008–2011)	Diabetes (type 2)	No difference between intervention and control regarding physical activity or A1c in the mHealth studies	High
Holtz et al., 2012[37]	Systematic review	SMS, apps	Inform, instruct, record, display, guide, remind/alert, communicate	21 experimental studies (2004–2010)	Diabetes (type 1 and 2)	Three studies reported improvements in glycaemic control for the intervention, compared with controls Two studies showed improvements in knowledge about diabetes and diabetes management	High
Baron et al., 2012[38]	Systematic review	Mobile phone, PDA (+/- internet)	Inform, instruct, record, display, guide, remind/alert, communicate	24 experimental studies (2002–2011)	Diabetes (type 1 and 2)	Seven studies with type 2 diabetes patients showed improvements in glycaemic control for the intervention, compared with controls	High/Moderate
Krishna et al., 2008[39]	Systematic review	Cell phone	Monitoring, SMS, advice and self-care Inform, instruct, record, display, guide,	18 experimental studies (2003–2007) (N=1176)	Diabetes	Nine out of 10 studies that measured haemoglobin A1c showed a significant improvement. Mixed results regarding other outcomes	High/Moderate

			remind/alert, communicate				
Russell-Minda et al., 2009[40]	Systematic review	Blood glucose devices; pedometers; cell phone and other wireless devices	Monitoring of blood glucose, pedometers, cell phone Inform, instruct, record, display, guide, remind/alert, communicate	18 RCTs (1989–2008)	Diabetes	Mixed results for a variety of outcomes Limited to moderate evidence of improvements in glycaemic control	High/Moderate
Hamine et al., 2015[22]	Systematic review	SMS, mobile phone + app, wireless devices	Inform, instruct, record, display, guide, remind/alert, communicate	107 studies (2003–2014)	Diabetes, cardiovascular, chronic lung diseases	Significant improvements in DM-specific clinical outcomes such as blood glucose and A1c were reported in 11 out of 26 studies Significant improvements in clinical outcomes such as blood pressure, weight, and lipid profile were reported in seven out of 13 CVD-related studies Three out of six RCTs in chronic lung disease reported improvements in lung function parameters	High
Buhi et al., 2012[41]	Systematic review	SMS +/- internet +/- wireless devices	Inform, instruct, record, display, guide, remind/alert,	34 studies (2004–2010)	Diabetes (17) Substance use:	Six out of 17 studies focusing on diabetes found improvements in blood glucose levels when SMS	High

			communicate		smoking cessation (8) Fitness: weight (4), physical activity (1) Chronic lung diseases: asthma (1) Other (2)	was utilised One study focusing on asthma found significant improvements between groups	
de Jongh et al., 2012[42]	Meta-analysis	SMS	Inform, instruct, record, display, guide, remind/alert, communicate	4 RCT (2004–2009) (N=182)	Diabetes, cardiovascular (hypertension), chronic lung diseases (asthma)	Mobile phone messaging had few direct impacts on health outcomes related to the management of diabetes and hypertension One study involving asthma patients found significant improvements on peak expiratory flow variability and pooled symptom scores	Very high
Krishna et al., 2009[43]	Systematic review	SMS, internet, voice, email	Inform, instruct, record, display, guide, remind/alert, communicate	20 RCT + 5 quasi-experimental (2004–2008) (N=38,060)	Diabetes, cardiovascular (hypertension), chronic lung diseases	Significant improvements in medication compliance, asthma symptoms, HbA1C, stress levels, smoking quit rates, and self-efficacy	High/Moderate

					(asthma), other (e.g. smoking, HIV)	Process improvements were also reported (e.g. lower failed appointments and quicker diagnosis and treatment)	
Allet et al., 2010[44]	Systematic review	Wireless devices	Record	25 studies (1990–2009)	Cardiovascular, diabetes, COPD, other (osteoarthritis)	Two studies in arthritis patients showed significant improvements in daily step counts between intervention and control groups Mixed results for the five cardiovascular disease studies, 10 diabetes studies, and four COPD studies	High/Moderate
Chow et al., 2015[45]	RCT	SMS	Inform, instruct, remind/alert	N=710 patients	Cardiovascular (coronary heart disease)	Patients in the intervention group received four semi-personalised SMSs per week for six months, and the majority reported the text messages to be useful (91%), easy to understand (97%), and appropriate in frequency (86%) At six months, levels of Low-Density Lipoprotein Cholesterol (LDL-C) were significantly lower in intervention participants, with concurrent reductions in systolic BP and BMI, significant increases in physical activity, and a	High

						significant reduction in smoking	
Belisario et al., 2013[46]	Systematic review	Smartphone and tablet self-management apps	Inform, instruct, record, display, guide, remind/alert, communicate	2 RCT (2000–2013) (N=408)	Chronic lung disease (asthma)	One study found no statistically significant differences on asthma symptom scores, asthma-related quality of life, visits no the ED or hospital admissions The other study found statistically significant improvements in asthma-related quality of life, lung function, and number of visits to the ED	Very high
Ryan et al., 2012[47]	RCT	Mobile	Monitoring	N=288 adults and adolescents UK	Chronic lung diseases (asthma)	Mobile technology did not improve asthma control or increase self-efficacy compared with paper based monitoring when both groups received clinical care to guidelines standards	Moderate
Ehrenreich et al., 2011[49]	Systematic review	Mobile phones and handheld computers	Inform, instruct, record, display, guide, remind/alert, communicate	8 studies (1997–2009)	Substance use (smoking cessation) Mental health	Studies used mobile phones to target smoking cessation. In all, the intervention participants were significantly more likely to achieve abstinence Three studies used handheld computers targeting anxiety Improvement in anxiety in only	High

						one study	
Donker et al., 2013[50]	Systematic review	Apps	Inform, instruct, record, display, guide, remind/alert, communicate	8 studies (2008–2013) (N=227)	Mental health	No significant differences between intervention and control groups regarding depressive symptoms, stress, anxiety, and substance use	High
Depp et al., 2015[51]	RCT	Smartphones with internet enabled	Inform, instruct	N=82 USA	Mental health (bipolar disorder)	Patients receiving psychoeducation in intervention group (smartphone) reduced depressive symptoms at 12 week compared to control group (paper-and-pencil). The effect was not maintained at 24 weeks	Moderate
Heron et al., 2010[58]	Review	Palmtop computers or mobile phone	Ecological momentary interventions Inform, instruct, record, display, guide, remind/alert, communicate	27 experimental studies (1985–2009)	Other (health behaviours, psychological and physical symptoms)	Mixed results from low quality studies on the effectiveness of ambulatory treatment for anxiety, and diabetes management, among other outcomes	Low
Park et al., 2014[53]	Systematic review	SMS	Support medication adherence Inform, instruct, remind/alert	29 studies (2002–2013)	Medication adherence	18 of the 29 studies were efficacious in improving medication adherence rates or biomarkers after receiving text messages (P<0.05), while 11 studies reported no difference	High
Anglada-	Systematic	Mobile phone –	SMS as medication	20	Medication	Adherence improved in four of the	Moderate/High

Martinez et al., 2015[54]	review	SMS, app	reminders, healthy lifestyle reminders, or both Inform, instruct, remind	experimental studies (2004–2014)	adherence	five studies on HIV-infected patients, in eight of the studies on patients with other chronic diseases, and in one study performed in healthy individuals	
Finitsis et al., 2014[52]	Meta-analysis	SMS	Inform, instruct, remind/alert, communicate	8 RCTs (2001–2012)	Medication adherence (HIV)	SMS can support therapy adherence Larger effects when interventions were sent less frequently than daily, supported bidirectional communication, included personalised message content, and were matched to participants' antiretroviral dosing schedule	Very high
Mbuagbaw et al., 2015[56]	Systematic review of systematic reviews	SMS	Inform, instruct, record, display, guide, remind/alert, communicate	9 systematic reviews (2010–2014)	Medication adherence and appointment attendance (HIV and other chronic conditions)	Mixed results but some evidence supporting the use of text messaging as a tool to improve adherence to medication and attendance at scheduled appointments	High
Nglazi et al., 2013[55]	Systematic review	SMS	Inform, instruct, record, remind/alert	4 experimental studies N= 565 (2005–2012)	Medication adherence (tuberculosis)	Mixed results Low-quality studies	
Hamine et	Systematic	SMS, mobile	Inform, instruct, record,	107 studies	Adherence	Of the 27 RCTs that measured the	High

al., 2015[22]	review	phone + app, wireless devices	display, guide, remind/alert, communicate	(2003–2014)	behaviours (diabetes, cardiovascular diseases, chronic lung disease)	effect of mHealth on adherence behaviours, a significant difference between groups was observed in 15 studies (56%)	
Cocosila et al., 2008[57]	RCT	Mobile phone - SMS	Adherence to taking vitamin C pill Inform, instruct, remind/alert	N=102 healthy subjects Canada	Adherence to a primary prevention intervention	Non-statistically significant difference between intervention and control groups in medication adherence	Moderate

1.2 Cost-effectiveness

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings* (only statistically significant results are reported)	Grade of evidence
Ryan et al., 2012[47]	RCT	Mobile	Monitoring	N=288 adults and adolescents UK	Chronic lung diseases (asthma)	Mobile technology did not improve asthma control or increase self-efficacy compared with paper based monitoring when both groups received clinical care to guidelines standards The mobile technology was not cost effective	Moderate
Kim J, 2012[59]	Quasi-experimental	Telemedicine	Monitoring	N=144 Korea	Chronic lung diseases (COPD)	High satisfaction Average acceptable fees (in USD) of the service system: u-health device, $421.28; home visit, $21.53/visit; tele-education, $0.53/min or $26.57/month; and total service fee, $44.26/month	Moderate/Low
Kollmann et al., 2007[60]	Feasibility	Smartphone app	Inform, instruct, record, display, guide, remind/alert, communicate	10 patients Austria	Diabetes	T1DM patients would need to pay €10 per month for a data bundle on their mobile phone contract in order to use a mobile-enabled application to enter diabetes-	Low

						related data for healthcare professionals to view on a web portal	

1.3 mHealth and self-reporting

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings* (only statistically significant results are reported)	Grade of evidence
Garcia-Palacios, 2014[62]	RCT	Smartphone	Diary	N=47 Spain	Other (chronic pain/ fibromyalgia)	More accurate and complete ratings Good acceptability	High
Palmier-Claus J, 2012[63]	Quasi-experimental	Smartphone	Self-reporting, self-tracking	N=44 UK	Mental health	Ambulatory monitoring of symptoms showed excellent test-retest reliability and sensitivity to change Compliance was 82%	Moderate/Low
Berke EM, 2011[61]	Quasi-experimental	Wearable device with several sensors	Self-tracking	N=8 Location not specified	Fitness (physical activity and sociability)	Mobile sensing of sociability and activity was well correlated with traditional measures (surveys)	Low

Appendix 2: Papers included for Question 2 – Benefits of using mHealth technologies to track health behaviours for prevention purposes

2.1 Preventive activities and behavioural interventions

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings* (only statistically significant results are reported)	Grade of evidence
Free, 2013[34]	Meta-analysis	SMS, mobile phone, MP3/4, PDA	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. feedback, goal setting; tailoring; prompt self-monitoring of behaviour; identify barriers to behaviour/problem solving/identify ways of overcoming barriers)	49 disease management studies and 27 health behaviour studies	Fitness (physical activity, calorie intake) Substance use (smoking cessation, alcohol consumption) Other (safe sex)	No statistically or clinically significant changes in weight for trials using SMS messages to reduce calorie intake and increase physical activity (standard mean difference [SMD]) or for trials using application software to reduce calorie intake SMS-based smoking cessation interventions more than doubled biochemically-verified smoking cessation at six months Three trials reported statistically significant increases in adherence to antiretroviral medication with text message reminders	Very high
Fanning, 2012[64]	Meta-analysis	SMS, PDA, pedometer, accelerometer, native mobile	Inform, instruct, record, display, guide, remind/alert, communicate	11 studies (RCTs) (2007–2012) N=1351	Fitness (physical Activity)	Moderate to large effect for pedometer steps Significant moderate effect for	High

		software	(e.g. provide information, motivational messages, reminders; SMS to self-report or provide feedback)	participants		interventions delivered via mobile phone Effects were non-significant for moderate-vigourous PA duration, and PDA delivered interventions. Small number of studies and considerable heterogeneity Little rigorous study of the influence of mobile technology on physical activity	
Foster, 2013[65]	Meta-analysis	Remote or web 2.0 technologies (e.g. internet smartphones) (Also includes more traditional methods e.g. telephone, mail-outs)	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. interaction in group or individual meetings; counselling and advice; self-directed or prescribed exercise; home based or facility based exercise; and written education or motivational support material)	11 studies (RCTs) (1991–2011) N=5862 healthy adults	Fitness (physical Activity)	The effect of the interventions on cardiovascular fitness at one year (two studies, 444 participants) was positive and moderate (SMD 0.40; 95% CI 0.04 to 0.76; high quality evidence) The effect of the interventions on self-reported PA at one year (nine studies, 4547 participants) was positive and moderate (SMD 0.20; 95% CI 0.11 to 0.28; moderate quality evidence) One study reported positive results at two years (SMD 0.20; 95% CI 0.08 to 0.32; moderate quality evidence)	Very high

Lyzwinski, 2014[66]	Meta-analysis	Smartphones, PDAs, iPods, Mp3 players, and other modern portable devices	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. SMS, MMS, calculator, storage of food photos, gamification, social networking, goal setting, tailoring, podcast, audio blog, meal calendar)	17 studies (RCTs) (2007–2013) N=1796 participants	Fitness (weight)	Overall medium effect size for weight loss of 0.43 (95% CI 0.252 to 0.609), favouring the intervention Mixed results for reductions in BMI, waist circumference, body fat percentage, as well as improvements in dietary intake and physical activity	Very high
Vaes, 2013[67]	Meta-analysis	Activity trackers	Record, display, guide (Activity monitor-based counselling interventions versus control)	24 experimental studies N=2908 (21 studies – type 2 diabetes; 3 studies – COPD)	Fitness (physical activity)	Activity monitor-based interventions have beneficial effects on physical activity, HbA1c, systolic blood pressure, and BMI in patients with type 2 diabetes Data in patients with COPD are limited	Very high
O'Reilly, 2013[68]	Systematic review	Mobile journal or questionnaire, SMS, on-body activity-sensing	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. encouragement of physical activity with automated or personalised SMS; self-	22 studies (RCTs, quasi-experimental designs) (2006–2012) N=1988 participants	Fitness (physical activity, sedentariness)	Of the 12 studies that used mobile technologies to influence physical activity (PA) behaviour, nine reported significant changes in PA or sedentary behaviour	High

			monitoring and measuring of physical activity via mobile journals				
Bacigalupo, 2013[69]	Systematic review	Mobile device (text, pager or mobile phone)	Inform, instruct, record, display, guide, communicate (e.g. motivational messages, prompts for self-monitoring of food intake and physical activity)	7 studies (1998–2011) N=584 participants	Fitness (weight)	Strong evidence across several high-quality RCTs that weight loss occurs in the short-term with mobile technology interventions (75% studies support use of mobile interventions for BMI 25–39.9) Moderate evidence for the medium-term (no studies with follow-ups >12 months)	High
Shaw et al., 2012[70]	Systematic review	SMS	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. two-way communication where participants transmitted information such as weight or physical activity via SMS to researchers; diet and exercise self-monitoring; goal reminders or plan reminders; tailored	14 RCTs (2007–2010)	Fitness (weight loss)	Of the 14 interventions in this review, 11 showed a statistically significant effect on weight loss, diet or exercise, and one study showed a statistically significant effect on BP	High

			feedback on physical activity, dietary)				
Stephens, 2013[71]	Systematic review	SMS, smartphone apps	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. SMS as a primary intervention was often supported by education, in-person weigh-ins, or telephone calls; two-way, participant-driven communication; smartphone apps recording calorie intake and consumption; daily exercise; showing daily goals status; gamification in apps)	7 experimental studies (2006–2009) N=1377 participants	Fitness (weight reduction, physical activity)	Five out of the seven studies reported statistically significant results in at least one outcome. However, studies were low to moderate in quality and the majority of significant findings were not between intervention and control groups and not in the primary outcome	Moderate
Bort-Roig et al., 2014[72]	Systematic review	SMS, smartphone apps, wireless devices	Inform, instruct, record, display, guide, remind/alert, communicate	17 experimental studies	Fitness	Only five studies assessed physical activity intervention effects, showing mixed results Four studies (three pre–post and one comparative) reported physical activity increases	Moderate
Oh et al., 2015[73]	RCT	Mobile phone + sensors	Weight control and exercise; weight loss; use of pedometers	N=446 Korea	Fitness (obesity, weight loss)	Positive results as the intervention group had superior results in terms of weight loss after 24	High

						weeks	
Buhi et al., 2012[41]	Systematic review	SMS +/- internet +/- wireless devices (e.g. internet, paper diaries, personal digital assistants, training sessions, clinic visits, voicemail, calls, voice response, patient data monitoring devices)	Inform, instruct, record, display, guide, remind/alert, communicate	34 studies (2004–2010)	Diabetes (17) Substance use: smoking cessation (8) Fitness: weight (4), physical activity (1) Chronic lung diseases: asthma (1) Other (2)	Three studies focusing on weight loss found significant improvements between groups Seven out of eight studies focusing on smoking cessation revealed statistically significant differences in smoking cessation	High
Krishna et al., 2009[43]	Systematic review	SMS, internet, voice, email	Inform, instruct, record, display, guide, remind/alert, communicate	20 RCTs + 5 quasi-experimental (2004–2008) (N=38,060)	Diabetes, cardiovascular (hypertension), chronic lung diseases (asthma), other (e.g. smoking, HIV)	One study focusing on physical activity found a statistically significant difference in percent body fat lost Four smoking cessation studies reported significantly greater success in behaviour change among the intervention group participants who received a smoking cessation-related educational intervention delivered	High/Moderate

						to their cell phones	
Whittaker et al., 2009[74]	Meta-analysis	Mobile phone	Mobile phone use to promote smoking cessation	15 papers	Substance use (smoking cessation)	Evidence of short-term effect of programs delivered by mobile phone	Moderate
Vidrine et al., 2006[75]	RCT	Mobile phone	8 counselling sessions delivered via mobile phone	N=95 individuals with HIV (N=77 completed the 3-month follow-up assessment) USA	Substance use (smoking cessation)	Individuals living with HIV are receptive to, and can be helped by, smoking cessation treatment Counselling delivered by mobile phone can significantly increase smoking abstinence rates	High
Heron et al., 2010[58]	Review	Palmtop computers or mobile phone	Ecological momentary interventions Inform, instruct, record, display, guide, remind/alert, communicate	27 experimental studies (1985–2009)	Other (health behaviours, psychological and physical symptoms)	Mixed results from low-quality studies on the effectiveness of ambulatory treatment for healthy eating, physical activity, weight loss, smoking cessation, eating disorders, and alcohol use	Low

Appendix 3: Papers included for Question 3 – Influence of demographic and socio-economic factors on the benefits of mHealth

3.1 Benefits for different sub-populations

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings*	Study author, year
Saffari, 2014[32]	Meta-analysis (2005–2013)	SMS +/- internet	Inform, instruct, record, display, guide, remind/alert, communicate	10 studies (RCTs) N=960 participants	Diabetes (type 2)	Younger patients with shorter diabetes duration seem to benefit more from the intervention	High
Liang et al., 2011[33]	Meta-analysis (1990–2010)	Mobile phone +/- internet, mobile device	Inform, instruct, record, display, guide, remind/alert, communicate	22 experimental studies N=1657	Diabetes (type 1 and 2)	Greater improvement in glycaemic control for patients with type 2 diabetes than those with type 1 diabetes	High
Baron et al., 2012[38]	Systematic review (2002–2011)	Mobile phone, PDA (+/- internet)	Inform, instruct, record, display, guide, remind/alert, communicate	24 experimental studies	Diabetes (type 1 and 2)	One study reported a significant reduction in HbA1c only in the group with shorter diabetes duration	High
Burner et al., 2013[76]	Qualitative	Mobile phone	Diabetes self-management	N=23 low-income USA	Diabetes	Men and women differed in regards to self-efficacy, knowledge gained, and desired content in future mHealth interventions	Low
Piette J et al., 2012[77]	RCT	Cloud computing model + phone +	Inform, instruct, record, display, guide,	N=200	Cardiovascular (hypertension)	In the subgroup of intervention patients with low literacy or high	Moderate

		wireless device using automated calls	remind/alert, communicate Self-management calls plus home blood pressure (BP) monitoring	Low and middle income countries		information needs there was an 8.8mm Hg reduction in average systolic blood pressure and a significantly greater proportion of intervention than control patients having BPs in the acceptable range	

3.2 Australian studies

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings	Grade of evidence
Phillips et al., 2014[78]	RCT	MMS and SMS	Information/education/ reminders Inform, instruct, remind/alert	N=53 Aboriginal children Australia	Other (chronic otitis media – tympanic membrane perforation)	No significant difference in clinic attendance nor in healed perforation, middle ear discharge or perforation size between the groups	Moderate
Proudfoot J, 2010[79]	Survey + focus groups + interviews	Mobile phones	Monitoring, self-management	N=525 + 47 + 20 Australia	Mental health	Attitudes toward the use of mobile phones for the monitoring and self-management of depression, anxiety, and stress appear to be positive as long as privacy and security provisions are assured, and as long as the intervention is not intrusive and is easy to use, providing feedback to users.	Moderate /Low
Varnfield M et al., 2011[80]	Feasibility study	Mobile phone + internet + accelerometer + diary app	Inform, instruct, record, display, guide, remind/alert, communicate	N=15 Australia	Cardiovascular (cardiac rehabilitation)	Participants find the mobile-phone modalities practical and easy to use, and preliminary results show high usage rates and acceptance.	Low
Brusse et al., 2014[81]	Review	Mobile apps	-	Australian Indigenous populations	Health promotion	Little evidence pertaining to effectiveness, with current interventions being very limited in scope and not widely adopted	Low

3.3 Barriers to adoption and use by different sub-populations

Study author, year	Study type	mHealth mode	Task	N of studies /participants, population, setting	Health domain	Results and main findings	Grade of evidence
Jimison, 2008[82]	Review	Interactive health information technology (general)	General	692 studies	Other (chronic conditions)	The systems examined depended on the active engagement of consumers and patients and the involvement of health professionals	Moderate
Nelson et al., 2015[83]	Quasi-experimental study	SMS and interactive automated calls	Receiving messages promoting treatment adherence	N=80 USA	Diabetes (type 2)	Racial/ethnic minorities, older adults, persons with lower health literacy, and persons with more depressive symptoms appeared to be the least engaged in the mHealth intervention	Moderate
Kim, 2014[84]	Review	Mobile phone		-	Other (elderly)	mHealth is being increasingly used as a way to support health management and self-monitoring, but elderly people still face some barriers to their current use	Moderate /Low
Chaudhuri, 2014[85]	Systematic review (2013 and before)	Fall detection devices	Monitoring	-	Other (falls)	Older adults appear to be interested in using such devices although they express concerns over privacy and understanding exactly what the device is doing at specific times	High

Appendix 4: Papers included for Question 4 – Strategies to operationalise the use of mHealth technologies for chronic disease management and prevention purposes

4.1. Operational steps and strategies to increase uptake

Grey literature

Title	Source	Year
Emerging mHealth: paths for growth mHealth[28]	PricewaterhouseCoopers	2012
Power to the patient: how mobile technology is transforming healthcare[29]	The Economist – Intelligence Unit	2015
Patient apps for improved healthcare: from novelty to mainstream[27]	IMS Institute for Healthcare Informatics	2013
Implementing a mobile health solution in the clinical setting – White Paper Series[30]	Seamless MD	2014
Towards the Development of an mHealth Strategy: a literature review[31]	WHO	2008
mHealth in an mWorld – how mobile technology is transforming healthcare[26]	Deloitte Center for Health Solutions	2012

4.2. Features influencing adoption

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings	Grade of evidence
Saffari et al., 2014[32]	Systematic review and meta-analysis (2005–2013)	SMS +/- internet	Inform, instruct, record, display, guide, remind/alert, communicate	10 studies (RCTs) (N=960 participants)	Diabetes	Effects on glycaemic control were greater for interventions that used SMS + internet rather than SMS alone	High
Tatara et al., 2009[92]	Review	Mobile phone or PDA +/- PC, blood glucose monitor	Self-management	28 studies	Diabetes	Ease of use and data presentation (fast analysis of results) were important aspects for adoption Time required to use the application is an important element for success Automatic and wireless transmission of blood glucose data is highly accepted by the participants	Moderate
Carter et al., 2013[97]	Quasi-experimental	App	Goal setting, self-tracking calorie intake, tailored support Inform, instruct, record, display, guide, remind/alert, communicate	N=128 USA	Fitness (weight loss)	Trial retention was 93% in the smartphone group, 55% in the website group, and 53% in the diary group at six months Adherence was statistically significantly higher in the mobile	Low

						app group compared with the website group and the diary group	
Inouye J, 2015[93]	Feasibility study	Pedometer, Fitbit, watch, camera	Self-tracking Record, display,	N=9 USA	Fitness	Participants found the Fitbit to be unobtrusive and easy to use and reinforced increasing their physical activity; however, success using the watch was highly variable	Low
Park et al., 2014[53]	Systematic Review (2002–2013)	SMS	Support medication adherence Inform, instruct, remind/alert	29 studies	Medication adherence	Negative studies tended to have more basic and repetitious content with a simple medication reminder, while positive studies delivered a variety of educational and motivational content with tailored or personalised SMS	High
Wenze M, 2014[98]	Quasi-experimental	PDA	Ecological momentary intervention Inform, instruct, record, display, guide	N=14 USA	Mental health	Participants stated that EMI sessions were helpful, user-friendly, and engaging, and reported satisfaction with the timing and burden of sessions, as well as the method of delivery High adherence (participants completed 92% of sessions)	Low
Pinnock et al., 2006[113]	Survey	mHealth in general	Self-tracking and monitoring Inform, instruct, record,	N=130 health professionals and 202 patients	Asthma	Patients rated the technology positively and considered that it may help clinicians to provide care, especially during acute attacks	Low

			display, guide, remind/alert, communicate	UK		Although rated similarly, professionals were more sceptical about benefits Both professionals and patients had concerns about the time and cost implications	
Pinnock et al., 2007[114]	Qualitative	Mobile phone	Monitoring Inform, instruct, record, display, guide, remind/alert, communicate	N=48 (34 adults and teenagers with asthma, 14 asthma nurses and doctors	Asthma	Participants considered that mobile phone-based monitoring systems can facilitate guided self-management although, paradoxically, may engender dependence on professional/technological support	Low
Foster, 2013[65]	Meta-analysis	Remote or web 2.0 technologies (e.g. internet smart phones) (Also includes more traditional methods e.g. telephone, mail-outs)	Interaction between implementer and participants (in groups or individuals, one-off or ongoing): counselling or advice; self-directed or prescribed exercise; home based or facility based exercise; written education or motivational support material	11 studies (RCTs) (1991–2011) N=5862 healthy adults	Fitness (physical activity)	The most effective interventions applied a tailored approach to the type of physical activity and used telephone contact to provide feedback and to support changes in physical activity levels	Very high

O'Reilly, 2013[68]	Systematic review (2006-2012)	Mobile journal or questionnaire, SMS, on-body activity-sensing	Encourage physical activity with automated or personalised SMS Self-monitoring and measuring of physical activity (via mobile journals and questionnaires)	22 studies (RCTs, quasi-experimental designs) N=1988 participants	Fitness (physical activity, sedentariness)	Mixed results for usability The studies that reported acceptability assessment outcomes revealed that on-body sensing systems, mobile journals, and SMS messaging, received positive acceptability ratings from participants One study that used a mobile journal and three studies that used SMS messaging determined that these mobile technologies are feasible ways to deliver physical activity interventions. Text messaging or smartphone applications are well accepted by participants The nine studies that reported significant changes in physical activity or sedentary behaviour employed SMS communication to promote physical activity, physical activity self-monitoring through mobile journaling, or both SMS and journaling	High

Shaw et al., 2012[70]	Systematic review	SMS	Inform, instruct, record, display, guide, remind/alert, communicate (e.g. two-way communication where participants transmitted information such as weight or physical activity via SMS to researchers; diet and exercise self-monitoring; goal reminders or plan reminders; tailored feedback on physical activity and diet)	14 RCTs (2007–2010)	Fitness (weight loss)	Seven studies measured feasibility and acceptability of SMS as a mode for weight loss interventions. SMS was found feasible and acceptable in all seven studies One SMS per day may be appropriate in helping motivate people to engage in weight loss behaviours without generating a considerable burden	High
De Leon, 2014[96]	Systematic review	Mobile messaging, print communication, email, telephone, newspaper	Periodic messaging and prompting	55 studies (RCTs, pre-post, observational) (2001–2012) N=35,719 participants	Fitness (weight, physical activity, diet), substance use (smoking cessation, alcohol intake)	Periodic messaging has positive short-term effects across a number of health behaviours and across media and frequency Of the 55 original research articles using periodic messaging, 42 reported significant differences in short-term behavioural-change between intervention and comparison groups across all behaviours, with the exception of sun protection and the dietary	High

						behaviour of iodine consumption Three studies additionally suggested long-term behavioural changes Given that the included interventions varied by many factors, including behaviour, prompt, use of feedback, goal-setting, and theoretical models, it was difficult to form a conclusive judgment regarding which combination of elements is most effective	
Abroms et al., 2011[99]	Review	iPhone apps	Smoking cessation apps	N=47	Substance use (smoking cessation)	iPhone apps for smoking cessation rarely adhere to established guidelines for smoking cessation	Moderate
Zampieri, 2011[101]	Feasibility study	Portable data-logger on a waist belt with five inertial sensors attached to participant's body	Assess balance and mobility in people with moderate-to-severe stage Parkinson's disease	N=14 participants (6 with Parkinson's disease, 8 healthy controls) USA	Other (Parkinson's disease)	Home testing is feasible on patients with Parkinson's Disease	Low

Rodriguez-Villegas, 2014[102]	Feasibility study	Wearable apnoea detection device	Automatically detect apnoeas/hypopnoeas.	N=30 participants (20 healthy controls and 10 patients who had been referred for sleep apnoea diagnosis) UK	Other (sleep)	Demonstrated technical feasibility – the wearable apnoea detection device had 88.6% sensitivity and 99.6% specificity	Low
Lee, 2011[103]	Feasibility study	Mobile phone (accelerometer with computer program for detecting falls)	Use motion signals detected by the mobile phone to detect falls	N=18 healthy adults UK	Other (falls)	Fall detection using a mobile phone is technically feasible – the specificity and sensitivity were 0.81 and 0.77	Low
Grey – Consumer Health Information Corporation	Survey	Apps	-	N=395 USA	Other (behaviour change)	Health apps have a high rate of dropouts with 26% being used only once and 74% being discontinued by the tenth use 79.9% of respondents preferred an app that would analyse the health information they were logging and provide personal feedback For health apps to be successful patient adherence tools, they must be practical, easy-to-use and	Moderate

						follow established evidence-based guidelines	
Leijdekkers et al., 2012[115]	Cross-sectional (analysis of usage data)	Mobile app	Inform, instruct, record, display, guide	N=5000+ Worldwide	Fitness	Measurements recorded using mobile health apps are mainly entered manually by the user. This allows for inaccurate data entry, which could compromise its reliability Self-motivation to record data over a longer period can be a challenge without the involvement of a health professional	Low

4.3 Past failures

Study author	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings	Grade of evidence
Wolf J, 2013[104]	Case-control	Smartphone applications	Diagnostic Inform, guide, communicate	60 melanoma cases and 128 benign lesion controls	Dermatology	Sensitivity of the four tested apps ranged from 6.8% to 98.1%; specificity ranged from 30.4% to 93.7%; positive predictive value ranged from 33.3% to 42.1%; and negative predictive value ranged from 65.4% to 97.0% The highest sensitivity for melanoma diagnosis was observed for an app that sent the image directly to a dermatologist The lowest sensitivity was observed for apps that used automated algorithms to analyse images The performance of apps assessing melanoma risk was highly variable, and three out of four apps incorrectly classified 30% or more of melanomas	Moderate

Dulin et al., 2014[100]	Feasibility	Smartphone	Self-management of alcohol use	N=28 USA	Substance use (alcoholic patients)	Tools related to managing alcohol craving, monitoring consumption, and identifying triggers to drink, were rated by participants as particularly helpful There were significant reductions in hazardous alcohol use while using the system and drinks per day diminished by 52%	Moderate

4.4 Past successes

Study author, year	Study type	mHealth mode	Task	N of studies/ participants, population, setting	Health domain	Results and main findings	Grade of evidence
Quinn et al., 2008[116]	RCT	Cell phone	Inform, instruct, record, display, guide, remind/alert, communicate	N=30	Diabetes patients	Cell phone intervention easy to use Patients had lifestyle changes and medication changes (due to better lifestyle)	Moderate/ High
Aikens J, 2014[117]	Quasi-experimental	Interactive voice response mHealth service	Assessment of health status and self-care + tailored education Inform, instruct, record, display, guide, remind/alert, communicate	N=303 USA	Diabetes	The system detects abnormal glycaemia and blood pressure levels that might otherwise go unreported, although thresholds for clinician notifications might require adjustment to avoid overloading clinicians Patient engagement might be enhanced by addressing health literacy and psychological distress	Moderate
Gay V, 2012[115]	Cross-sectional	App	Self-tracking Record, display	-	Fitness	Usage data collected from myFitnessCompanion from 5500+ users between June 2011 and January 2012 shows an increasing uptake every month	Low

Granholm et al., 2012[118]	Feasibility study	SMS	Inform, instruct, record, display, guide, remind/alert, communicate	N=55 USA	Mental health	Long-term use of mobile technologies to assist in the assessment and treatment of people with serious mental illness is feasible	Low
Holtz et al., 2009[119]	Feasibility study	SMS	Registering parameters Record, display	N=4 USA	Asthma	Patients are satisfied monitoring their asthma with this system	Low
Owen et al., 2015[120]	Cross-sectional	App	Coaching Inform, instruct, record, display, guide, remind/alert, communicate	153,834 downloads and 156 user reviews	Mental health	The app was favourably received	Low
Park et al., 2014[53]	Systematic review	SMS	Support medication adherence Inform, instruct, remind/alert	29 studies	Medication adherence	Text messaging interventions are feasible and acceptable with the majority of studies reporting high participant satisfaction (>80%) in receiving text messages for health management	High
Welch et al., 2013[121]	Feasibility study (RCT)	App on PDA	Inform, instruct, record, display, guide, remind/alert, communicate	N=44 USA	Other (haemodialysis)	App designed to facilitate dietary and fluid self-monitoring seems to be well accepted by users	Moderate

Carter et al., 2013[97]	RCT	Smartphone app	Text messages Self-monitoring weight management intervention (dietary entry)	N=128 UK	Fitness (weight)	Trial retention was 40 out of 43 (93%) in the smartphone group, 19 out of 42 (55%) in the website group, and 20 out of 43 (53%) in the diary group at six months Adherence was statistically significantly higher in the smartphone group with a mean of 92 days (SD 67) of dietary recording compared with 35 days (SD 44) in the website group and 29 days (SD 39) in the diary group (P<0.001)	High
Becker et al., 2013[122]	Cross-sectional (analysis of usage data + survey)	Mobile app	Monitoring, reminder Inform, instruct, record, display, guide	N=11,688 app users N=2279 survey respondents Germany	Medication adherence	The smartphone application supporting drug adherence was downloaded more than 11,000 times and it was used regularly by chronically ill users over a longer period of time The majority of users were middle-aged and male	Moderate