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Informing Policy with Evidence

Amenability of health burdens to digital intervention: a report for the Office for Life Sciences

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Contents:

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Summary

The aim of this report is to inform policy around the potential of digital health to address current and future NHS pressures, focusing on the following research questions:

1. What are the biggest causes of pressure on the UK's health and care system? (measured both in terms of costs and health outcomes).
2. What areas of high disease burden appear to be most amenable to digital interventions?
3. Does existing technology match the largest health and cost pressures?
4. Where there are gaps between NHS pressures and availability of technology, are the health problems amenable to digital interventions?

We focus on mobile health technologies ('mHealth'). To identify key areas of disease burden, we used NHS programme budgeting data, reflecting costs of disease, and the UK input into the Global Burden of Disease study, reflecting outcomes; noting for both the highest ranking clinical areas and rates of change over time. We conducted an 'umbrella review' to identify relevant existing digital technology, including interventions only if they have published evidence of effectiveness (and preferably cost-effectiveness) or if robust evaluation is under way. To test our review findings and to identify gaps in the evidence base and whether they are viewed as 'amenable' to digital health interventions, we interviewed of a number of opinion leaders. Findings are synthesised alongside three case studies which combine published literature with expert opinion: focusing on mental health, older people and digital health in China. Our report concludes with tentative recommendations for policy makers and regulators, researchers and research commissioners, clinicians and NHS commissioners, and product developers.

Main findings

While there is substantial and growing digital activity in the health sector, much less is known about its benefits to patients and clinicians, and to relieving pressure on the NHS. This review of mobile health interventions finds in general that there is a serious lack of good evaluative evidence.

We conclude that practitioners and policy makers must approach digital technologies in the same way as all other healthcare interventions – balancing benefits, risks and costs. Among our key findings:

- Digital health has the *potential* to relieve pressure on frontline professionals in the health and care system. But such interventions tend to address single diseases, not reflecting emerging trends in multiple morbidities, which need to be better identified and addressed.

- The risk of unequal access to digital interventions must be addressed early if policy makers are to avoid widening existing health inequalities.

- Digital interventions may be able to address health problems, for example by replacing existing processes, but if they are not used by patients and welcomed by health care professionals they will not reduce overall costs, and could potentially add to them.

- While there is potential for digital health interventions to reduce demand on NHS services, for example by improving lifestyle behaviours and increasing levels of self-management of chronic conditions, the evidence base for effectiveness remains at an early stage, and benefits may be seen only in the medium to long-term.

- Mental health has the most substantial high-quality evidence base for digital intervention. Using digital platforms to deliver existing evidence-based interventions, for example cognitive behavioural therapy, permits greater reach. The best evidence of benefit is from digital interventions supplementing rather than replacing face-to-face mental health interventions.

- Musculoskeletal conditions may be amenable to short courses of face-to-face physiotherapy supplemented by digital reminders and instructions, to increase effectiveness and reduce clinician contact time for rehabilitation.

- Digital platforms could also support acute illness or injury requiring short to medium-term rehabilitation or other therapeutic interventions. Cardiac and stroke rehabilitation programmes, for instance, could be supported in this way, although the research evidence on such digital interventions is at an early stage.

- For long-term chronic illnesses, the research found that digital interventions currently support prevention – such as smoking cessation apps to reduce cancer risk – and can assist patients who require extended adherence regimes such as the self-management of asthma or diabetes. Other digital interventions focus on early detection – such as melanoma.

- In neurological conditions such as epilepsy and Parkinson's disease, digital interventions and sensor technology can potentially support diagnosis and rehabilitation, optimise treatment and help avoid adverse events.

- The biggest users of health care are those with more than one clinical condition; co-morbidities and complexities create real-life challenges for digital health that should not be underestimated.

1. Background

> *"We can't deliver a healthcare service which meets the challenges of increasing demand and reduced or static resources unless we make digital technology work for us. It is not the whole answer, but part of the answer."*
>
> *Digital health expert, interview 2016*

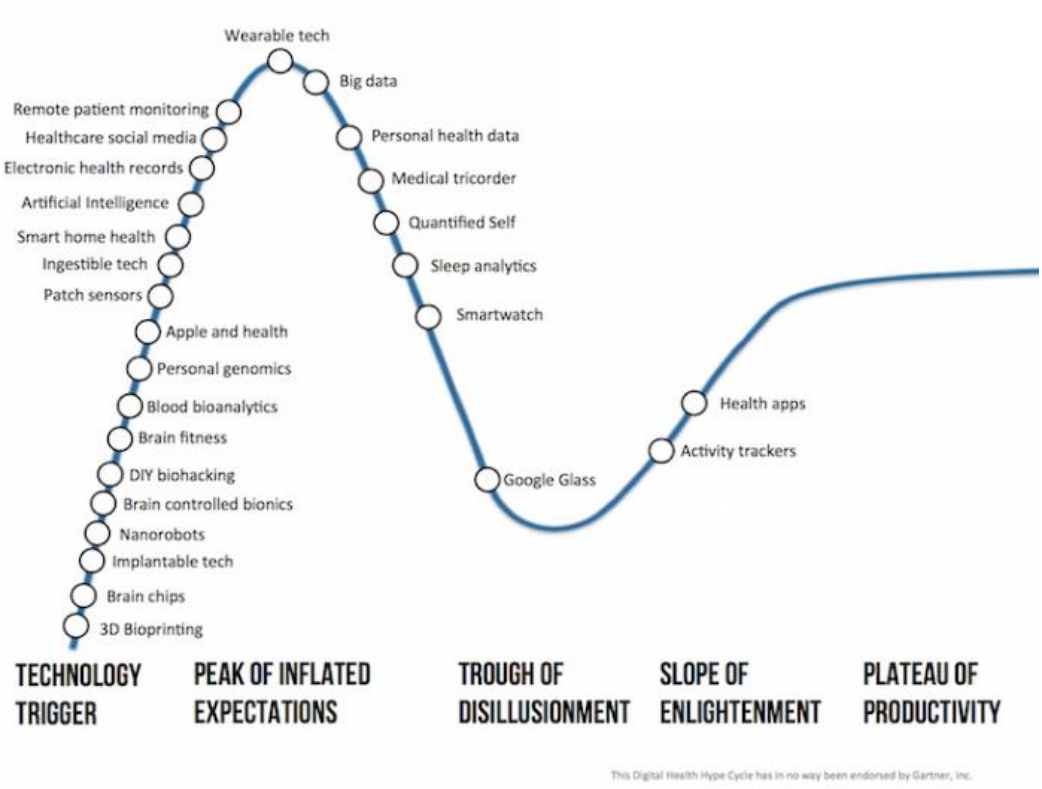
The English NHS budget, £116.4 billion in 2015/16, will increase to £133.1 billion by 2020/21. In real terms, this is an average annual increase of less than one per cent per year.[1] Increasing demands on the NHS, alongside constrained funding, creates a need for sustainable improvements in productivity of the health care system.[2]

Digital health has been described as one way of delivering 'huge productivity improvements' in health care.[3] But digital health,[4] and digital technologies in general,[5] are prone to over-optimistic views of their potential for transformation. The mixed picture of digital health was described recently by the Chief Executive of the American Medical Association:

> *We have really remarkable tools — robotic surgery, new forms of radiation treatment, emerging biologics; and we live in a time of rapid development in the digital world ... [But] appearing in disguise among these positive products are other digital so-called advancements that don't have an appropriate evidence base, or that just don't work that well — or that actually impede care, confuse patients and waste our time. From ineffective electronic health records, to an explosion of direct-to-consumer digital health products, to apps of mixed quality. This is the digital snake oil of the early 21st century. Even those digital products that might be helpful often lack a way of enriching the relationship between the physician and the patient. It's like trying to squeeze a 10-gallon product idea into a 2-gallon health care knowledge base. More and more we're seeing digital tools in medicine that, unlike digital tools in other industries, make the provision of care less, not more, efficient.*
>
> *J Madara, 2016*[6]

The 'digital health hype cycle' (Figure 1), described by Davies in 2014,[7] provides a useful illustration of the potential gap between hopes for technology and its establishment in terms of productive value. This gap appears both in terms of a time lag, as technologies become embedded and service delivery changes to make the best use of effective technology; and in terms of products and interventions falling by the wayside when they do not enhance health or health care.

Figure 1: The digital health hype cycle



Source: Davies 2014[7]

2. Purpose

The aim of this report is to inform policy around the potential of digital health to address current and future NHS pressures, focusing on the following research questions:

1. What are the biggest causes of pressure on the UK's health and care system? (measured both in terms of costs and health outcomes).
2. What areas of high disease burden appear to be most amenable to digital interventions?
3. Does existing technology match the largest health and cost pressures?
4. Where there are gaps between NHS pressures and availability of technology, are the health problems amenable to digital interventions?

3. Methods

3.1. Inclusion and exclusion criteria

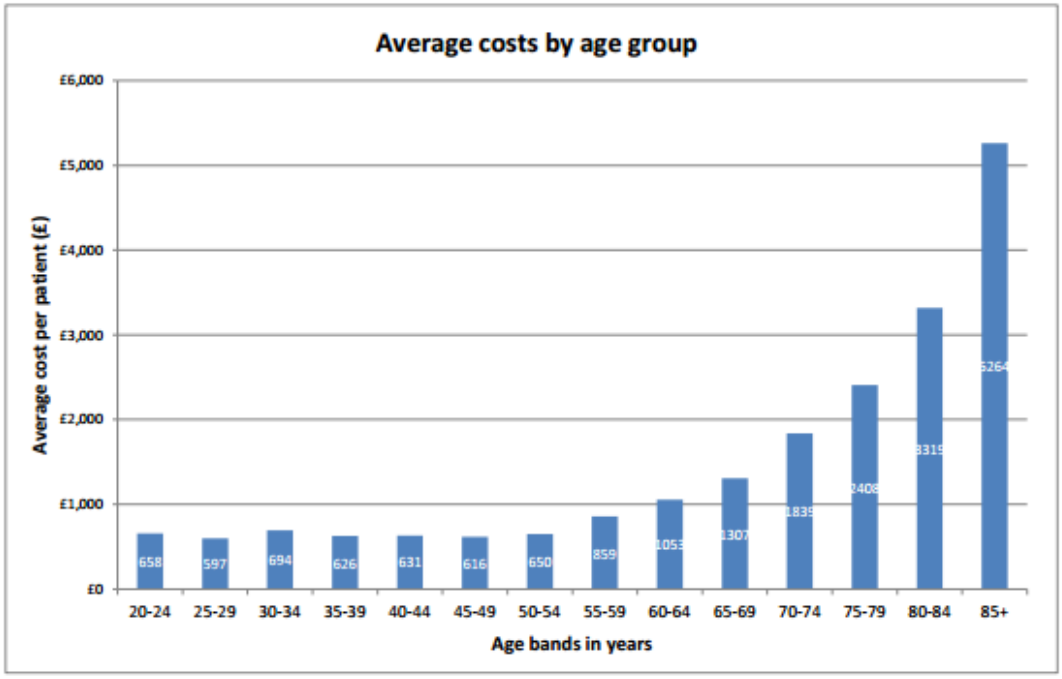
In this report we focus on mobile health technologies ('mHealth'), which has been defined as "medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices".[8] We included all mobile health interventions in the disease areas under consideration and in specified cross cutting areas, and also software-based applications delivered by other devices: electronic, internet and computerised. Such applications were used in the context of intervention delivery and were patient-facing. We excluded technology relating to remote consultations (telemedicine) and to information and datasets, also interventions based on digital and augmented reality, and digital technologies that were not patient-facing (e.g. those aimed at professionals or carers).

3.2. Identifying areas of disease burden

To identify key areas of disease burden, we used several approaches. First, reflecting costs of disease, we used NHS programme budgeting data, which estimates NHS expenditure in disease categories across the care pathway.[9] Second, reflecting health outcomes, we used the UK input into the Global Burden of Disease study 2010.[10] For both of these measures of 'burden of disease' we noted the highest ranking clinical areas, and also explored rate of change over time.

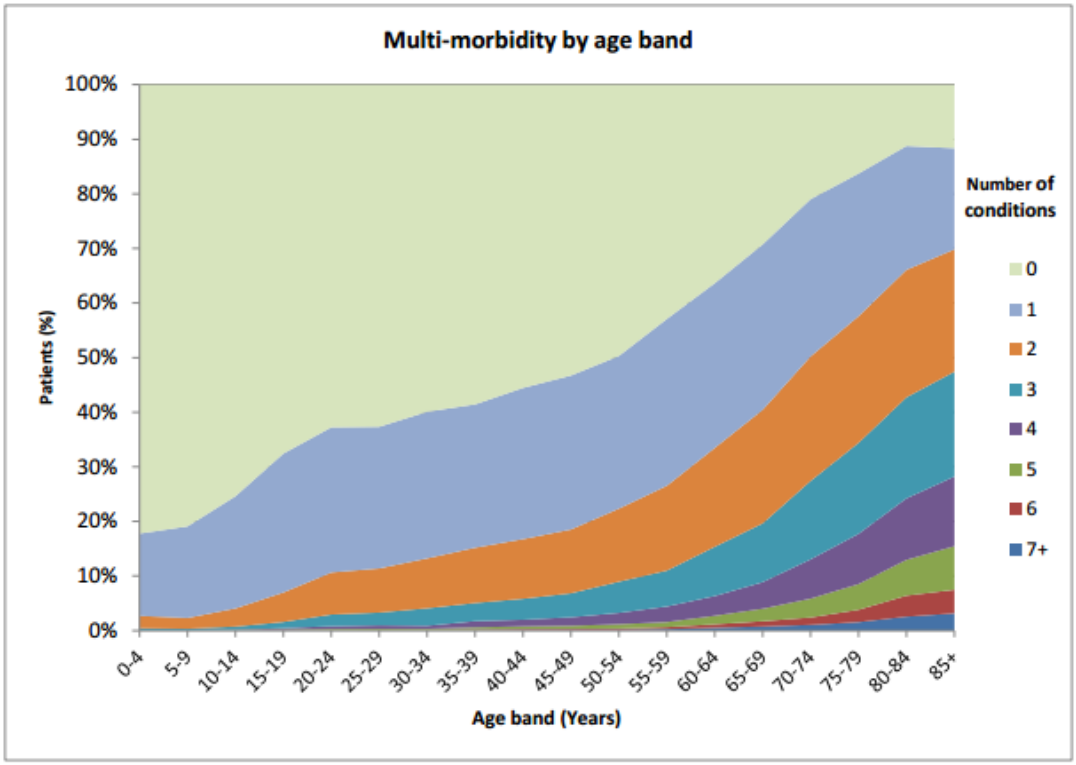
It is crucial however to recognise that these and other clinical conditions do not occur in isolation. Research studies have demonstrated convincingly that the highest users of health care services are those with more than one co-existing clinical condition, and that multiple morbidity is a key driver of health care costs, more important even than age.[11] This is illustrated in Figures 2 and 3, which show average NHS costs by age group and number of existing chronic conditions by age group.[11] Analysing individual patient data, researchers found that age alone explained less than 4 per cent of variation in costs, whereas comorbidity explained around 20 per cent of variation.[11]

Figure 2: Health care costs by age group



Source: Kasteridis et al (2014)[11]

Figure 3: Number of chronic conditions by age group



Source: Kasteridis et al (2014)[11]

In considering future health technology development, including digital health interventions, it is important to consider applications in populations with multiple morbidities. Recent NICE guidance highlights the need to take account of multi-morbidity in tailoring approaches to care.[12] The Department of Health's framework of principles for system-wide action on co-morbidities highlights the challenges for the health and care system, with a focus on two different sources of co-morbidity:

> *There are at least two key populations with comorbidities requiring a different emphasis of action: those who have comorbidities mostly due to increased life expectancy and longer exposure to risk factors over time; and those who have comorbidities mostly from more intense exposure to risk factors, particularly smoking, obesity, alcohol and physical inactivity due to challenging personal, occupational and societal factors throughout the lifecourse including persistent and widening inequalities.*
>
> Department of Health 2014[13]

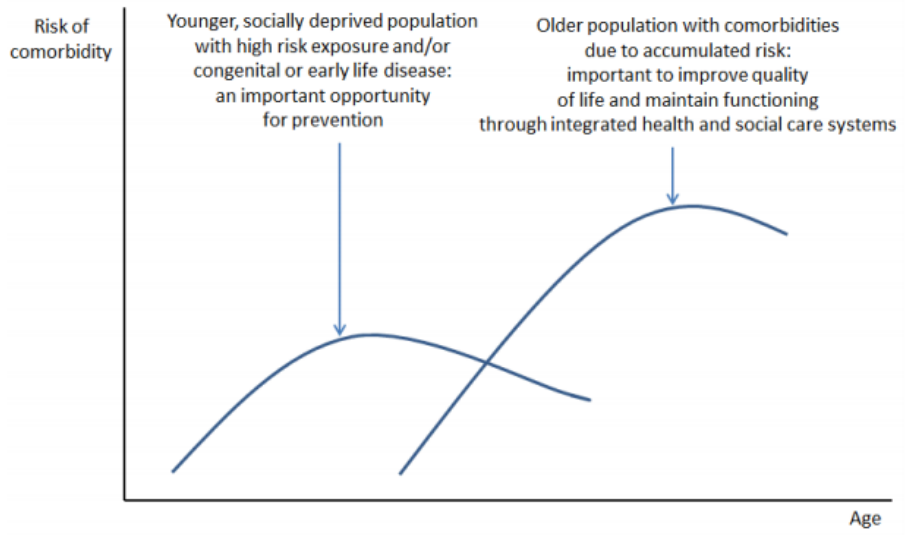
Figure 4 illustrates these two key populations across the life course. Reflecting this framework, we include digital health interventions that address cross-cutting issues relating to co-morbidity, with a particular focus on improving quality of life and maintaining functioning in an older population; and on joint disease prevention in a younger, more socially deprived population. While there is potential for digital health interventions to promote health and prevent disease by improving lifestyle behaviours which could reduce a number of health risks, there is also potential for a 'digital divide' which could impact negatively on health inequalities.[14]

We therefore included the following cross cutting issues for consideration in the review in addition to the single disease areas: prevention, health inequalities, ageing and co-morbidities.

3.3. Mapping available digital interventions to key areas of disease burden and cross-cutting areas, and identifying gaps

Exploring whether or not the biggest areas of disease burden are 'amenable' to digital intervention is not straightforward. The marketplace for digital health interventions, however, has many characteristics of a highly competitive global market. Barriers to market entry, at least at a small scale (e.g. apps), are low in principle, although in practice there may be barriers to widespread take up, particularly by clinicians. There are many buyers and sellers: providers of digital interventions range from huge multinational corporations to individual app developers. We have no specific reason to think that this market is not functioning well and operating under competitive conditions. If this is true, we can assume that where potential demand for an intervention is high (which would be true of all these highly burdensome health problems), potential profits would be high and suppliers would respond accordingly. If an area is 'amenable' to digital intervention, this means that products should exist already or be under development. In this report, therefore, we focus first on mapping *available* digital interventions to disease and cross-cutting areas.

Figure 4: Illustrative diagram of two key populations at risk of co-morbidities across the life course



Source: Department of Heath 2014[13]

Even with this simplifying assumption, the vast number of existing digital interventions makes mapping interventions to areas a daunting task. To make this more manageable and to focus attention on evidence-based interventions rather than 'digital snake oil',[6] we used a scoping review approach to identify relevant existing digital technology. This essentially includes interventions only if they have published evidence of effectiveness (and preferably cost-effectiveness) or if robust evaluation is under way. The vast majority of digital interventions, even those that are used widely, lack evaluation using a traditional evidence-based framework. As the published literature on digital health is too large to undertake a full systematic review, we conducted an 'umbrella review' (otherwise known as a 'review of reviews'). To identify areas where new interventions are emerging and currently under evaluation, we explored the international register of ongoing clinical trials. To test our review findings and to identify gaps in the evidence base and whether they are viewed as 'amenable' to digital health interventions, we conducted interviews of a number of opinion leaders.

Findings from all three stages are synthesised, and in addition we consider three areas in more detail, using case studies which combine published literature with expert opinion. We one area where there is a substantial literature and apparent amenability to digital health (mental health); and one area where there are concerns about limited amenability (older people). Finally, we include a case study on digital health in China, to explore similarities and differences between China and the UK in terms of cost and health care pressures (including disease burden) and how digital health is being used to address these pressures. The different context and culture of health care in China may provide a contrast to the UK system and highlight different ways that digital health is used in practice.

3.3.1. Review of reviews

Relevant publications were identified using a systematic search of MEDLINE, CINAHL and Cochrane databases. The search was limited to review articles from 2011 to 2016 and the terms were present in the title or abstract. The search terms used were *cell phones, *computers, handheld, digital, digital tech*,*mobile applications, *smartphone, *telemedicine, wear* tech*, *e-health, *m-health.

3.3.2. Identifying ongoing or unpublished clinical trials

The ISCRTN directory was searched for trials taking place from 2011 onwards. ISRCTN is a registry of clinical trials containing basic study information, following the requirements set out by the World Health Organization (WHO) International Clinical Trials Registry Platform (ICTRP) and the International Committee of Medical Journal Editors (ICMJE) guidelines.[15] Search terms used were digital, smartphone, technology and mobile.

3.3.3. Interviewing opinion leaders

We used a purposive sample of opinion leaders in digital health, including academic researchers in this field, individuals who have developed specific digital health interventions, and more general stakeholders. Individuals were identified by recommendations from Office for Life Sciences project commissioners, by noting authors of particularly relevant research papers and opinion pieces, and by 'snowballing' recommendations of interviewees. Ten experts were interviewed, including researchers, developers and other stakeholders, and semi-structured interview schedules were created for the three different groups of interviewees, focusing on the following themes:

- How products or interventions are developed (both clinically and technically);
- Approaches to research and establishing effectiveness;
- Views on take up of digital health interventions in the NHS;
- Areas more and less amenable to digital health interventions;
- Barriers to development and uptake of digital health interventions;
- Expectations of NHS funding for digital health;
- Regulation of the digital health marketplace.

Interviews took place either face-to-face or over the telephone, individually with one or both of the report authors. Interviews were recorded (with the permission of the interviewees) and summarised in written notes.

3.4. Synthesis

The three different data sources (reviews, trials, interview responses) are synthesised using a mixed methods approach and reported thematically. Case studies are summarised within the main findings, where they illustrate particular themes, and are also reported separately.

4. Findings

4.1. Burden of disease

Ranking the burden of disease by health loss and by NHS costs gives overlapping clinical areas (see Table 1). As well as the six (combined) highest ranking clinical areas, we included diabetes, as it shows a sharp increase in disease burden over recent years (Table 2), and its prevalence is projected to increase further in future years, with substantial health and cost consequences.

Table 1: Burden of disease ranks

Causes	**DALYs lost per 100,000 population**	**Rank**	**Burden of Disease (programme budgeting)**		**Rank**
			%	£billion	
Cancer	4589	1	6.0%	5.68	3
Cardiovascular/Circulatory diseases	4376	2	7.3%	6.90	2
Musculoskeletal disorders	4224	3	5.6%		4
Mental and behavioural disorders	3133	4	11.9%	11.28	1
Chronic respiratory diseases	1924	6	4.9%	4.69	7
Neurological Disorders	1639	7	4.7%	4.44	8
Diabetes	*337*	-	*1.62%*	*1.54*	-

Source: NHS programme budgeting data (NHS England)[9] and Global Burden of Disease study[10]

Table 2: Burden of disease changes over time

Causes	**Burden of Disease (programme budgeting) (£billion)**		
	04/05	12/13	Percentage change
Cancer	3.71	5.68	53%
Cardiovascular/Circulatory diseases	6.02	6.90	15%
Musculoskeletal disorders	3.53	5.34	51%
Mental and behavioural disorders	7.22	11.28	56%
Chronic respiratory diseases	3.08	4.69	52%
Neurological Disorders	1.73	4.44	157%
Diabetes	*0.67*	*1.54*	130%
TOTAL	*58.99*	*94.78*	61%

Source: NHS programme budgeting data (NHS England)[9]

4.2. Mapping available digital interventions to key areas of burden, and identifying gaps

4.2.1. Assessing availability of digital interventions between the key disease areas

Our search methods identified a total of 970 reviews from the search of MEDLINE, CINAHL and Cochrane databases, after removal of duplicates. After a review of titles and abstracts, 162 reviews remained, 90 in the key areas identified. Studies are listed in appendix A, and a database of references is available from the authors on request.

The search of the ISCRTN directory of ongoing randomised controlled trials identified 42 relevant studies, 33 in the key areas identified. Studies are listed in appendix A, and a database of references is available from the authors on request.

Summaries of the disease areas with most evidence from the reviews and trials identified are illustrated in Figures 5 and 6, and Table 3. The biggest disease area in terms of evidence around digital health interventions is mental health – at the time of searching there were 27 reviews and 8 ongoing trials in the broad area of digital interventions for mental and behavioural disorders. In our chosen cross-cutting areas, the most studied area is reducing lifestyle risk factors (e.g. weight loss, promoting physical activity) with 21 reviews and 14 ongoing trials.

This picture was largely confirmed by our interviews with experts. In general, in discussing which disease areas were thought most 'amenable' to digital health interventions, respondents confirmed that mental health (particularly common mental health disorders and addiction problems) and lifestyle behaviour interventions were the areas that currently had most digital health activity. Our interviewees did not, on the whole, separate 'amenability' from 'availability', and in general appeared to support our initial assumption that if areas were amenable, products would exist or be under development.

Figure 5: Reviews and trials identified by disease area

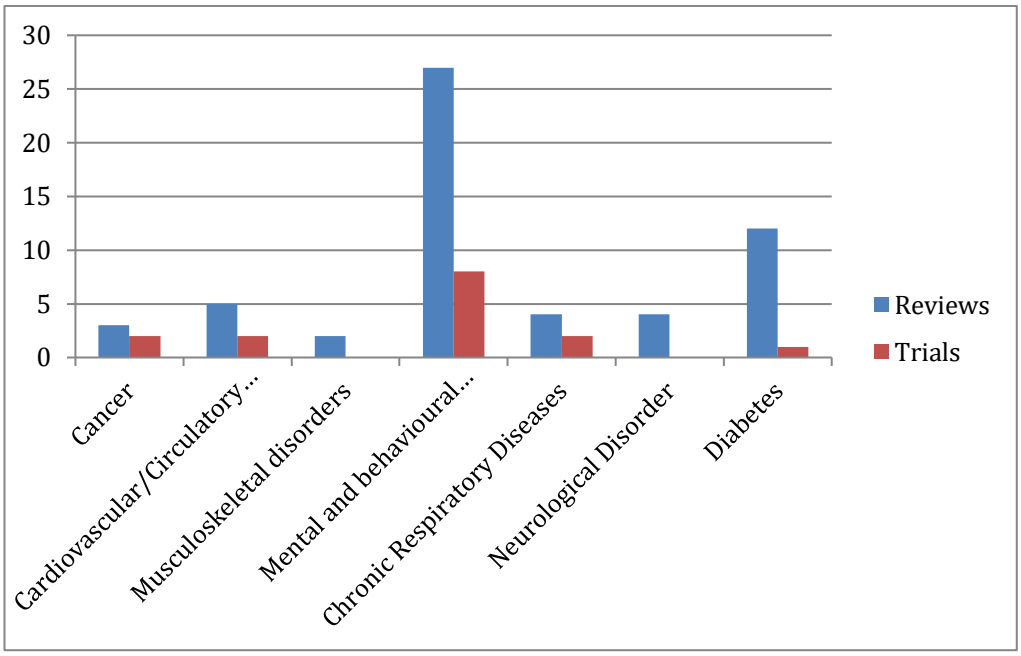


Figure 6: Reviews and trials in cross cutting areas

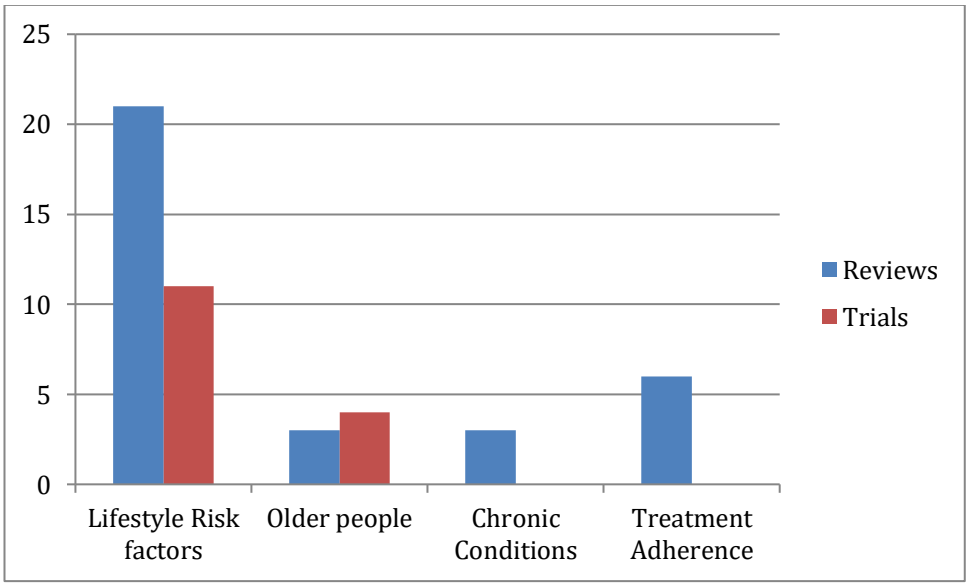


Table 3: Summary of reviews and trials included

Causes	Number of reviews	Number of trials
Cancer	3	2
Cardiovascular/Circulatory diseases	5	2
Musculoskeletal disorders	2	0
Mental and behavioural disorders (total)	27	8
Mental health (general/other)	14	5
Addiction	6	2
Depression/Anxiety	4	1
Eating Disorders	3	0
Chronic Respiratory Diseases	4	2
Neurological Disorder	4	0
Diabetes	12	1
Lifestyle Risk factors	21	14
Dietary	2	3
Weight loss	9	2
Exercise	5	4
Other	3	0
Smoking cessation	1	4
Reducing alcohol consumption	1	1
Older people	3	4
Chronic Conditions	3	0
Treatment Adherence	6	0

Interviewees speculated on other predictors of where digital interventions are clustered and why. One comment mentioned 'fashion' in disease areas – "*there are lots of breast cancer and diabetes apps but not for bladder or bowel cancer" (Digital health expert, interview 2016).* This could be viewed as a challenge to our assumption that amenable interventions are likely to be available, if there are areas which are in principle amenable but in practice, for whatever reason, are unattractive to developers and/or patients.

Another focused on the underlying objectives and motivations of the patient population, which makes some areas more amenable than others: *"People with heart disease, their goal for self-management is to forget they have heart disease. Anything that reminds them that they have heart disease is on a hiding to nothing." (Digital health expert, interview 2016).*

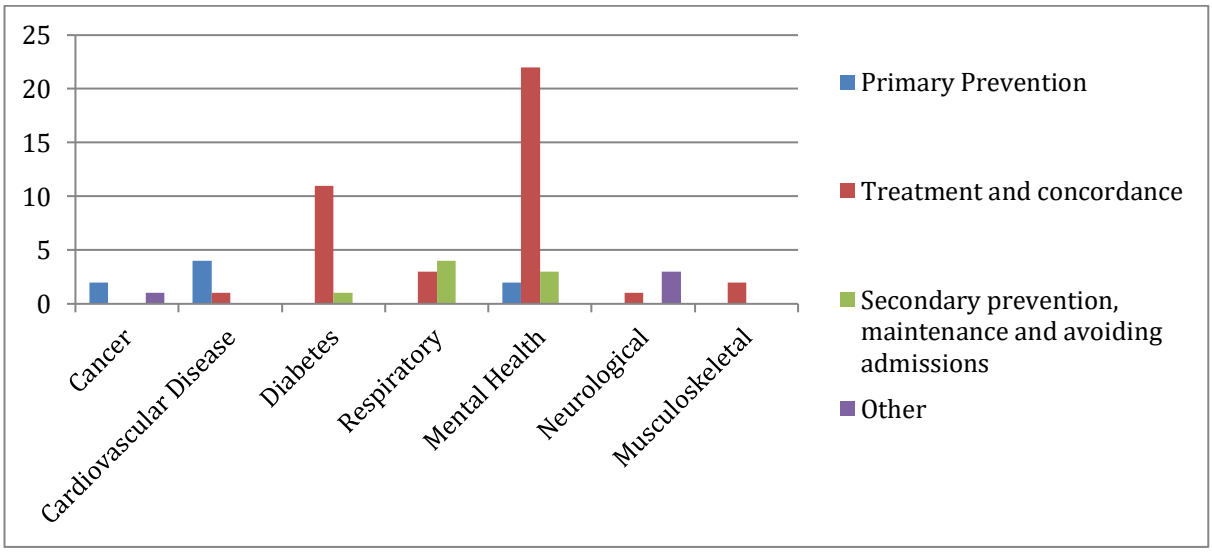
Finally, there were discussions about the 'digital divide', and whether some diseases are more likely to occur in less 'tech-friendly' populations (primarily older people and those with other reasons for lack of access to internet and smartphone technology). This is explored further in our case study of older people (see Appendix B). Acceptability to patients and indeed to prescribers, commissioners and funders of care are crucial to the question of whether health problems are amenable to digital intervention. Digital interventions may be able to address health problems, for example by replacing existing

processes, but if they are not used by patients and welcomed by health care professionals they will not reduce overall costs, and could potentially add to them.

4.2.2. Assessing availability of digital interventions within the key disease areas

Exploring these broad disease areas in more detail from our review reveals further information about apparent amenability of conditions to digital intervention. There are considerable differences between the health problems in terms of which stage of disease is addressed with digital interventions, and how. Figure 5 summarises this, and more information is detailed in Appendix A. Figure 5 shows that digital interventions within the broad areas of mental health and diabetes are most likely to focus on treatment and concordance, in contrast to cancer and cardiovascular disease, where the area most researched is prevention. Appendix A lists all of the review studies and ongoing trials in the main disease areas and in cross-cutting themes.

Figure 5:Existing reviews by disease area and intervention focus



4.2.2.1. Cancer

In cancer, most digital health interventions (at least those tested in research studies) have focused on prevention, particularly on changing risky behaviours such as smoking (many of these studies overlap with the cross-cutting behaviour change theme). Two reviews focused on primary prevention and one explored interventions to improve empowerment and physical activity in cancer survivors through web based interventions Both prevention reviews examined smartphone apps, one for detection of melanoma and one for promoting behaviour change to reduce cancer risk. The reviews did not identify any digital products that had a statistically significant effect. Apart from melanoma, no reviews were identified for specified cancers, however if you search for cancer apps on google play, there are

hundreds of different apps for different types of cancer, including lung, skin, colon, breast, ovarian and prostate. Most apps appear to contain information about symptoms, prevention and support.

The search of the ISCRTN database identified two recently completed clinical trials. The PREVENCANADOL project found that a web based intervention supplemented with text messages, aimed at adolescents to reduce their cancer risk, had a positive impact but led only to minimal changes in risky behaviours. The ONCOMED pilot trial evaluated an e-health intervention for cancer patient support. Patients complete a web based questionnaire addressing chemotherapy associated toxicity symptoms, and based on the responses, the e-health system can trigger alerts.

In addition, two cancer assessment tools are currently available on www.nhs.uk , one for bowel cancer and one for skin cancer.

4.2.2.2. Cardiovascular disease

In cardiovascular disease, digital intervention research has tended to focus on self-management of hypertension and reducing cardiovascular risk – essentially primary and secondary prevention strategies. We identified five reviews for cardiovascular disease, four for primary prevention and one exploring treatment and concordance. All four primary prevention reviews aimed to reduce cardiovascular risk, finding some positive benefits, not always reaching statistical significance. A review of self-management for hypertension assessed the use of technology for blood pressure control.

Two ongoing trials were identified, the SUPPORT-CVD trial which uses a low-cost technology-assisted and community-based programme of evidence-based CVD management, aiming to reduce the risk of serious cardiovascular events in high-risk individuals. The HOME-BP (Home & Online Management & Evaluation of Blood Pressure) trial is assessing a digital intervention for self-management of uncontrolled, essential hypertension in primary care.

4.2.2.3. Diabetes

Twelve reviews were identified assessing digital interventions in diabetes. Eleven were for self-management (treatment and concordance, e.g. insulin dose calculators, virtual support) involving the internet or mobile phone apps. One was for secondary prevention (promoting physical activity). One trial is ongoing, the Digital Diabetes Project, which is a pilot study to test the usability and acceptability of virtual support for patients with type 1 diabetes in Highland region.

4.2.2.4. Respiratory disease

Respiratory conditions had four reviews of digital interventions, all relating to asthma self-management, reminders and text messages to improve treatment concordance and medication adherence.

There are two ongoing trials in respiratory conditions, both for COPD, one using digital interactive materials to promote physical activity and the second using digital pens to record symptoms.

4.2.2.5. Neurological conditions

Neurological conditions are diverse, and digital interventions reflect this. A review of digital health in epilepsy focused on tools for self-management. Other reviews focusing on neurological conditions including Parkinson's disease and acquired brain injury assessed wearable sensors and accelerometers to detect patterns of movement and functional activity, which are particularly relevant in diagnosis and treatment of these conditions. No ongoing trials were found.

4.2.2.6. Musculoskeletal conditions

Despite being a substantial cause of NHS utilisation, musculoskeletal problems appear to have relatively little attention from digital health developers. Two reviews were found, both of self management and treatment concordance in arthritis (one rheumatoid and one osteo-arthritis). No trials were identified.

4.2.2.7. Mental health

Mental health is the area most addressed by (researched) digital interventions. We found 27 reviews, two of primary prevention (addiction, suicide), 22 of treatment concordance and three of secondary prevention. Interventions exist and have been reviewed which treat a number of conditions, including depression, anxiety, eating disorders and addictions. We also identified eight trials and seven NHS recommended online tools.

There are a number of possible reasons for the apparent 'amenability' of mental health to digital interventions, as discussed in our case study of mental health (see Box 1 and Appendix B). First, there has been a substantial increase in incidence and prevalence of mental health disorders over recent decades. Attempts to prevent exacerbation of mild to moderate mental health problems (particularly depression and anxiety) have focused on brief interventions, increasingly delivered by non-medical health professionals. Layard's[16] recommendations for substantial investment in psychological therapies resulted in training of thousands of new therapists to deliver short, focused interventions, mainly based on cognitive behavioural therapy. Despite this substantial investment, demand for therapy exceeds supply, and various forms of computerised and internet-based delivery have been created, with substantial efforts to evaluate them. These are (relatively) easy to transfer to apps and other methods of digital delivery.

A similar trend is evident in other digital interventions relating to behaviour change. Screening and brief interventions to reduce problem drinking, for example, have been evaluated as delivered by GPs, by other health professionals and then by computers and internet-based methods. Ease of transfer

between delivery methods, and an established, clinically designed intervention with an existing evidence base has contributed to the success of digital interventions in these two areas. It may be that in both these areas, the nature of the intervention (in particular both are short, defined, and focused on areas within patients' direct control) make digital interventions more likely to be effective, in comparison with interventions that require longer term treatment.

Box 1: Digital mental health

- Umbrella review identified 27 reviews and seven trials, although this may be an underestimate of the evidence base;
- The most frequent interventions are based on therapeutic interventions (e.g. CBT) delivered online or via other digital tools or apps;
- The digital interventions (particularly those demonstrated to be effective) are in general not novel products but new platforms for delivery of existing evidence based treatments;
- Most of the digital interventions aim to treat mild to moderate depression and anxiety – this is an area with high and increasing demand, and current staff shortages;
- Unsupported digital interventions tend to have low rates of adherence – there is a strong case for using these tools to supplement rather than replace face-to-face therapy. This may increase costs but also increase concordance with treatment and consequent effectiveness.
- There is likely to be, for most interventions, a minimum cut-off for interpersonal support below which people do not engage with them, and a point beyond which there are diminishing returns on clinician input; further research is needed to confirm the optimally efficient mix of digital and person-to person therapeutic interaction (telephone, internet or face-to-face);
- There are few products for more severe and enduring mental illnesses, and those that exist have not demonstrated effectiveness;
- Selected online mental health products are used in the NHS, and recommended on the NHS Choices web site. There appear, however, to be some discrepancies between NHS recommendations and recent research and clinical guidelines.

4.2.2.8. Older people and co-morbidities

The nature of the interventions available for older people is diverse (see Box 2 and Appendix B). Technology available and with some research evidence includes tools to aid communication with health

professionals and with family and friends; technology to help with everyday living needs and maintain independent living; smartphone apps to aid memory; medication reminders and apps to keep a record of health outcomes. Mobile phones can be used as tracking devices or to alert carers of a fall. Falls are a leading cause of injury and hospitalisation amongst older people, and also a major source of fear and loss of independence. Wearable sensors can also provide alerts of falls, and exercise programmes have been designed to prevent falls, using electronic devices like Microsoft Kinect or Nintendo Wii.

The most burdensome disease associated with ageing is dementia, of which the largest cost is attributable to institutionalisation. Reminders and tracking devices may address some problems with this patient group, but interventions based on providing information are less suited to them. There are however examples of online and other supportive interventions for *carers* of people with dementia. As our review focused on patient-facing interventions, we may have missed evidence on this important area, and this may merit further exploration.

There are limitations identified by many of the reviews synthesising digital interventions for older people, including problems of compliance and battery life. Many of the studies identified were small feasibility studies, and there are few of no real-life pragmatic randomised trials with meaningful outcome measures. Exercise programmes, for example, were evaluated over a short timescale with outcome measures focused on posture and functioning, rather than over the longer term measuring falls or hospital admissions.

Box 2: Digital health and older people

- Older people are the highest users of NHS services, due to multiple chronic conditions and therapeutic interactions, which makes their care complex;
- There is less research in digital health for older people than in other health areas: our review identified three reviews and four ongoing trials;
- Digital health interventions identified for older people are diverse, and include: tracking devices, movement sensors, mobile phone cameras, online support groups and exercise programmes using computer consoles;
- There is a shortage of pragmatic research in practical application of the products, which is needed to justify NHS investment and funding;
- Digital health for older people is a growing market as more older people engage with smartphones and as comfort with technology increases;
- There remains considerable potential for a 'digital divide' as some get left behind.

4.2.3. Overall evidence of effectiveness and risks of digital interventions

Without attempting any formal synthesis or meta-analysis, our umbrella review explored whether effectiveness had been established by the existing reviews. As illustrated in the Appendices, the vast majority of reviews reported insufficient evidence to determine overall effectiveness of these interventions (these reviews are in blue text in Appendix A). Those areas with some evidence of effectiveness (in green text in Appendix A) were:

- Digital health interventions to reduce cardiovascular risk in cardiac patients and those with heightened risk of cardiovascular disease;[17,18]
- Internet delivered cognitive behavioural therapy for treating anxiety disorders[19] and other psychiatric and somatic conditions;[20]
- Electronic screening and brief interventions for reducing alcohol consumption.[21]

Importantly, the review of reviews also identified some areas of potential harm from digital interventions (in red text in Appendix A). Most notably, these included:

- Smartphone apps for detecting melanoma, where none of the apps had been validated for diagnostic accuracy;[22]
- Insulin dose calculator apps for people with diabetes, which were thought to be inadequately tested or monitored, and prone to incorrect interpretation.[23]

A review of insulin dose calculator apps found that only one out of 46 calculators was determined adequate according to the pre specified criteria and 31/46 carried a risk of inappropriate dose. The authors commented that 'the majority of insulin dose calculator apps provide no protection against, and may actively contribute to, incorrect or inappropriate dose recommendations that put current users at risk of both catastrophic overdose and more subtle harms resulting from suboptimal glucose control.'[23]

The potential for harm from digital interventions was highlighted in a number of interviews.

> *"The assumption that digital health is harm free is entirely untrue" (Digital health expert interview, 2016)*

One of our interviewees highlighted a number of areas where harm can be done from digital health interventions. These included:

- Where the intended outcome is harmful e.g. web sites and online forums such as pro-suicide or pro-anorexia groups;
- Where the digital intervention is fraudulent or deliberately misleading;
- Where the intervention is developed in a way that is wrong – perhaps due to an innocent mistake;
- Where algorithms are incorrect;

- Where a digital intervention affects negatively patient motivation in general – if, for example, a weight control app doesn't work for an individual, that patient can believe they are un-helpable and become disillusioned;
- Where data protection is inadequate and personal information put at risk.

We would add to this list the potential harm from using digital interventions where benefits do not justify their costs, potentially displacing more efficient uses of scarce NHS resources.

The overall picture revealed by our review confirms therefore that there is substantial digital health activity, in terms of both technology and research, but there remains substantial uncertainty about the effectiveness and cost-effectiveness of much of this activity. The reviews almost all highlight lack of good evaluation. Some highlight potential harms from digital interventions. In general, this reveals the crucial need to approach digital interventions in the same way as all other health care interventions – balancing benefits, risks and costs.

4.2.4. Forms and levels of evidence in digital health

Our approach to assessing the evidence base for these interventions was to use a traditional health services research framework, with an implied hierarchy of evidence that views meta-analysis of well-designed randomised controlled trials as a gold standard.[24] A number of our expert informants were from similar disciplinary backgrounds and approach digital health interventions with a similar view. We are however aware that this is not the only view of 'evidence', particularly in the digital field, and other informants took a very different approach. There are different forms of relevant evidence in this field, including development activity, safety engineering approaches, clinical trials, economic evaluation, and assessing equity effects. Different views on evidence were apparent from our interviews:

> *"How to evaluate digital health apps is one of the pieces of puzzle to encourage widespread adoption. A lot of the consumer groups have difficulty finding quality apps in an overcrowded market, a large proportion are poor in terms of quality… [we need to determine] how best to evaluate them in order to provide guidance for choice" (Digital health expert, interview 2016).*

Evaluating a digital intervention, for a computer scientist, would largely focus on the programming process, with additional information about safety of devices. RCTs are time consuming and costly, which is often at odds with digital technology, where interventions (particularly apps) can be developed quickly and inexpensively. In addition, safety cases for digital interventions include review of algorithms, computer code and potentially manufacturing processes which requires a level of transparency, at least to regulatory bodies.

Other approaches to evaluation include an engineering approach, user reviews, expert reviews, and accreditation with a kite mark or seal of approval. At present, some digital interventions are viewed as

medical devices (and consequently require approval by the Medicines and Healthcare products Regulatory Agency (MHRA)), but most are not, and therefore receive less formal scrutiny. We interviewed developers with experience of developing interventions in both situations, and the approach to 'evidence' differed between them. None of our interviewees were involved in 'safety-critical' devices (for example products that would be inserted into the body) but some were developing interventions which could be used for diagnosis or monitoring, and were consequently viewed as medical devices. There are key differences between medicines, where RCTs are more traditionally used, and digital health interventions, which can include an amendment to the care pathway as well as the intervention itself, and consequently requires supported introduction. These issues are considered in detail in the recently published Accelerated Access Review. [25]

Substantial work is under way attempting to address information shortages in digital health, particularly as part of the 'personalised health and care 2020' report and roadmaps being created by the National Information Board.[26] This includes a work stream on 'providing citizens with access to an assessed set of NHS and social care 'apps'[27] now part of the Paperless 2020 portfolio of deliverables, led by NHS England. Two pilot assessment activities have resulted from this work. The first is being led by NHS Digital and aims to establish a technical assessment process for apps to allow them to access national systems such as the NHS Spine; and the second, being led by NICE, is piloting the development of advice for digital health app developers that, for a small number of potentially high value apps for use in clinical settings, evaluates the evidence of their effectiveness, cost and resource impact on the health system. The intention is that the NICE advice output builds on a technical assessment undertaken by NHS Digital. These pilot activities should contribute to addressing at least some of the concerns of our interviewees regarding how digital health interventions are evaluated and regulated. Nonetheless, as regulation and evaluation were mentioned by all of our interviewees as possible barriers to implementation and uptake of digital health interventions, we report a selection of their comments here.

One interviewee discussed the view that apps should be proportionately evaluated according to their risk. Higher risk would include those used for diagnosis and treatment. Lower risk would include those simply presenting information. Other interviewees commented that the quality of a digital product is not just limited to its efficacy, in particular that digital tools must work in practice and not just in trials. They must be safe, useable and functional. The technology must be stable as well as ensuring data privacy and data security. Evidence should underpin the design. This means that trials and other evaluative designs need to have both internal and external validity, tested in populations that reflect later use. A good example of this is the HeLP-Diabetes research programme, which includes a development phase, randomised controlled trial and implementation study.[28]

MindTech, in collaboration with Leeds and York NHS Foundation trust and the University of Leeds is developing a toolkit for appraising digital mental health products specifically. The current version of the toolkit addresses five areas, purpose and relevance, technical quality, source, access and risk.[29]

A view was expressed in one interview that some research commissioners (including NIHR on occasion) are encouraging trials of digital health interventions too soon in the development process. RCTs are appropriate only following clear development, piloting and refinement of the intervention. The same interviewee believed that it is often unclear why some interventions work and others do not, and in what circumstances they work. The view was that there was *"much too little work on what works for whom and in what circumstances" (Digital health expert, interview 2016).*

We interviewed a health economist who has been involved in evaluating numerous digital products. With digital products the largest costs are in the development process: clinical and developer time as well as the associated support costs. This, along with the fact that many digital products are preventative, presents a challenge to establishing cost effectiveness. Trials conducted over a limited time period will only measure intermediate outcomes whereas the true outcomes may only be estimated after a lengthy follow up period. In these cases the costing model needs to adopt an epidemiological or disease model such as UKPDS Outcomes Model.[30] Funding models also determine how interventions should be costed – if interventions are developed in the private sector and then prescribed to individual patients, like pharmaceuticals, the NHS cost is essentially the price charged to access the product. But if they are made widely and freely available, like web sites or apps, development will have to be rewarded using a different model. In this case, investment is likely to be required to fund the development period, which means that by the time of a NICE or similar appraisal, most costs are in the past ('sunk costs') and the ongoing costs are for maintenance and updating. Our expert suggested there needs to be formal guidance on how to evaluate the cost-effectiveness of digital interventions, particularly with regards to sunk costs and marginal costs to ensure that all evaluations are comparable.

In our view, digital health fits well into the MRC framework for evaluation of complex interventions.[31] While not always meeting the definition of a complex intervention, some digital interventions definitely are, and either way, this framework is helpful. There is a potential problem with duplication of effort if, for example, researchers and clinicians develop digital delivery mechanisms when they could draw on and refine existing interventions. The MRC guidance recommends a clear review and development phase for interventions, followed by piloting and feasibility testing, and only then a formal evaluation. Evidence from RCTs should then be combined with other sources of information, including economic evaluation to judge the likely value of the intervention, and also (particularly for public health interventions), consideration of sources of variation in outcomes, subgroup analysis and likely impacts on inequalities in health.[21]There are, however, challenges around (often slow) research timelines and potentially rapid technological change.

Where digital health products are not viewed as medical devices (as defined by MHRA)[32] it may still be appropriate for them to go through a process of approval and accreditation, particularly if they are to be recommended (through NHS Choices) or even funded by the NHS (which in some cases should trigger a review by the National Institute for Health and Care Excellence (NICE) including assessment of cost-effectiveness). Where products are funded or otherwise signalled as 'approved', they must meet requirements of clinical quality (with an appropriate evidence base) and also comply with privacy and

data protection regulations.[33] Detailed discussion of regulatory mechanisms is however beyond the scope of this review, and methods of review and accreditation of eHealth interventions are under development by NIB, NICE and other bodies. NICE's interest in digital health interventions signals to developers the need to consider not only the effectiveness of new products, but also the resource implications and cost-effectiveness.

4.2.5. Health inequalities and the 'digital divide'

There are a number of reasons to be concerned that increasing the use of digital health interventions, even those which are demonstrated to be effective, could perpetuate or even increase health inequalities. Straightforward public health information programmes aimed at behaviour change, as well as screening programmes and other preventive measures, have long been subject to the 'inverse care law', which means that the people who benefit most are those who need the interventions least.[34] This is very likely to be the case with some digital health interventions. One of our interviewees commented that *"just putting things out there reaches those with least need" (Digital health expert, interview 2016)*, and that we need to develop and evaluate methods of encouraging uptake and adoption of effective interventions.

A review of online prevention aimed at lifestyle behaviours reinforced this view, finding that the reach of interventions is undiversified, reaching primarily female, white, highly educated people.[35] This review found overall effects to be small and unsustainable, with some indicative evidence for the effectiveness of tailored feedback, use of theory, interactivity, goal setting, and combinations of online and in-person contact.[35] The authors commented on the difficulty to reach high-risk populations, and on the need to find a balance between recruiting participants online (which maximises potential reach) and in person (which reduces reach but may increase effectiveness).[35] Other survey based studies have also confirmed that digital health interventions are more likely to be used by women and those of higher socio-economic status.

The 'digital divide' does not necessarily apply to lower socio-economic groups, but also potentially to older people and particular groups of working age adults who do not use computers on a day-to-day basis. This will include those with sensory and perception difficulties, who can find mainstream digital interventions very difficult to use. Most recent figures from the Office for National Statistics suggest that in 2016 more than 8 in 10 people went online almost every day, and that 51% of adults use the internet to look for health related information. This is not, however, evenly spread throughout the population – less than 30% of over 65s use the internet for health information, compared with nearly 70% of those aged 25-44, and in fact 'many older people are still to catch up with the digital revolution, with nearly half of single pensioners still having no internet access at all' (ONS 2016).[36] There is debate in the literature about whether or not smartphones are 'bridging the digital divide', but even with their proliferation, there are still substantial subgroups of the UK population who remain inexperienced in, uncomfortable with or potentially even excluded from the use of digital technology.

A combination of digital technology and public health information and behaviour change interventions could in principle reach some subgroups of the population but not others, and could consequently maintain or even increase health inequalities. This should be monitored and indeed addressed in future research studies: exploring, for example, measures to ensure that under-represented populations are engaged in digital health. This may involve blended approaches with support from clinicians or others, or targeting research on groups most likely to be adversely affected by the 'digital divide'.

4.3. International approaches to digital health

Health policy makers around the world recognise the potential of digital health to improve the quality and efficiency of health care systems. In established health care systems there are calls for improved use of digital health and health data systems in the European Union[37,38] and in the OECD.[39] In developing countries, there are ongoing projects funded by international agencies to develop potential for digital health to help to address particular health problems such as tuberculosis;[40] and to support particular health care systems.[41] Despite all this activity, however, health policy makers in general remain understandably cautious with regard to digital health, particularly in terms of concerns about costs and benefits of large IT projects, payment mechanisms for apps and mobile health, and data security implications of the 'big data' that potentially emerges from all digital health interventions. There is a view expressed that, for these reasons and others, health care systems are 'struggling to convert ambition into reality'. [42]

To complement and contrast with our review of digital health in a UK NHS setting we explored issues that are emerging in the Chinese health care system. This is summarised in Box 3 and in the case study in Appendix B. It is interesting to note both the similarities and differences between China's approach to digital health and that emerging here. There are many overlapping ambitions (for example the desire to use digital health to improve health care productivity, and to prevent disease) and concerns (for example around data security). The major difference between the UK and China in terms of approaches to digital health is the focus in China on remote access to health care (telemedicine), which has particular potential benefits in China given the shortages in health provision in rural areas.

Overall, Dr Tan's brief review of digital health in China (see Appendix B) reveals many similarities with the views expressed in publications and by the experts we interviewed. Policy makers in China are investing in IT systems and electronic health records, and in remote access to treatment and monitoring. Mobile health technologies appear to be a smaller part of the Chinese digital health agenda, but are developing along similar lines to the rest of the world, despite different internet systems and policies.

Box 3: Digital health in China

- The Chinese population in ageing and is there is a nationwide shortage of doctors.
- There are particular challenges regarding access to health care as around half of the Chinese population live in rural areas but 80% of medical institutions are in urban areas.
- The major disease burdens are cardiovascular disease, cancer and respiratory disease
- The current uses of digital technology focus particularly on appointments and payment systems, remote access to medical assessment, and information and education.
- The Chinese government has intensified efforts to boost digital health care in a bid to increase access to care, improve health and reduce costs.
- Electronic health records (EGR) systems have grown rapidly due to government incentives and financial support.
- Adoption of digital health technologies is occurring particularly around:
    - Electronic Health Records to enable individuals to manage their health and engage with care providers;
    - Digital tools for physicians;
    - Digital tools for hospital management.
- There is potential for use of the 'big data' produced by digital health care systems, e.g. by pharmaceutical companies

5. Discussion and recommendations

This rapid review and expert consultation has covered only a fraction of this vast and rapidly changing field of research and development. Our conclusions and recommendations are consequently tentative.

As digital health appears to be a well-functioning market, with numerous suppliers and without obvious causes of market failure, we assumed that if substantial health problems (with consequently high potential demand for interventions) were 'amenable' to digital interventions, there would be products in existence or under development. This assumption was supported by our expert interviewees, who tended to make the same link between 'amenability' and 'availability'.

Our review of evidence did not find any substantial individual clinical areas that do not appear to be amenable to digital intervention. Reviews of evidence of interventions appear across disease areas. Evidence suggests that digital health has the *potential* to address all of the largest single-disease causes of pressure on the UK's health and care system, but there are broader societal trends (e.g. multiple morbidities, inequalities in access to digital technology) that cause additional pressures which have not yet been addressed. In addition, it is apparent from our review that quite different forms of intervention are developing in the different disease areas, often addressing different points in the course of the conditions. Our review of published evidence found that in cancer, for example, digital interventions generally focus on primary prevention (e.g. stop smoking apps) and early detection (e.g. melanoma screening). In diabetes, interventions cluster around self-management and avoiding exacerbation. In neurological conditions like epilepsy and Parkinson's disease, digital interventions and sensor technology can contribute to diagnosis, optimising treatment and avoiding adverse events, as well as contributing to rehabilitation. In mental health, there are digital interventions across the life course of the disease, although with varying levels of demonstrable effectiveness and a clear focus on mild to moderate anxiety and depression, rather than the more severe forms of illness.

Although we found digital activity and research in all of the areas of disease burden that we considered there was substantial variability between them. Mental health has the best evidence-based digital health activity, with areas like musculoskeletal conditions apparently receiving much less attention. This may primarily be due to the nature of therapeutic interventions in digital mental health. The interventions which have been demonstrated to be effective (and in some cases cost-effective) are those which have taken existing evidence based interventions (e.g. cognitive behavioural therapy) and delivered them using digital platforms, permitting greater reach. In many of the reviews, the potential for increased effectiveness to be achieved by combining face-to-face mental health interventions with digital (online or similar) supplements, exercises and reminders was mentioned. There appears to be a lack of good evidence on the balance between reach, costs and effectiveness which would inform policy around digital health in mental health and other areas.

There may be other areas where short-term, defined interventions (mirroring cognitive behavioural therapy for anxiety and depression) exist, and could be amendable to digital intervention. In musculoskeletal conditions, for example, there may be potential for short courses of face-to-face physiotherapy to be supplemented by digital reminders and instructions. This could feasibly increase effectiveness and reduce clinician contact time for rehabilitation following injury. This may also apply to other areas of acute illness or injury requiring short- to medium-term rehabilitation or other therapeutic interventions. Cardiac[43] and perhaps stroke[44] rehabilitation programmes could also, in principle, be supported in this way, although research evidence on such digital interventions is at an early stage. Nevertheless the major disease burdens which were the subject of this review are primarily long-term chronic illnesses. The digital interventions that we found, therefore, tended to be either preventive (e.g. stop smoking apps to reduce cancer risk) or require long-term adherence (e.g. self-management for asthma and diabetes). There may be shorter-term interventions for more acute conditions that would not have been revealed in our review, which focused on selected disease groups.

There is potential for digital health interventions to reduce demand on NHS services, for example by improving lifestyle behaviours (stopping smoking, increasing physical activity) and increasing levels of self-management of chronic conditions. The evidence base for digital interventions, however, remains at an early stage, and effects may be seen only in the medium to long-term. The reviews that we located reported that many areas lack evidence from high-quality randomised controlled trials, which should be expected if the NHS is to introduce, endorse or fund new interventions. Development of processes of evaluation and endorsements of apps, led by the National Information Board,[45] will link with the NICE evaluation framework, but also provide more a more graded range of quality signals that may not always require full NICE assessments. Planned processes for evaluation are described in the recently published Accelerated Access Review, which suggests 'a comprehensive mechanism for app evaluation that assesses efficacy, cost impact and usability. This will increase commissioner, clinician and patient confidence in digital products'.[25] Some apps will be subject to NICE review, and, if judged to be a cost-effective use of NHS resources, will be available for 'prescription'.

5.1. Recommendations for policy makers and regulators

- Digital health is without doubt an exciting prospect, with potential to improve productivity in health care. Our review found, however, that many interventions are at an early stage of research, development and implementation, and change is likely to be marginal rather than transformational.
- Review findings and some of our interviews suggested that digital health interventions should be treated as other treatments, balancing effects, risks and costs.
- A number of our experts stated that in many cases digital health interventions should not be viewed as 'standalone' treatments. They often need to be integrated with and supplemented by clinical face-to-face contact.

- In NHS practice, many patients have co-morbidities and complexities that create real-life challenges for digital health that should not be underestimated. There is a need for more investment in pragmatic research studies with appropriate patient-centred outcome measures and medium to long-term follow up.
- Discussions in literature and in consultation with some of our experts expressed concern that digital interventions, even those that are effective, may have potential to widen health inequalities. The 'inverse care law' may be exacerbated by the 'digital divide'. There may be a role for government agencies to support developers to meet the needs of population groups who are at risk of reduced access to digital intervention.
- Our review highlighted a need for clear evidence of effectiveness and cost effectiveness, particularly if interventions are to be endorsed or funded by the NHS – this should progress if NICE's pilot activities prove successful.
- Discussions in literature and in consultation with some of our experts reported that funding processes are potentially complex: business models for apps and internet-based interventions (e.g. advertising and/or direct-to-consumer sales) may not always be entirely consistent with NHS principles. This may be ameliorated by the National Technology Tariff,[46] particularly for interventions with a strong evidence base, but support may be required (e.g. template agreements, IP advice) for local commissioners contracting individually with technology providers.
- Preventative interventions may not be considered 'core NHS business', which may create a role for other sectors to facilitate delivery and evaluation of digital interventions.
- Some of our interviewees commented that where technology is intended to replace rather than add to services, it is necessary to ensure that active implementation takes place, and monitor how services change.

5.2. Recommendations for researchers and research commissioners

- There is a need for a genuinely interdisciplinary approach to research in digital health. Collaboration between clinicians, developers, patients and academic researchers is crucial in this field. There are interesting examples of such collaborations in the Healthcare Technology Co-operatives (HTCs).[47]
- Evidence reviews and the experts we interviewed both suggested that the most effective digital health interventions start with a clinical problem, rather than being led by technology (although some technical solutions can sometimes be adapted for new areas).
- Future research should include and perhaps focus on population sub-groups who are (from available evidence) relatively more likely to be affected by the 'digital divide': men, older people, people with disabilities, complex needs and comorbidities.
- Digital health research may usefully be guided by the MRC framework for evaluating complex interventions. This reinforces the need for a clear development phase with refinement, piloting and feasibility tests before randomised trials, which should be pragmatic. Appropriate evaluation

strategies are important, balancing access to interventions with the need to generate good evidence of their cost-effectiveness.

5.3. Recommendations for clinicians and NHS commissioners

- Clinical engagement with product development, piloting and research is essential for digital health to address real world health problems.
- Digital interventions should be viewed similarly to other treatments: balancing effects, risks and costs.
- Some patients are likely to be aware of and using some interventions – it is therefore necessary to develop and keep up-to-date in terms of knowledge of interventions, potential harms and the evidence base. This may be facilitated by collaboration with other clinicians and sharing knowledge, including through the Academic Health Sciences Networks (AHSNs), as recommended in the Accelerated Access Review.[25]
- Procurement processes for digital health interventions need to be clearly defined to providers. Again, systems are proposed for this, as described in the Accelerated Access Review.[25]
- Digital interventions, even those that are effective, may have potential to widen health inequalities if they improve ability to benefit for groups who are already relatively healthier.

5.4. Recommendations for product developers

- It is essential to understand the hierarchy of evidence and the need for good evaluation to convince medical professionals and NHS funders of the value of new products.
- To obtain NHS endorsement, funding or ongoing investment, pragmatic randomised trials with appropriate real-world outcome measures and accompanying economic evaluation would normally be expected, although there may be low-risk interventions where less rigorous evaluation may be acceptable.
- All clinical and other claims should be supported with references and sources of information.
- User-centred design in digital health care is essential to maximise the potential for take-up and for NHS or other regulatory endorsement. In addition, developers should take into account factors that may exclude population groups, including language and cultural differences, and impairments to manual dexterity and mental functioning.
- Although potentially challenging, there is a need for transparency of algorithms, at least for regulatory checks. Some examples exist (e.g. Google DeepMind) of larger developers providing transparency around the development process, by granting independent experts the right to inspect processes and code.
- Long-term sustainability of digital interventions is a concern for clinicians, funders and health policy makers. Development is the start, not the end of a process of implementation.

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Appendix A: Review summary tables

Table A1: summary of reviews

	Primary prevention			Treatment and concordance		
	Reviews	Trials	Other	Reviews	Trials	Other
Cancer	Reviews (2) (Behaviour change, melanoma)	Trial(1) (behaviour change)	Other(2) (bowel and skin cancer symptom check)	-	Trial (1) (patient support)	-
Cardiovascular Disease	Reviews(4) (targeting CVD risk factors(4))	Trial (1)(prevention disadvantaged pop.)	-	Reviews(1)(self management of hypertension)	Trial(1) (management of hypertension in primary care)	-
Diabetes				Reviews(11) Self management	Trial(1) Remote treatment	
Respiratory			Other(1)(asthma)	Reviews(3)(Asthma)		

Mental Health	Reviews(2)(suicide, addiction)	Trials(1)(positive psychology)		Reviews (22) (Anxiety/Depression(5), Eating disorder (3), Addiction(4), other (10))	Trials(7)(Addiction, anxiety, schizophrenia, agoraphobia, psychosis, stress)	Other(7)(phobia(1), common mental health problems(5) sleep(1))
Neurological				Review(1)(Epilepsy)		
Musculoskeletal				Reviews(2)(rheumatic disease and osteoarthritis)		

	Secondary prevention, maintenance and avoiding admissions			Other		
	Reviews	Trials	Other	Reviews	Trials	Other
Cancer		-	-	Review(1) (web based rehab advice)		
Cardiovascular Disease		-	-	-		
Diabetes	Papers(1)(promote physical activity)					
Respiratory	Reviews(1)(Asthma)	Trials(2) (COPD)				

Mental Health	Reviews(3) (addiction, mental health (2))					
Neurological				Review(3)(Parkinson's, acquired brain injury, neurological rehab))		
Musculoskeletal						

Table A2: Digital health in cancer

Reviews			
Area	**Citation**	**Abstract**	**Intervention**
Primary Prevention	Bender JL, Yue RY, To MJ, Deacken L, Jadad AR. A lot of action, but not in the right direction: systematic review and content analysis of smartphone applications for the prevention, detection, and management of cancer. Journal of Medical Internet Research. 2013;15(12):e287	There are hundreds of cancer-focused apps with the potential to enhance efforts to promote behavior change, to monitor a host of symptoms and physiological indicators of disease, and to provide real-time supportive interventions, conveniently and at low cost. However, there is a lack of evidence on their utility, effectiveness, and safety. Future efforts should focus on improving and consolidating the evidence base into a whitelist for public consumption.	**Smartphone App**

Primary Prevention	Kassianos AP, Emery JD, Murchie P, Walter FM. Smartphone applications for melanoma detection by community, patient and generalist clinician users: a review. British Journal of Dermatology. 2015;172(6):1507-18.	Smartphone 'apps' are widely available but experts remain cautious about their utility and safety. Reviewed currently available apps for the detection of melanoma (July 2014), aimed at general community, patient and generalist clinician users. 39 apps were identified with the majority available only for Apple users. Apps included information and education; taking and storage of images of skin lesions either for review by a dermatologist or for self-monitoring to identify change; reminders to help users monitor their skin lesions. A few (n = 9) offered expert review of images. 4 provided a risk assessment to patients about the probability that a lesion was malignant or benign, and one calculated users' future risk of melanoma. None of the apps appeared to have been validated for diagnostic accuracy or utility using established research methods. Apps for melanoma detection require further validation of their utility and safety.	**Apps**
Other	Kuijpers W, Groen WG, Aaronson NK, van Harten WH. A systematic review of web-based interventions for patient empowerment and physical activity in chronic diseases: relevance for cancer survivors. Journal of Medical Internet Research. 2013;15(2):e37	We identified 7 common elements of interactive, Web-based interventions in chronic disease settings that could possibly be translated into eHealth recommendations for cancer survivors. While further work is needed to determine optimal intervention characteristics, the work performed in other chronic disease settings provides a basis for the design of an interactive eHealth approach to improve patient empowerment and physical activity in cancer survivors. This may subsequently improve their health status and quality of life and reduce their need for supportive care. [7 key elements; education, self-monitoring, feedback/tailored information, self management training, personalized exercise program, (6+7) communication, either with health care providers or with fellow patients]	**Web based**
Trials			

Primary prevention	ISRCTN27988779	PREVENCANADOL project: impact of a website and some mobile phone SMS on behavioral risk of cancer in school population and its adult environment	
Treatment and concordance	ISRCTN00735390	Evaluation of an e-health intervention for cancer patients support	
NHS endorsed interventions			
Primary prevention	Bowel cancer	http://www.nhs.uk/Tools/Pages/Bowel-cancer-self-assessment.aspx?Tag=Self+assessments	
Primary prevention	Skin cancer	http://www.nhs.uk/Tools/Pages/moleassessment.aspx?Tag=Self+assessments	

Table A3: Digital health in cardiovascular disease

Reviews			
Area	**Citation**	**Abstract**	**Intervention**
Primary Prevention	Franklin NC, Lavie CJ, Arena RA. Personal health technology: A new era in cardiovascular disease prevention. Postgraduate Medicine. 2015;127(2):150-8 9p	We conclude that virtually all the technological tools and resources identified (e.g. Internet-based communications including websites, weblogs and wikis, mobile devices and applications, social media, and wearable monitors) can be strategically leveraged to enhance self-care behaviors for CVD risk reduction and SP but further research is needed to evaluate their efficacy, cost-effectiveness, and long-term maintainability.	
Primary Prevention	Pietrzak E, Cotea C, Pullman S. Primary and Secondary Prevention of Cardiovascular Disease: IS THERE A PLACE FOR INTERNET-BASED INTERVENTIONS? Journal of Cardiopulmonary Rehabilitation & Prevention. 2014;34(5):303-17 15p	There is emerging evidence that Internet-based interventions may reduce cardiovascular risk in cardiac patients and in populations with a heightened risk of CVD. Such interventions may also represent an alternative method of providing CVD prevention strategies.	
Primary Prevention	Neubeck L, Lowres N, Benjamin EJ, Freedman SB, Coorey G, Redfern J. The mobile revolution--using smartphone apps to prevent cardiovascular disease. Nature Reviews	In this Review, we assess the current literature and content of existing apps that target patients with CVD risk factors and that can facilitate behaviour change. We present an overview of the current literature on mobile technology as it relates to prevention and management of CVD. We also evaluate how apps can be used throughout all age groups with different CVD prevention needs.	

	Cardiology. 2015;12(6):350-60 11p		
Primary Prevention	Widmer RJ, Collins NM, Collins CS, West CP, Lerman LO, Lerman A. Digital health interventions for the prevention of cardiovascular disease: a systematic review and meta-analysis. Mayo Clinic Proceedings. 2015;90(4):469-80	Overall, these aggregations of data provide evidence that DHIs can reduce CVD outcomes and have a positive impact on risk factors for CVD	
Treatment and concordance	Chandak A, Joshi A. Self-management of hypertension using technology enabled interventions in primary care settings. Technology & Health Care. 2015;23(1):119-28 10p	Summary: Interventions to improve BP control for self-management of hypertension should be aimed at both physicians as well as the patients. More interventions should utilize the JNC-7 guidelines and cost-effectiveness of the intervention should also be assessed.	
Trials			
Primary prevention	ISRCTN11394514	A trial of low-cost, technology-assisted, integrated care delivery programme to prevent serious cardiovascular events in disadvantaged populations **DOI 10.1186/ISRCTN11394514**	
Treatment and concordance	ISRCTN13790648	Development of a hypertension self-management digital intervention to be integrated and supported within primary care	

Table A4: Digital health in diabetes

Reviews			
Area	**Citation**	**Abstract**	**Intervention**
Treatment concordance	Huckvale, K., S. Adomaviciute, J. T. Prieto, M. K. Leow and J. Car (2015). "Smartphone apps for calculating insulin dose: a systematic assessment." BMC Medicine 13: 106.	The majority of insulin dose calculator apps provide no protection against, and may actively contribute to, incorrect or inappropriate dose recommendations that put current users at risk of both catastrophic overdose and more subtle harms resulting from suboptimal glucose control. Healthcare professionals should exercise substantial caution in recommending unregulated dose calculators to patients and address app safety as part of self-management education.	**Insulin Dose calculator**
Treatment concordance	Garabedian, L. F., D. Ross-Degnan and J. F. Wharam (2015). "Mobile Phone and Smartphone Technologies for Diabetes Care and Self-Management." Current Diabetes Reports 15(12): 109.	Found only 20 peer-reviewed articles, published since 2010, with robust evidence about the effectiveness of mHealth interventions for diabetes. The majority of these interventions showed improvement on primary endpoints, such as HbA1c; mHealth technologies that interacted with both patients and providers were more likely to be effective. There was little evidence about persistent use by patients, use by a patient's health care provider, or long-term effectiveness. No robust studies evaluated the more than 1100 publicly available smartphone apps for diabetes. More research with valid study designs and longer follow-up is needed to evaluate the impact of mHealth technologies for diabetes care and self-management.	

Treatment concordance	Sheehy, S., G. Cohen and K. R. Owen (2014). "Self-management of diabetes in children and young adults using technology and smartphone applications." Current Diabetes Reviews 10(5): 298-301.	A large number of smartphone apps are targeted at people with diabetes, but a limited number of well designed evaluation studies have been performed. As our review shows, the evidence base for efficacy of most of these applications is minimal and improvement in hard outcomes such as HbA1c and complication development is largely lacking.	
Treatment concordance	Cotter, A. P., N. Durant, A. A. Agne and A. L. Cherrington (2014). "Internet interventions to support lifestyle modification for diabetes management: a systematic review of the evidence." Journal of Diabetes & its Complications**28**(2): 243-251.	Web-based strategies provide a viable option for facilitating diabetes self-management. Future research is needed on the use of web-based interventions in underserved communities and studies examining website utilization patterns and engagement over time.	

Treatment concordance	Arnhold, M., M. Quade and W. Kirch (2014). "Mobile applications for diabetics: a systematic review and expert-based usability evaluation considering the special requirements of diabetes patients age 50 years or older." Journal of Medical Internet Research 16(4): e104.	A vast number of diabetes apps already exist, but the majority offer similar functionalities and combine only one to two functions in one app. Patients and physicians alike should be involved in the app development process to a greater extent. We expect that the data transmission of health parameters to physicians will gain more importance in future applications. The usability of diabetes apps for patients aged 50 or older was moderate to good. But this result applied mainly to apps offering a small range of functions. Multifunctional apps performed considerably worse in terms of usability. Moreover, the presence of a documentation or analysis function resulted in significantly lower usability scores. The operability of accessibility features for diabetes apps was quite limited, except for the feature "screen reader".	
Treatment concordance	van Vugt, M., M. de Wit, W. H. Cleijne and F. J. Snoek (2013). "Use of behavioral change techniques in web-based self-management programs for type 2 diabetes patients: systematic review." Journal of Medical Internet Research 15(12): e279.	A relatively small number of theory-based online self-management support programs for T2DM have been reported using only a select number of BCTs. The development of future online self-management interventions should be based on the use of theories and BCTs and should be reported accurately.	
Treatment concordance	Eng, D. S. and J. M. Lee (2013). "The promise and peril of mobile health applications for diabetes and endocrinology." Pediatric Diabetes 14(4): 231-238.	Although mobile health apps have great potential for improving chronic disease care, they face a number of challenges including lack of evidence of clinical effectiveness, lack of integration with the health care delivery system, the need for formal evaluation and review and organized searching for health apps, and potential threats to safety and privacy	

Treatment concordance	El-Gayar, O., P. Timsina, N. Nawar and W. Eid (2013). "Mobile applications for diabetes self-management: status and potential." Journal of Diabetes Science & Technology 7(1): 247-262.	Available applications support self-management tasks such as physical exercise, insulin dosage or medication, blood glucose testing, and diet. Other support tasks considered include decision support, notification/alert, tagging of input data, and integration with social media. The review points to the potential for mobile applications to have a positive impact on diabetes self-management. Analysis indicates that application usage is associated with improved attitudes favorable to diabetes self-management. Limitations of the applications include lack of personalized feedback; usability issues, particularly the ease of data entry; and integration with patients and electronic health records.	
Treatment concordance	Arsand, E., D. H. Froisland, S. O. Skrovseth, T. Chomutare, N. Tatara, G. Hartvigsen and J. T. Tufano (2012). "Mobile health applications to assist patients with diabetes: lessons learned and design implications." Journal of Diabetes Science & Technology 6(5): 1197-1206.	Self-management is critical to achieving diabetes treatment goals. Mobile phones and Bluetooth can supportself-management and lifestyle changes for chronic diseases such as diabetes. A mobile health (mHealth) research platform--the Few Touch Application (FTA)--is a tool designed to support the self-management of diabetes. The FTA consists of a mobile phone-based diabetes diary, which can be updated both manually from user input and automatically by wireless data transfer, and which provides personalized decision support for the achievement of personal health goals.	
Treatment concordance	Chomutare, T., L. Fernandez-Luque, E. Arsand and G. Hartvigsen (2011). "Features of mobile diabetes applications: review of the literature and analysis of current applications compared against evidence-	While a wide selection of mobile applications seems to be available for people with diabetes, this study shows there are obvious gaps between the evidence-based recommendations and the functionality used in study interventions or found in online markets. Current results confirm personalized education as an underrepresented feature in diabetes mobile applications. We found no studies evaluating social media concepts in	

	based guidelines." Journal of Medical Internet Research 13(3): e65.	diabetes self-management on mobile devices, and its potential remains largely unexplored.	
Treatment concordance	Pal K, Eastwood Sophie V, Michie S, Farmer Andrew J, Barnard Maria L, Peacock R, et al. Computer-based diabetes self-management interventions for adults with type 2 diabetes mellitus. Cochrane Database of Systematic Reviews [Internet]. 2013; (3). Available from: http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD008776.pub2/abstract	Computer-based diabetes self-management interventions to manage type 2 diabetes appear to have a small beneficial effect on blood glucose control and the effect was larger in the mobile phone subgroup. There is no evidence to show benefits in other biological outcomes or any cognitive, behavioural or emotional outcomes.	**Intervention: computer-based responsive software applications**
Secondary prevention	Connelly, J., A. Kirk, J. Masthoff and S. MacRury (2013). "The use of technology to promote physical activity in Type 2 diabetes management: a systematic review." Diabetic Medicine 30(12): 1420-1432.	Technology-based interventions to promote physical activity are effective; using further methods to promote participant adherence is associated with greater benefit. Further research should look into strategies to enhance adherence and sustainability in order to increase the effectiveness of technology-based physical activity intervention in diabetes care.	
Trials			
Treatment concordance	Digital Diabetes Project.ISRCTN57929056	This study will investigate the usability and acceptability of digital communication methods to patients with indifferent control of their type 1 diabetes.	

Table A5: Digital health in respiratory medicine

Reviews			
Area	**Citation**	**Abstract**	**Intervention**
Treatment and concordance	Nickels A, Dimov V. Innovations in technology: social media and mobile technology in the care of adolescents with asthma. Current Allergy & Asthma Reports. 2012;12(6):607-12.	Three studies fulfilled the criteria for adolescent intervention using Internet-based sites but did not provide evidence for effectiveness. Two studies focused on mobile technology. One study included text message reminders for controller medication use in asthma patients. Perceived usefulness, satisfaction, and ease of use of text messages were high, but there was no improvement in asthma control. The search found no studies exploring the use of smartphone applications or social media services. Current studies of technology use in adolescents with asthma do not provide consistent evidence of effectiveness. The positive attitude toward use of social media or mobile technology opens the possibility for future studies to further explore the potential benefits of such interventions.	**Internet based /text message reminder**

Treatment and concordance	Morrison D, Wyke S, Agur K, Cameron EJ, Docking RI, Mackenzie AM, et al. Digital asthma self-management interventions: a systematic review. Journal of Medical Internet Research. 2014;16(2):e51	Digital self-management interventions show promise, with evidence of beneficial effects on some outcomes. There is no evidence about utility in those over 65 years and no information about socioeconomic status of participants, making understanding the "reach" of such interventions difficult. Digital interventions are poorly described within reviews, with insufficient information about barriers and facilitators to their uptake and utilization. To address these gaps, a detailed quantitative systematic review of digital asthma interventions and an examination of the primary qualitative literature are warranted, as well as greater emphasis on economic analysis within trials.	**Intervention: online or computerized interventions facilitating self-management**
Treatment and concordance	Al-Durra M, Torio MB, Cafazzo JA. The use of behavior change theory in Internet-based asthma self-management interventions: a systematic review. Journal of Medical Internet Research. 2015;17(4):e89.	The findings of this literature review indicate that the majority of published Internet-based interventions do not use any documented behavioral change theory, clinical guidelines, and/or assessment tools to inform their design. Further, it was found that the application of clinical guidelines and assessment tools were more salient across the reviewed interventions. A consequence, as such, is that many Internet-based asthma interventions are designed in an ad hoc manner, without the use of any notable evidence-based theoretical frameworks, clinical guidelines, and/or assessment tools.	
Secondary prevention	Marcano Belisario JS,Huckvale K, GreenfieldG, Car J, Gunn LH. Smartphone and tablet self management apps for asthma. Cochrane Database of Systematic Reviews 2013,	Due to the lack of enough included studies and the considerable differences between them, we were unable to obtain conclusive answers to our research question. One study showed that the use of a smartphone app can result in better asthma-related quality of life and lung function, and reduced visits to the emergency department. The other study failed to show any significant improvements in asthma related outcomes after using a smartphone app as a delivery mechanism.	**Smartphone app**

	DOI:10.1002/14651858.CD010013.pub2.		
Trials			
Secondary prevention	Digital interventions for chronic obstructive pulmonary disease (COPD). ISRCTN75958874	Can interactive digital materials enhance people with COPDs engagement and motivation to increase physical activity compared to standard written materials?	
Secondary Prevention	The eHealth Diary: Digital pen telemonitoring of patients with advanced COPD and heart failure within specialised home care.ISRCTN34252610	The hypothesis is that special home healthcare and use of the telehealth system will detect early signs of deterioration of heart failure and COPD and monitor drug intake, and thereby decrease acute hospital re-admissions and increase the patients' quality of life.	
NHS endorsed interventions			
Primary Prevention	Smoking in asthma	http://www.nhs.uk/Tools/Pages/Asthma.aspx?Tag=Stop+smoking	

Table A6: Digital health in mental health

Reviews			
Area	**Citation**	**Abstract**	**Intervention**

Primary prevention	Wray TB, Merrill JE, Monti PM. Using Ecological Momentary Assessment (EMA) to Assess Situation-Level Predictors of Alcohol Use and Alcohol-Related Consequences. *Alcohol Research : Current Reviews*. 2014;36(1):19-27.	Ecological momentary assessment (EMA) has afforded several important advances in the field of alcohol research, including testing prominent models of alcohol abuse etiology in "high resolution." Using high-tech methods for signaling and/or assessment, such as mobile electronic diaries, personal data assistants, and smartphones, EMA approaches potentially can improve understanding of precipitants of drinking, drinking patterns, and consequences. For example, EMA has been used to study complex drinking patterns and dynamic predictors of drinking in near–real time. Compared with other methods, EMA can better sample and capture changes in these phenomena that occur in relatively short time frames. EMA also has several potential applications in studying the consequences of alcohol use, including physical, interpersonal, behavioral, and legal problems.	**Ecological momentary assessment (EMA)**
Primary prevention	Christensen H, Batterham PJ, O'Dea B. E-health interventions for suicide prevention. International Journal of Environmental Research & Public Health [Electronic Resource]. 2014;11(8):8193-212.	E-health interventions are now being considered as a means to identify at-risk individuals, offer self-help through web interventions or to deliver proactive interventions in response to individuals' posts on social media. In this article, we examine research studies which focus on these three aspects of suicide and the internet: the use of online screening for suicide, the effectiveness of e-health interventions aimed to manage suicidal thoughts, and newer studies which aim to proactively intervene when individuals at risk of suicide are identified by their social media postings. We conclude that online screening may have a role, although there is a need for additional robust controlled research to establish whether suicide screening can effectively reduce suicide-related outcomes, and in what settings online screening might be most effective. The effectiveness of Internet interventions may be increased if these interventions are	**cCBT, iCBT, Deprexis, CATCH-IT**

		designed to specifically target suicidal thoughts, rather than associated conditions such as depression. The evidence for the use of intervention practices using social media is possible, although validity, feasibility and implementation remains highly uncertain.	
Secondary Prevention	Beckjord E, Shiffman S. Background for Real-Time Monitoring and Intervention Related to Alcohol Use. Alcohol Research. 2014;36(1):9-18.	Real-time assessment, known as ecological momentary assessment (EMA), and real-time intervention (ecological momentary intervention [EMI]) can significantly extend the reach and impact of interventions to help individuals reduce their drinking behavior. For EMA, the user provides information on the variable of interest (e.g., drinking or craving) via a mobile device. This data reporting can occur either at pre-specified times or in certain high-risk situations. The primary benefits of EMA include external validity, minimized recall bias, and the ability to capture dynamic patterns in human behavior. EMI refers to interventions that are delivered via mobile devices at the time when the user needs it (i.e., in a high-risk situation). Key constructs of EMI are what interventions are delivered and when they are delivered. Timing of the EMI often is determined by the user's EMA reports. Both have been studied in people with alcohol use disorders. EMA and EMI often are used in conjunction with each other because EMA can help inform the optimal timing of EMI and help tailor its content. Further development of high-impact, algorithm-driven, technology-mediated real-time intervention may help reduce drinking and promote positive health behavior change.	**EMA/EMI**
Secondary prevention, maintenance	Valenza G, Lanata A, Paradiso R, Scilingo EP. Advanced technology meets mental health: how smartphones,	Personalized Monitoring Systems for Care in Mental Health (PSYCHE) project [2][3][4]. PSYCHE identifies a personalized, pervasive, cost-effective, and multiparametric platform for the long-term acquisition of data gathered from patients affected by mental disorders. The mission of	**Sensorized clothes**

	textile electronics, and signal processing can serve mental health monitoring, diagnosis, and treatment. IEEE Pulse. 2014;5(3):56-9.	the project is to include a technological platform in mental health care, where a closed loop between clinicians and patients is implemented. Patients are monitored by means of sensorized clothes and can interact with user-friendly interfaces on smartphones to communicate with clinicians, who, in turn, can check the mental status of patients by means of professional Web-based interfaces.	
Secondary prevention, maintenance	Kauppi K, Välimäki M, Hätönen Heli M, Kuosmanen Lauri M, Warwick-Smith K, Adams Clive E. Information and communication technology based prompting for treatment compliance for people with serious mental illness. Cochrane Database of Systematic Reviews [Internet]. 2014; (6).	we could only include two studies with a total of 358 participants. The studies had a moderate risk of bias, and therefore risk overestimating any positive effects of ICT-based prompting. Both included studies compared semi-automatised ICT-based prompting intervention with standard care groups in mental health outpatient care. The interventions were SMS-message and an electronic assistant device. One included study reported our primary outcome, compliance. There was not any clear evidence that ICT-based prompts increase improvement in compliance. The evidence base on the effects of ICT-based prompts is still inconclusive. Data to clarify ICT-based prompting effects are awaited from an ongoing trial, but further well-conducted trials considering the different ICT-based prompts are warranted.	
Treastment and concordance	Ehrenreich B, Righter B, Rocke DA, Dixon L, Himelhoch S. Are mobile phones and handheld computers being used to enhance delivery of psychiatric treatment? A systematic review. Journal of Nervous &	Five studies used mobile phones to target smoking cessation. Those receiving the smoking cessation intervention were significantly more likely to achieve abstinence compared with those under the control condition. Three studies used non-personal digital assistant (PDA) handheld computers targeting anxiety. Compared with those in the control condition, those who received the non-PDA handheld computer intervention had significant improvement in anxiety outcomes in only one of the three studies.	**Smoking cessation apps**

	Mental Disease. 2011;199(11):886-91		
Treatment and compliance	Renton T, Tang H, Ennis N, Cusimano MD, Bhalerao S, Schweizer TA, et al. Web-based intervention programs for depression: a scoping review and evaluation. Journal of Medical Internet Research. 2014;16(9):e209	RESULTS: The review identified 32 programs meeting inclusion criteria. There was a great deal of variability among the programs captured in this evaluation. Many of the programs were developed for general adolescent or adult audiences, with few (n=2) focusing on special populations (eg, military personnel, older adults). Cognitive behavioral therapy was the most common therapeutic approach used in the programs described. Program interactive components included mood assessments and supplementary homework sheets such as activity planning and goal setting. Only 12 of the programs had published evidence in support of their efficacy and treatment of depressive symptoms. CONCLUSIONS: There are a number of interactive depression interventions available through the Internet. Recommendations for future programs, or the adaptation of existing programs include offering a greater selection of alternative languages, removing registration restrictions, free trial periods for programs requiring user fees, and amending programs to meet the needs of special populations (eg, those with cognitive and/or visual impairments). Furthermore, discussion of specific and relevant topics to the target audience while also enhancing overall user control would contribute to a more accessible intervention tool.	Web based interventions for depression
Treatment and compliance	Andrews G, Newby JM, Williams AD. Internet-delivered cognitive behavior therapy for anxiety disorders is here to stay.	Anxiety disorders are common and disabling. Cognitive behavior therapy is the treatment of choice but is often difficult to obtain. Automated, internet-delivered, cognitive behavior therapy (iCBT) courses may be an answer. There are three recent systematic reviews of randomized controlled trials that show that the benefits are substantial (d=1.0) and	**CBT**

	Current Psychiatry Reports. 2015;17(1):533.	similar to face to face CBT. There are two large effectiveness trials that demonstrate strong effects when iCBT is used in primary care; 60 % of patients who complete the courses no longer meet diagnostic criteria. The courses are suitable for most people with a primary anxiety disorder. Research studies usually exclude people whose anxiety is secondary to schizophrenia, bipolar disorder, or substance abuse or who are actively suicidal. Little additional input from clinicians is required. Patients find the courses very convenient. Clinically, the principal advantage is the fidelity of the treatment. What you prescribe is what the patient sees.	
Treatment and compliance	Vallury KD, Jones M, Oosterbroek C. Computerized Cognitive Behavior Therapy for Anxiety and Depression in Rural Areas: A Systematic Review. Journal of Medical Internet Research. 2015;17(6):e139.	CONCLUSIONS: CCBT can be effective for addressing depression and anxiety and is acceptable among rural participants. Further work is required to confirm these results across a wider range of countries, and to determine the most feasible model of CCBT delivery, in partnership with people who live and work in rural and remote communities.	**CBT**
Treatment and compliance	Aardoom, J. J., Dingemans, A. E., Spinhoven, P. and Van Furth, E. F. (2013), Treating eating disorders over the internet: A systematic review and future research directions. Int. J. Eat. Disord., 46: 539–552. doi: 10.1002/eat.22135	Twenty-one studies were included. Methodological quality varied. Internet-based treatments were superior to waiting lists in reducing ED psychopathology, frequency of binge eating and purging, and in improving (ED-related) quality of life. Internet-based treatment was more effective for individuals with less comorbid psychopathology, binge eating as opposed to restrictive problems, and individuals with binge eating disorder as opposed to bulimia nervosa. Higher levels of compliance were related to more improvements in ED symptoms. Study dropout ranged from 5.3 to 76.8%. Inclusion of face-to-face assessments and therapist support seemed	Internet based treatment for eating disorders

		to enhance study compliance. Overall, the internet can be considered an acceptable vehicle for delivering ED treatment.	
Treatment and compliance	Bauer, S. and Moessner, M. (2013), Harnessing the power of technology for the treatment and prevention of eating disorders. Int. J. Eat. Disord., 46: 508–515. doi: 10.1002/eat.22109	This review suggests that technology-enhanced interventions offer multiple opportunities to improve care for eating disorders. More research is needed on the efficacy, effectiveness, cost-effectiveness, and reach of these approaches to ultimately estimate their public health impact. It is discussed to what extent innovative models of care integrating technology-enhanced interventions and face-to-face interventions may improve service delivery for eating disorders.	**cCBT**
Treatment and compliance	Juarascio A. S., Manasse S. M., Goldstein S. P., Forman E. M., and Butryn M. L. (2014) Review of Smartphone Applications for the Treatment of Eating Disorders, Eur. Eat. Disorders Rev., 23; pages 1–11, doi: 10.1002/erv.2327.	mHealth tools may be a feasible modality for delivering evidence-based treatments and principles (EBPs), and may enhance treatment for eating disorders (EDs). However, research on the efficacy of mHealth tools for EDs and the extent to which they include EBPs is lacking. The current study sought to (i) review existing apps for EDs, (ii) determine the extent to which available treatment apps utilize EBPs, and (iii) assess the degree to which existing smartphone apps utilize recent advances in smartphone technology. Overall, existing ED intervention apps contained minimal EBPs and failed to incorporate smartphone capabilities. For smartphone apps to be a feasible and effective ED treatment modality, it may be useful for creators to begin taking utilizing the abilities that set smartphones apart from in-person treatment while incorporating EBPs. Before mHealth tools are incorporated into treatments for EDs, it is necessary that the feasibility, acceptability, and efficacy be evaluated.	**Smartphone App**
Treatment and compliance	Alvarez-Jimenez M, Alcazar-Corcoles MA, Gonzalez-Blanch C, Bendall S, McGorry PD,	Interventions included web-based psycho-education; web-based psycho-education plus moderated forums for patients and supporters; integrated web-based therapy, social networking and peer and expert moderation;	

	Gleeson JF. Online, social media and mobile technologies for psychosis treatment: a systematic review on novel user-led interventions. Schizophrenia Research. 2014;156(1):96-106.	web-based CBT; personalized advice based on clinical monitoring; and text messaging interventions. Preliminary evidence indicated that online and mobile-based interventions show promise in improving positive psychotic symptoms, hospital admissions, socialization, social connectedness, depression and medication adherence. The heterogeneity, poor quality and early state of current research precludes any definite conclusions. Future research should investigate the efficacy of online and mobile interventions through controlled, well-powered studies, which investigate intervention and patient factors associated with take-up and intervention effects	
Treatment and compliance	Cunningham JA, Gulliver A, Farrer L, Bennett K, Carron-Arthur B. Internet interventions for mental health and addictions: current findings and future directions. Current Psychiatry Reports. 2014;16(12):521.	There is considerable evidence for the effectiveness of Internet-based interventions targeting depression, anxiety disorders, alcohol use and smoking. Small to moderate effect sizes have been reported for interventions targeting depression, anxiety and alcohol use, and smoking interventions have shown large effects. The addition of human support to depression and anxiety interventions has generally resulted in larger treatments effects, but this trend has not been observed in trials of interventions targeting alcohol use. There is some evidence that online interventions can be as effective as face-to-face therapies, at least for anxiety disorders. Despite a proliferation of research activity in this area, gaps in knowledge remain. Future research should focus on the development and evaluation of interventions for different platforms (e.g. smartphone applications), examining the long-term impacts of these interventions, determining active intervention components and identifying methods for enhancing tailoring and engagement. Careful consideration should be given to the ongoing technical and clinical expertise required to	**Internet intervention, iCBT**

		ensure that Internet interventions are delivered safely and professionally in a rapidly changing technology environment.	
Treatment and compliance	Harrison AM, Goozee R. Psych-related iPhone apps. Journal of Mental Health. 2014;23(1):48-50.	we conducted a pilot, web-based review exploring free iPhone apps using a replicable search strategy within the iTunes Store search function. A selection of apps were selected and subjectively assessed in terms of their usability, utility, graphics, and associated costs for the consumer. We concluded that the apps reviewed, though novel, are limited in their scope and utility. We also note a significant gap in more scientific, evidence-based app technology, and pose some pertinent ethical questions when developing future psych-related apps.	**Apps**
Treatment and compliance	Musiat P, Tarrier N. Collateral outcomes in e-mental health: a systematic review of the evidence for added benefits of computerized cognitive behavior therapy interventions for mental health. Psychological Medicine. 2014;44(15):3137-50	The results suggest that cCBT interventions are cost-effective and often cheaper than usual care. Limited evidence was found with regard to geographic flexibility, time flexibility, waiting time for treatment, stigma and the effects on help-seeking. Although the results of this systematic review on the collateral outcomes provide support for the potential of cCBT, these outcomes need to be better assessed within individual e-mental health studies	**cCBT**
Treatment and compliance	van der Krieke L, Wunderink L, Emerencia AC, de Jonge P, Sytema S. E-mental health self-management for psychotic disorders: state of the art and future perspectives. Psychiatric Services. 2014;65(1):33-49.	Interventions included psychoeducation, medication management, communication and shared decision making, management of daily functioning, lifestyle management, peer support, and real-time self-monitoring by daily measurements (experience sampling monitoring).People with psychotic disorders were able and willing to use e–mental health services. Results suggest that e–mental health services are at least as effective as usual care or nontechnological approaches. Larger effects were found for medication management e–mental health	**E–mental health self-management interventions**

		services. No studies reported a negative effect. Results must be interpreted cautiously, because they are based on a small number of studies.	
Treatment and compliance	Nicholas J, Larsen ME, Proudfoot J, Christensen H. Mobile Apps for Bipolar Disorder: A Systematic Review of Features and Content Quality. Journal of Medical Internet Research. 2015;17(8):e198-e 1p	In general, the content of currently available apps for BD is not in line with practice guidelines or established self-management principles. Apps also fail to provide important information to help users assess their quality, with most lacking source citation and a privacy policy. Therefore, both consumers and clinicians should exercise caution with app selection. While mHealth offers great opportunities for the development of quality evidence-based mobile interventions, new frameworks for mobile mental health research are needed to ensure the timely availability of evidence-based apps to the public.	**smartphone Apps**
Treatment and compliance	Parikh SV, Huniewicz P. E-health: an overview of the uses of the Internet, social media, apps, and websites for mood disorders. Current Opinion in Psychiatry. 2015;28(1):13-7	E-health strategies, particularly online psychotherapy and tools to document symptoms, are useful and likely effective. Social communication strategies show enormous popularity, but urgently require research evaluation for impact.	**E-health**
Treatment and concordance	Davies EB, Morriss R, Glazebrook C. Computer-delivered and web-based interventions to improve depression, anxiety, and psychological well-being of university students: a	The findings suggest Web-based and computer-delivered interventions can be effective in improving students' depression, anxiety, and stress outcomes when compared to inactive controls, but some caution is needed when compared to other trial arms and methodological issues were noticeable. Interventions need to be trialed on more heterogeneous student samples and would benefit from user evaluation. Future trials	

	systematic review and meta-analysis. Journal of Medical Internet Research. 2014;16(5):e130.	should address methodological considerations to improve reporting of trial quality and address post-intervention skewed data.	
Treatment and concordance	Gainsbury, S. and Blaszczynski A. A systematic review of Internet-based therapy for the treatment of addictions. (2011) Clinical Psychology Review. 31(3): 490–498	Internet therapy may be suitable for those unwilling or unable to access traditional treatment. ► Few empirical studies exist for Internet therapy for addictions and more research is needed. ► Early studies show positive results for online therapy including appropriate behavioral change.	
Treatment and concordance	Donoghue K, Patton R, Phillips T, Deluca P, Drummond C. The effectiveness of electronic screening and brief intervention for reducing levels of alcohol consumption: a systematic review and meta-analysis. Journal of Medical Internet Research. 2014;16(6):e142.	**eSBI as an electronic intervention aimed at providing information and advice designed to achieve a reduction in hazardous/harmful alcohol consumption with no substantial face-to-face therapeutic component..** A significant reduction in weekly alcohol consumption between intervention and control conditions was demonstrated between 3 months and less than 12 months follow-up indicating eSBI is an effective intervention	**eSBI.**
Treatment and concordance	Quanbeck A, Chih M-Y, Isham A, Johnson R, Gustafson D. Mobile Delivery of Treatment for Alcohol Use Disorders: A Review of the Literature. *Alcohol Research : Current Reviews*. 2014;36(1):111-122.	**Several systems for treating alcohol-use disorders (AUDs) exist that operate on mobile phones. These systems are categorized into four groups: text-messaging monitoring and reminder systems, text-messaging intervention systems, comprehensive recovery management systems, and game-based systems.** Although many commercial applications for treatment of AUDs exist, few (if any) have empirical evidence of effectiveness. The available evidence suggests that although	**Systems for treating alcohol-use disorders (AUDs) on mobile phones.**

		texting-based applications may have beneficial effects, they are probably insufficient as interventions for AUDs. Comprehensive recovery management systems have the strongest theoretical base and have yielded the strongest and longest-lasting effects, but challenges remain, including cost, understanding which features account for effects, and keeping up with technological advances.	
Treatment and concordance	Gulliver A, Farrer L, Chan JK, Tait RJ, Bennett K, Calear AL, et al. Technology-based interventions for tobacco and other drug use in university and college students: a systematic review and meta-analysis. Addiction Science & Clinical Practice. 2015;10:5.	University students have high levels of tobacco and other drug use, yet they are unlikely to seek traditional care. Technology-based interventions are highly relevant to this population. Across all 12 studies, a total of 20 technology-based interventions were reviewed. A range of technology was employed in the interventions, including stand-alone computer programs (n = 10), internet (n = 5), telephone (n = 3), and mobile SMS (n = 2). CONCLUSIONS: Although technological interventions have the potential to reduce drug use in tertiary students, very few trials have been conducted, particularly for substances other than tobacco. However, the improvement shown in abstinence from tobacco use has the potential to impact substantially on morbidity and mortality.	**Technology based interventions for students**
Treatment and concordance	Donker T, Petrie K, Proudfoot J, Clarke J, Birch MR, Christensen H. Smartphones for smarter delivery of mental health programs: a systematic review. Journal of Medical Internet Research. 2013;15(11):e247.	Mental health apps have the potential to be effective and may significantly improve treatment accessibility. However, the majority of apps that are currently available lack scientific evidence about their efficacy. The public needs to be educated on how to identify the few evidence-based mental health apps available in the public domain to date. Further rigorous research is required to develop and test evidence-based programs. Given the small number of studies and participants included in this review, the high risk of bias, and unknown efficacy of long-term follow-up, current findings should be interpreted with caution, pending	**Apps, *Mobilyze!, Mobile-type, DBT Coach, Mobile Stress Management, Get Happy Program***

		replication. Two of the 5 evidence-based mental health apps are currently commercially available in app stores.	
Treatment and concordance	Mohr DC, Burns MN, Schueller SM, Clarke G, Klinkman M. Behavioral intervention technologies: evidence review and recommendations for future research in mental health. General Hospital Psychiatry. 2013;35(4):332-8.	Videoconferencing and standard telephone technologies to deliver psychotherapy have been well validated. Web-based interventions have shown efficacy across a broad range of mental health outcomes. Social media such as online support groups have produced disappointing outcomes when used alone. Mobile technologies have received limited attention for mental health outcomes. Virtual reality has shown good efficacy for anxiety and pediatric disorders. Serious gaming has received little work in mental health.	**web-based intevention. Social media. Virtual reality. Gaming**
Treatment and concordance	Andersson G, Cuijpers P, Carlbring P, Riper H, Hedman E. Guided Internet-based vs. face-to-face cognitive behavior therapy for psychiatric and somatic disorders: a systematic review and meta-analysis. World Psychiatry. 2014;13(3):288-295. doi:10.1002/wps.20151.	Internet-delivered cognitive behavior therapy (ICBT) has been tested in many research trials, but to a lesser extent directly compared to face-to-face delivered cognitive behavior therapy (CBT). We conducted a systematic review and meta-analysis of trials in which guided ICBT was directly compared to face-to-face CBT. Studies on psychiatric and somatic conditions were included. Systematic searches resulted in 13 studies (total N=1053) that met all criteria and were included in the review. There were three studies on social anxiety disorder, three on panic disorder, two on depressive symptoms, two on body dissatisfaction, one on tinnitus, one on male sexual dysfunction, and one on spider phobia. Face-to-face CBT was either in the individual format (n=6) or in the group format (n=7). We also assessed quality and risk of bias. Results showed a pooled effect size (Hedges' g) at post-treatment of −0.01 (95% CI: −0.13 to 0.12), indicating that guided ICBT and face-to-face treatment produce equivalent overall effects. Study quality did not affect outcomes. While the overall results	**iCBT**

		indicate equivalence, there are still few studies for each psychiatric and somatic condition and many conditions for which guided ICBT has not been compared to face-to-face treatment. Thus, more research is needed to establish equivalence of the two treatment formats.	
Trials			
Primary Prevention	ISRCTN15315334 Positive Psychology Smartphone Application.	This study is aiming to increase positive feelings in people's everyday lives. Provision of short positive psychology activities to individuals will increase levels of positive emotions relative to a control group.	Other
Treatment and concordance	ISRCTN67177737 Healthy Mind: A study of a web and smartphone stress management tool.	This study will disseminate 'Healthy Mind' a digital stress management intervention that is available as both a stand-alone Android application and a stand-alone website ('Healthy Paths').	Other
Treatment and concordance	ISRCTN34966555 Active Assistance for Psychological Therapy (Actissist): Using mobile technology to deliver cognitive behaviour therapy for psychosis.	The ACTISSIST project seeks to develop a mobile phone application (app) to deliver a CBT intervention to people with early psychosis. In this phase of the research (phase 3 of 3) participants will be randomly assigned to one of two conditions. Over a 12-week period participants will either receive the Actissist app, or a symptom monitoring app (ClinTouch). The principal aim of this phase is to assess the feasibility and acceptability of delivering a CBT intervention via a mobile phone to people with early psychosis.	Psychosis
Treatment and concordance	ISRCTN98453199 Evaluating the effectiveness of "Agoraphobia Free": A novel mobile application for treating Agoraphobia	The aim of this study is to examine whether the agoraphobia-specific mobile intervention ("agoraphobia-free") is more effective than the generic, control intervention ("stress free").	Agoraphobia
Treatment and concordance	ISRCTN15399617 Improving the continuity of care in	Is an aftercare intervention delivered via mobile phones and internet a feasible add-on to treatment as usual for patients with schizophrenia?	Schizophrenia

	schizophrenia through an intervention delivered via mobile phones and internet: a pilot study		
Treatment and concordance	ISRCTN10515845 Alcohol and disadvantaged men: developing a brief intervention for delivery by mobile phone	Can a brief intervention delivered by mobile reduce heavy drinking among disadvantaged young to middle aged men?	Addiction
Treatment and concordance	ISRCTN76298775 The iChill Project: can generalised anxiety disorder be prevented and treated using e-health interventions?	The effectiveness of online therapy for the prevention and treatment of generalised anxiety disorder: a multicentre randomised controlled trial	Anxiety
Treatment and concordance	ISRCTN15853981 Using a smartphone application as an adjunct to counselling in substance misuse treatment.	The Application to Improve Motivation (AiM) has been developed to help users improve their motivation to make and maintain a desired health behaviour change, such as drinking, smoking and exercise. This study aims to explore the utility and potential impact of this smartphone application used alongside routine clinical practice for people being treated for substance misuse.	substance misuse
NHS endorsed interventions			
Treatment and concordance	Big White Wall	http://www.nhs.uk/conditions/online-mental-health-services/pages/introduction.aspx	
Treatment and concordance	FearFighter	http://www.nhs.uk/conditions/online-mental-health-services/pages/introduction.aspx	

Treatment and concordance	leso digital health	http://www.nhs.uk/conditions/online-mental-health-services/pages/introduction.aspx	
Treatment and concordance	Kooth	http://www.nhs.uk/conditions/online-mental-health-services/pages/introduction.aspx	
Treatment and concordance	SilverCloud	http://www.nhs.uk/conditions/online-mental-health-services/pages/introduction.aspx	
Treatment and concordance	Sleepio	http://www.nhs.uk/conditions/online-mental-health-services/pages/introduction.aspx	
Treatment and concordance	Beating the blues	http://www.nhs.uk/Conditions/Cognitive-behavioural-therapy/Pages/How-does-it-work.aspx	

Table A7: Digital health in neurological conditions

Reviews			
Area	**Citation**	**Abstract**	**Intervention**
Treatment and concordance	Shegog R, Bamps YA, Patel A, Kakacek J, Escoffery C, Johnson EK, et al. Managing Epilepsy Well: Emerging e-Tools for epilepsy self-management. Epilepsy & Behavior. 2013;29(1):133-40.	MEW Network collaborators have conducted formative studies (n = 7) investigating the potential of e-Health to support epilepsy self-management and intervention studies evaluating e-Tools (n = 5). The MEW e-Tools (the MEW website, WebEase, UPLIFT, MINDSET, and PEARLS online training) and affiliated e-Tools (Texting 4 Control) are designed to complement self-management practices in each phase of the epilepsy care continuum.	**managing Epilepsy well (MEW) tools, WebEase, UPLIFT, PEARLS, Texting 4 Control, MINDSET**
Other	Maetzler, W., Domingos, J., Srulijes, K., Ferreira, J. J. and Bloem, B. R. (2013), Quantitative wearable sensors for objective assessment of Parkinson's disease. Mov. Disord., 28: 1628–1637. doi: 10.1002/mds.25628	**DynaPort MiniMod®, DynaPort MoveMonitor®, Physilog®, MicroMini Motionlogger,24-hour ECG Kinesia™, Parkinson's Kinetigraph, Xsens, SwayStar™,Triaxial G-Link accelerometers ,ADXL330®** There is a rapidly growing interest in the quantitative assessment of Parkinson's disease (PD)-associated signs and disability using wearable technology. Both persons with PD and their clinicians see advantages in such developments. Specifically, quantitative assessments using wearable technology may allow for continuous, unobtrusive, objective, and ecologically valid data collection. Also, this approach may improve patient-doctor interaction, influence therapeutic decisions, and ultimately ameliorate patients' global health status. In addition, such measures have the potential to be used as outcome parameters in clinical trials, allowing for frequent assessments; eg, in the home setting. This review discusses promising wearable	**Accelorometers and wearable tech**

		technology, addresses which parameters should be prioritized in such assessment strategies, and reports about studies that have already investigated daily life issues in PD using this new technology	
Other	Charters E, Gillett L, Simpson GK. Efficacy of electronic portable assistive devices for people with acquired brain injury: a systematic review. Neuropsychological Rehabilitation. 2015;25(1):82-121.	**PDA or electronic organiser, Mobile or smartphone, Electronic voice memo, NeuroPage or other paging system, Alternative and augmentative communication, Laptop, Combination of smart/mobile phones and PDAs**There was insufficient evidence to recommend any practice standards, but sufficient evidence to recommend the use of electronic reminder systems in supporting the everyday functioning of people with acquired brain injury as a practice guideline. Higher quality studies are required to support a broader range of compensatory roles that EPADs have the potential to play in neurorehabilitation and the long-term support of people with acquired brain injury.	**Mobile electronic portable assistive devices**
Other	Steins D, Dawes H, Esser P, Collett J. Wearable accelerometry-based technology capable of assessing functional activities in neurological populations in community settings: a systematic review. Journal of Neuroengineering & Rehabilitation. 2014;11:36.	This review aims to explore wearable accelerometry-based technology (ABT) capable of assessing mobility-related functional activities intended for rehabilitation purposes in community settings for neurological populations. In this review, we focus on the accuracy of ABT-based methods, types of outcome measures, and the implementation of ABT in non-clinical settings for rehabilitation purposes. While many studies support ABT's potential for telerehabilitation, few actually utilized it to assess mobility-related functional activities outside laboratory settings. To generate more appropriate outcome measures, there is a clear need to translate research findings and novel methods into practice	**wearable accelerometry-based technology**

Table A8: Digital health in musculoskeletal conditions

Reviews			
Area	**Citation**	**Abstract**	**Intervention**
Treatment concordance	Azevedo AR, de Sousa HM, Monteiro JA, Lima AR. Future perspectives of Smartphone applications for rheumatic diseases self-management. Rheumatology International. 2015;35(3):419-31.	Rheumatic diseases (RD) self-management interventions are designed to improve health-related quality of life, health care utilization, and perceived self-efficacy. Despite these demonstrated good results, there are several issues that hinder or render less appealing these interventions. One economically and socially viable solution is exploiting the potential of Smartphone technology. This potential comes from Smartphones pervasive presence in actual society, combined with the advantages of being personal, intuitive, and computationally powerful, with capability to support applications and assist its user throughout different activities of daily living and environments persistently. With their global acceptance increasing quickly, there is a great opportunity for mobile health in using Smartphone applications for RD self-management. Besides the potential of such applications, research on the development and evaluation of such applications is in the early stages. Therefore, it is important to foresee its future applicability in order to meet the needs of the twenty-first century.	**Smartphone**
Treatment concordance	Pietrzak E, Cotea C, Pullman S, Nasveld P. Self-management and rehabilitation in osteoarthritis: is there a place for internet-based interventions? Telemedicine	The electronic databases Cochrane, MEDLINE, and SCOPUS were searched to collect evidence on the impact of community-based Internet interventions for adult patients with osteoarthritis (OA) on health outcomes. Five studies met our review criteria. We found that Internet-based OA self-management interventions modestly but significantly improved four of six health status measures compared with usual care and	**Internet intervention**

	Journal & E-Health. 2013;19(10):800-5.	have been met with high acceptance and high user satisfaction. Preventive physiotherapy exercise delivered via videoconferencing for patients with OA-related knee pain significantly improved health measures including pain, stiffness, and physical function compared with the initial health status. Postoperative rehabilitation performed by a physical therapist via videoconferencing and "in-person" resulted in similar health measure improvements. The review findings show that the Internet may be successfully used as a medium for providing community-based self-management and rehabilitation interventions in OA.	

Table A8: Digital health in cross-cutting areas

Condition	Review Papers	Paper	Paper Summary	Technologies
Older People	**3**	Morris ME, Adair B, Ozanne E, Kurowski W, Miller KJ, Pearce AJ, et al. Smart technologies to enhance social connectedness in older people who live at home. Australasian Journal on Ageing. 2014;33(3):142-52	Smart technologies, such as tailored internet programs, may help older people better manage and understand various health conditions, resulting in subsequent improvements in aspects of social connectedness. Further research is required regarding how technological innovations could be promoted, marketed and implemented to benefit older people.	**The range of smart technologies under investigation included web-based information, intervention and communication programs.**
		Casilari E, Luque R, Moron MJ. Analysis of Android Device-Based Solutions for Fall Detection. Sensors. 2015;15(8):17827-94.	This paper presents a critical and thorough analysis of those existing fall detection systems that are based on Android devices. The review systematically classifies and compares the proposals of the literature taking into account different criteria such as the system architecture, the employed sensors, the detection algorithm or the response in case of a fall alarms. The study emphasizes the analysis of the evaluation methods that are employed to assess the effectiveness of the detection process. The review reveals the complete lack of a reference framework to validate and	**Fall detection system**

			compare the proposals. In addition, the study also shows that most research works do not evaluate the actual applicability of the Android devices (with limited battery and computing resources) to fall detection solutions.	
		Joe J, Demiris G. Older adults and mobile phones for health: a review. Journal of Biomedical Informatics. 2013;46(5):947-54.	Current work in using mobile phones for older adult use are spread across a variety of clinical domains. While this work is promising, current studies are generally smaller feasibility studies, and thus future work is needed to establish more generalizable, stronger base of evidence for effectiveness of these interventions.	**Mobile phones**

Chronic conditions	**5**			
		de Jongh T, Gurol-Urganci I, Vodopivec-Jamsek V, Car J, Atun R. Mobile phone messaging for facilitating self-management of long-term illnesses. Cochrane Database of Systematic Reviews 2012, Issue 12. Art. No.: CD007459. DOI: 10.1002/14651858.CD007459.pub2.	We found some, albeit very limited, indications that in certain cases mobile phone messaging interventions may provide benefit in supporting the self-management of long-term illnesses. However, there are significant information gaps regarding the long-term effects, acceptability, costs, and risks of such interventions. Given the enthusiasm with which so-called mHealth interventions are currently being implemented, further research into these issues is needed.	**mobile phone**
		Hermens H, op den Akker H, Tabak M, Wijsman J, Vollenbroek M. Personalized Coaching Systems to support healthy behavior in people with chronic conditions. Journal of Electromyography & Kinesiology. 2014;24(6):815-26.	Chronic conditions cannot be cured but daily behavior has a major effect on the severity of secondary problems and quality of life. Changing behavior however requires intensive support in daily life, which is not feasible with a human coach. A new coaching approach - so-called Personal Coaching Systems (PCSs) - use on-body sensing, combined with smart reasoning and context-aware feedback to support users in developing and maintaining a healthier behavior. Three different PCSs will be used to illustrate the different aspects of this approach: (1) Treatment of neck/shoulder pain. EMG patterns of the Trapezius muscles are used	**Personal coaching system**

			to estimate their level of relaxation. Personal vibrotactile feedback is given, to create awareness and enable learning when muscles are insufficiently relaxed. (2) Promoting a healthy activity pattern. Using a 3D accelerometer to measure activity and a smartphone to provide feedback. Timing and content of the feedback are adapted real-time, using machine-learning techniques, to optimize adherence. (3) Management of stress during daily living. The level of stress is quantified using a personal model involving a combination of different sensor signals (EMG, ECG, skin conductance, respiration). Results show that Personal Coaching Systems are feasible and a promising and challenging way forward to coach people with chronic conditions.	

		Hamine S, Gerth-Guyette E, Faulx D, Green BB, Ginsburg AS. Impact of mHealth chronic disease management on treatment adherence and patient outcomes: a systematic review. Journal of Medical Internet Research. 2015;17(2):e52.	We conducted a systematic review of the literature to evaluate the effectiveness of mHealth in supporting the adherence of patients to chronic diseases management ("mAdherence"), and the usability, feasibility, and acceptability of mAdherence tools and platforms in chronic disease management among patients and health care providers. There is potential for mHealth tools to better facilitate adherence to chronic disease management, but the evidence supporting its current effectiveness is mixed. Further research should focus on understanding and improving how mHealth tools can overcome specific barriers to adherence.	**SMS and mobile health**

Adherence	**6**			

		Bailey SC, Belter LT, Pandit AU, Carpenter DM, Carlos E, Wolf MS. The availability, functionality, and quality of mobile applications supporting medication self-management. Journal of the American Medical Informatics Association. 2014;21(3):542-6.	Hundreds of applications exist in the marketplace to support medication self-management. However, their quality, content, and functionality are highly variable. Research is needed to determine optimal capabilities, evaluate utility, and determine clinical benefit.	Apps Application features, % (N=424) Medication alert/reminder 91% Medication history, list or log 51.5%, Exports medication history 22% , Manages profiles for multiple users 21.8%, Uses visual aids 17.7% , Pharmacy refill reminder 15.1%, Drug reference or education 10.9%, Orders refills 8.3%, Organizes drug regimen 6.2%, Pharmacy locator 5.7% Provides drug cost and savings information 5.2%, Identifies pills 4.0% Checks for drug interactions 2.8%
		Linn AJ, Vervloet M, van Dijk L, Smit EG, Van Weert JC. Effects of eHealth interventions on medication adherence: a systematic review of the literature. Journal of Medical Internet Research. 2011;13(4):e103.	This review shows promising results on the effectiveness of Internet interventions to enhance patients' adherence to prescribed long-term medications. Although there is evidence according to the data synthesis, the results must be interpreted with caution due to low-quality adherence measurements. Future studies using high-quality measurements to	**WebEase, PATH, Health Buddy, SPPARO, Blue Angel**

			assess medication adherence are recommended to establish more robust evidence for the effectiveness of eHealth interventions on medication adherence.	
		Mistry N, Keepanasseril A, Wilczynski NL, Nieuwlaat R, Ravall M, Haynes RB, et al. Technology-mediated interventions for enhancing medication adherence. Journal of the American Medical Informatics Association. 2015;22(e1):e177-93.	This review shows the limited effectiveness of TMI for improving patient adherence and ultimately influencing clinical outcomes, primarily due to a lack of high-quality studies. The methodology for testing TMI for this purpose is generally suboptimal at present; strong, currently available methods need to be applied. Technology will also need to improve if clinically important effects are to be realized.	**Technology-mediated interventions: tekephone, SMS, Internet dependent program, Internet-Independent Computer Programs**

		Park LG, Howie-Esquivel J, Dracup K. A quantitative systematic review of the efficacy of mobile phone interventions to improve medication adherence. Journal of Advanced Nursing. 2014;70(9):1932-53.	To evaluate the characteristics and efficacy of mobile phone interventions to improve medication adherence. Secondary aims are to explore participants' acceptability and satisfaction with mobile phone interventions and to evaluate the selected studies in terms of study rigour, impact, cost and resource feasibility, generalizability and implications for nursing practice and research. While the majority of investigators found improvement in medication adherence, long-term studies characterized by rigorous research methodologies, appropriate statistical and economic analyses and the test of theory-based interventions are needed to determine the efficacy of mobile phones to influence medication adherence.	**SMS**

		Schneider MP, Gertsch A, Bugnon O. Cyberhealth serving to support individual intake of medication. Swiss Medical Weekly. 2013;143:w13827.	Because of its novelty, the impact of cyberhealth on drug intake has not yet been well explored. Initial results have provided some evidence, but more research is needed to determine the impact of cyberhealth resources on long-term adherence and health outcomes, its user-friendliness and its adequacy in meeting e-patient needs. The purpose of such Internet-based interventions, which provide different levels of customisation, is not to take over the roles of healthcare providers; on the contrary, cyberhealth platforms should reinforce the alliance between healthcare providers and patients by filling time-gaps between visits and allowing patients to upload and/or share feedback material to be used during the visits. This shift, however, is not easily endorsed by healthcare providers, who must master new eHealth skills, but healthcare systems have a unique opportunity to invest in the Internet and to use this powerful tool to design the future of integrated care. Before this can occur, however, important issues must be addressed and resolved, for example ethical considerations, the scientific quality of programmes,	**Internet**

			reimbursement of activity, data security and the ownership of uploaded data.	
		Gurol-Urganci I, de Jongh T, Vodopivec-Jamsek V, Atun R, Car J. Mobile phone messaging reminders for attendance at healthcare appointments. Cochrane Database of Systematic Reviews [Internet]. 2013; (12).	The review included eight randomised controlled trials published up to August 2012, involving 6615 participants. Four of these trials were newly included in this update. Low to moderate quality evidence included in this review shows that mobile phone text messaging reminders increase attendance at healthcare appointments compared to no reminders and postal reminders, and have the same impact on attendance as phone call reminders. Two studies reported that the costs per attendance of mobile phone text message reminders are less than phone call reminders.	**Text messages**

Trials **Disease Area**	**ISCRTN**	**Trial**
Dementia	ISRCTN86537017	The ATTILA Trial: Assistive Technology and Telecare to maintain Independent Living At home for people with dementia.
Dementia	ISRCTN16021595	A psycho-educational intervention for family caregivers of patients with dementia using a mobile application.
Falls	ISRCTN15932647	iStoppFalls – information and communication technologies (ICT) based system to predict and prevent falls.
Nursing home	ISRCTN11972147	SPEC study: evaluation of a technology-enhanced, integrated care model in nursing homes.

Table A9: Digital health and lifestyle behaviours

Healthy Eating

Review Papers	Paper	Paper Summary	Technologies
	Stumbo PJ. New technology in dietary assessment: a review of digital methods in improving food record accuracy. Proceedings of the Nutrition Society. 2013;72(1):70-6.	This paper describes six projects sponsored by the United States National Institutes of Health that use digital methods to improve food records and two mobile phone applications using crowdsourcing. The techniques under development show promise for improving accuracy of food records.per describes six projects sponsored by the United States National	**Food Intake Recording Software System (FIRSST), Improving Dietary Assessment Methods Using the Cell Phone and Digital Imaging (TADA), Integrated sensor technology for real-time recording of food intake (Dietary Data Recorder System) (DDRS), Automated Self-Assisted 24-h Dietary Recall (ASA24), A Unified Sensor System for Ubiquitous Assessment of Diet and Physical Activity (eButton), Mobile Food Intake Visualisation and Voice Recogniser (FIVR)**
	Aileen F. McGloin and Sara Eslami (2015). Digital and social media opportunities for dietary behaviour change. Proceedings of the Nutrition Society, 74, pp 139-	The abundance of data on citizens' digital behaviours, whether through search behaviour, global positioning system tracking, or via demographics and interests captured through social media profiles, offer exciting opportunities for effectively targeting relevant health messages. The digital environment presents great	**Useful for showing opportunities**

	148. doi:10.1017/S0029665114001505.	possibilities but also great challenges. Digital communication is uncontrolled, multi-way and co-created and concerns remain in relation to inequalities, privacy, misinformation and lack of evaluation. Although web-based, social-media-based and mobile-based studies tend to show positive results for dietary behaviour change, methodologies have yet to be developed that go beyond basic evaluation criteria and move towards true measures of behaviour change. Novel approaches are necessary both in the digital promotion of behaviour change and in its measurement.

TRIALS	ISCRTN	Title
	ISRCTN13601567	Early Food for Future Health: an E-health intervention aiming to promote healthy food habits from early childhood
	ISRCTN23466915	Effects of a smartphone intervention targeting fruit and vegetable consumption.
	ISRCTN14153741	Randomized controlled trial for dietary food measurement on mobile devices

Reducing Obesity

Review Papers	Paper	Paper Summary	Technologies
	Shaw R, Bosworth H. Short message service (SMS) text messaging as an intervention medium for weight loss: A literature review. Health Informatics Journal. 2012;18(4):235-50.	Nearly 68% of American adults are obese or overweight. Mobile devices such as mobile phones have emerged as a mode of intervention delivery to help people improve their health, particularly in relation to weight loss. This literature review examines the relationship between the use of short message service (SMS) text messaging as an intervention medium and weight loss. Results from this literature review (n = 14) suggest that SMS as an intervention tool for weight loss is still in its infancy. Initial results are promising but continued investigation is needed. We offer several recommendations for future research	SMS
	Wieland LS, Falzon L, Sciamanna CN, Trudeau KJ, Brodney Folse S, Schwartz JE, et al. Interactive computer-based interventions for weight loss or weight maintenance in overweight or obese people. Cochrane Database of Systematic Reviews. 2012(8)	Compared to no intervention or minimal interventions (pamphlets, usual care), interactive computer-based interventions are an effective intervention for weight loss and weight maintenance. Compared to in-person interventions, interactive computer-based interventions result in smaller weight losses and lower levels of weight maintenance. The amount of additional weight loss, however, is relatively small and of brief duration, making the clinical significance of these differences unclear.	interactive computer-based interventions

	Bacigalupo, R., Cudd, P., Littlewood, C., Bissell, P., Hawley, M. S. and Buckley Woods, H. (2013), Interventions employing mobile technology for overweight and obesity: an early systematic review of randomized controlled trials. Obesity Reviews, 14: 279–291. doi: 10.1111/obr.12006	A narrative synthesis was undertaken. Seven articles were included and appraised using the Cochrane risk of bias tool: four presented a low risk of bias and three presented a high risk of bias. There is consistent strong evidence across the included multiple high-quality RCTs that weight loss occurs in the short-term because of mobile technology interventions, with moderate evidence for the medium-term. Recommendations for improving the reporting and quality of future trials are made including reporting weight loss in percent to meet clinical standards, and including features such as long-term follow-up, cost-effectiveness and patient acceptability.	Text pager, mobile phone and accelerometer, telemonitoring, mobile phone
	Bennett GG, Steinberg DM, Stoute C, Lanpher M, Lane I, Askew S, et al. Electronic health (eHealth) interventions for weight management among racial/ethnic minority adults: a systematic review. Obesity Reviews. 2014;15 Suppl 4:146-58	Electronic health (eHealth) interventions have demonstrated efficacy for weight management. However, little is known about their efficacy among racial/ethnic minority populations, in whom there is a disproportionate prevalence of obesity. This systematic review evaluated the efficacy of eHealth weight management interventions among overweight and obese racial/ethnic minority adults. We required that trial samples be comprised of at least 50% racial/ethnic minorities or report outcomes by race/ethnicity. We searched five electronic databases for trials conducted through June 2012. Six papers met our eligibility criteria. These studies provide suggestive evidence that eHealth interventions can produce low magnitude, short-term weight loss among racial/ethnic minorities. Trials were methodologically sound, with high	eHealth intervention

		retention and participant engagement. There was no evidence detailing the efficacy of mobile health approaches, although this area is promising given high utilization rates of mobile devices among racial/ethnic minorities. More evidence, particularly from longer-term trials, is necessary to demonstrate that eHealth intervention approaches can produce clinically meaningful (?5% of initial body weight) weight loss among racial/ethnic minority populations.	
	Tang J, Abraham C, Greaves C, Yates T. Self-directed interventions to promote weight loss: a systematic review of reviews. Journal of Medical Internet Research. 2014;16(2):e58.	Current evidence suggests that self-directed interventions can independently promote weight loss and can augment interventions involving personal contact. Particular change techniques and delivery modes including individualized feedback, email counseling, and online social support appear to enhance effectiveness. Further reviews of the content of self-directed weight-loss intervention studies are needed to clarify which change techniques delivered through which delivery formats optimize intervention effectiveness	self directed intervention via interactive websites, smartphone applications, and text messaging
	Thomas JG, Bond DS. Review of innovations in digital health technology to promote weight control. Current Diabetes Reports. 2014;14(5):485.	The purpose of this review is to discuss studies in which digital technology has been used for behavioral weight control, report on advances in consumer technology that are widely adopted but insufficiently tested, and explore potential future directions for both. Web-based, mobile (eg, smartphone), virtual reality, and gaming technologies are the focus of discussion. The best evidence exists to support the use of digital technology for self-monitoring of weight-related behaviors and outcomes. However, studies are underway that	smartphone, virtual reality, gaming technology

		will provide additional, important information regarding how best to apply digital technology for behavioral weight control.	

Promoting exercise

Review Papers	Paper	Paper Summary	Technologies
	Boulos MN, Yang SP. Exergames for health and fitness: the roles of GPS and geosocial apps. International Journal of Health Geographics [Electronic Resource]. 2013;12:18.	GPS exergames may be a popular alternative (or supplement) to conventional sports such as football and skiing. Some of the apps and gadgets surveyed in this paper, such as EpicMix ski app, add additional dimensions to conventional sports. If GPS exergames can be as motivating to play as traditional video games, and they have the additional physical activity benefits, we should continue to research, explore and encourage their use.	GPS exergames. Examples : CodeRunner, Coke Zero LiveCycle app, Degree Confluence Project, Dokobots(no longer available), Endomondo Sports Tracker, EpicMix at Vail Resorts, Foursquare, Geocaching apps/Travel bugs, Geodashing, Geohashing apps, GPS Mission Pro Ghost Patrol, mIcrosoft health vault, Ingress (Google), LocoMatrix (multiple games), Oakley GPS Goggle,Mobile Adventure Walks, Moves, Nike+ Running app, Passage, Polarpersonaltrainer.com, RunAway, Serpent, Suunto Movescount, TrezrHunt, Urban Dash, Waymarking, ZEAL Optics Z3™ GPS Goggle, Zombie, Run! and 5k Training apps

	O'Reilly GA, Spruijt-Metz D. Current mHealth technologies for physical activity assessment and promotion. American Journal of Preventive Medicine. 2013;45(4):501-7	This review found that the mobile technologies utilized to develop mHealth PA and sedentary behavior assessment and promotion systems have included: mobile phone-based journals and questionnaires, SMS correspondence for self-monitoring of PA or communication about activities, and on-body activity sensing systems for PA detection and promotion. Several studies have shown that mobile PA journals and questionnaires are effective tools for measuring self-reported PA. Additionally, there is a lack of evidence of the efficacy of on-body mobile sensing systems for accurate PA measurement. Several studies have demonstrated that use of SMS-based and mobile journal–based interventions can positively affect PA and sedentary behavior. However, these technologies have been predominantly utilized in isolation. mHealth systems that integrate mobile technologies to provide real-time feedback, user- and health-provider-in-the-loop, personalized, and adaptive interventions need to be developed and tested for efficacy in order to take full advantage of mobile and connected capabilities.	mobile journals, SMS, on body activity sensing system.
	Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG. Measuring and influencing physical activity with smartphone technology: a systematic review. Sports Medicine. 2014;44(5):671-86.	Studies measured physical activity using native mobile features, and/or an external device linked to an application. Measurement accuracy ranged from 52 to 100 % (*n* = 10 studies). A total of 17 articles implemented and evaluated an intervention. Smartphone strategies to influence physical activity tended to be ad hoc, rather than theory-based approaches; physical activity profiles, goal setting, real-time	smartphone - technology including tri-axial accelerometer. Gyroscope, magnetic snesors, step counters.

		feedback, social support networking, and online expert consultation were identified as the most useful strategies to encourage physical activity change.	
	Lyons EJ, Lewis ZH, Mayrsohn BG, Rowland JL. Behavior change techniques implemented in electronic lifestyle activity monitors: a systematic content analysis. Journal of Medical Internet Research. 2014;16(8):e192-e 1p.	Electronic activity monitors contain a wide range of behavior change techniques typically used in clinical behavioral interventions. Thus, the monitors may represent a medium by which these interventions could be translated for widespread use. This technology has broad applications for use in clinical, public health, and rehabilitation settings.	Basis, BodyMedia, Fitbit, Fitbug, Gruve, Ibitz, Jawbone, Lumo, Misfit, Nike, Polar, Striiv, Withings
	Tate DF, Lyons EJ, Valle CG. High-Tech Tools for Exercise Motivation: Use and Role of Technologies Such as the Internet, Mobile Applications, Social Media, and Video Games. Diabetes Spectrum. 2015;28(1):45-54 10p	All of the technology tools reviewed here are popular and have substantial research supporting their preliminary effectiveness for enhancing physical activity. These tools have the capability to remotely deliver functions of behavioral interventions that have been shown to improve physical activity and A1C among patients with type 2 diabetes (e.g., goal-setting and social support).	Social media intervention. Active video games (Wii, Xbox, playstation). Mobile games (Zombies,Run!, The Walk, MyLand)
TRIALS	**ISCRTN**	**Title**	

	ISRCTN11693550	FitQuest: Does an active mobile phone game encourage children to take more exercise at school?	Mobile Phone
	ISRCTN18008011	Multidimensional Individualised Physical Activity profiles for behaviour Change using Technology	
	ISRCTN89676537	Assessing the effectiveness of web technologies to promote healthy living in children: a randomized controlled trial	
	ISRCTN99944116	A SMARTphone-based study to proMOte physical actiVity in primary care.	

Reducing smoking

Review Papers	Paper	Paper Summary	Technologies
Primary prevention	Whittaker R,McRobbie H, Bullen C, Rodgers A, Gu Y.Mobile phone-based interventions for smoking cessation. Cochrane Database of Systematic Reviews 2016, Issue 4. Art. No.: CD006611. DOI: 10.1002/14651858.CD006611.pub4.	Mobile phones are being used more to support healthy lifestyles. We wanted to know whether they could be used to support people to stop smoking. We reviewed the evidence on the effect of quit smoking programmes delivered by mobile phones to people who want to stop smoking. Study characteristics. We found 12 studies up to April 2015 that could be included. These studies included 11,885 people who were monitored to see if they managed to quit smoking and if they were still quit six months later. Key results When the information from all the studies were combined, smokers who received the support programmes were around 1.7 times more likely to stay quit than smokers who did not receive the programmes (9.3% quit with programmes compared with 5.6% quit with no programmes). Most of the studies were of programmes relying mainly on text messages.	**Mobile phones**
TRIALS	**ISCRTN**	**TITLE**	Technology
	ISRCTN33423896	Study of effectiveness of a smartphone app for stopping smoking focused on use of nicotine replacement therapy.	smartphone
	ISRCTN10548241	Study of effectiveness of a smartphone application for quitting smoking.	smartphone
	ISRCTN55259451	Managing cigarette cravings using the Physical over Smoking (PoS) App	smartphone

ISRCTN02427446	Efficacy of an Internet and mobile phone-based integrated smoking cessation and binge drinking intervention compared to a smoking cessation only intervention for smoking cessation in young people	Internet

Reducing alcohol consumption

Review Papers	Paper	Paper Summary	Technologies
Treatment and concordance	Donoghue K, Patton R, Phillips T, Deluca P, Drummond C. The effectiveness of electronic screening and brief intervention for reducing levels of alcohol consumption: a systematic review and meta-analysis. Journal of Medical Internet Research. 2014;16(6):e142.	A significant reduction in weekly alcohol consumption between intervention and control conditions was demonstrated between 3 months and less than 12 months follow-up indicating eSBI is an effective intervention	**eSBI as an electronic intervention aimed at providing information and advice designed to achieve a reduction in hazardous/harmful alcohol consumption with no substantial face-to-face therapeutic component.**

TRIALS	ISRTN	Title	Technology
	ISRCTN40104069	Evaluating the effectiveness of a smartphone app to reduce alcohol consumption in hazardous and/or harmful drinkers.	Smartphone App

Other

Review Papers	Paper	Paper Summary
	Higgins JP. Smartphone Applications for Patients' Health and Fitness. American Journal of Medicine. 2016;129(1):11-9.	Healthcare providers are often looking for ways to objectively monitor and improve their patients' health and fitness, especially in between patient visits. Some insurance companies are using applications data as incentives to improve health and lower premiums. As more and more people start to use smartphones, they may provide a tool to help improve a patient's health and fitness. Specifically, fitness applications or "apps" on smartphones are programs that use data collected from a smartphone's inbuilt tools, such as the Global Positioning System, accelerometer, microphone, speaker, and camera, to measure health and fitness parameters. The apps then analyze these data and summarize them, as well as devise individualized plans based on users' goals, provide frequent feedback, personalized coaching, and additional motivation by allowing milestones to be shared on social media. This article introduces evidence that apps can better help patients reach their health and fitness goals. It then discusses what features to look for in an app, followed by an overview of popular health and fitness apps. Last, patient scenarios with app recommendations, limitations of apps, and future research are discussed.
	Kohl LF, Crutzen R, de Vries NK. Online prevention aimed at lifestyle behaviors: a systematic review of reviews. Journal of Medical Internet Research. 2013;15(7):e146.	According to health priorities, interventions are largely targeted at weight-related behaviors, such as physical activity and dietary behavior. Evaluations are predominantly effect-focused and overall effects are small, variable, and not sustainable. Determinants of effectiveness are unclear; effectiveness cannot yet be unambiguously attributed to isolated elements. Actual reach of interventions is undiversified, mostly reaching participants who are female, highly educated, white, and living in high-income countries. One of the most substantial problems in online prevention is the low use of the interventions, a phenomenon seen across all behavior domains.

Vodopivec-Jamsek V, de Jongh T, Gurol-Urganci I, Atun R, Car J. Mobile phone messaging for preventive health care. Cochrane Database of Systematic Reviews [Internet]. 2012; (12).	We found very limited evidence that in certain cases mobile phone messaging interventions may support preventive health care, to improve health status and health behaviour outcomes. However, because of the low number of participants in three of the included studies, combined with study limitations of risk of bias and lack of demonstrated causality, the evidence for these effects is of low to moderate quality. The evidence is of high quality only for interventions aimed at smoking cessation. Furthermore, there are significant information gaps regarding the long-term effects, risks and limitations of, and user satisfaction with, such interventions.

Appendix B: Case studies

Case study: digital mental health

Background

Mental health is one of the largest causes of disease burden and disability, in the UK NHS and around the world. The 2014 Chief Medical Officer's report focused on this, reporting an annual cost to the UK economy of between £70 and £100 billion, with mental health accounting for 23 per cent of the UK's disease burden and over 40 per cent of sickness benefits.

In this case study we explore the use of digital health interventions in primary and secondary prevention and treatment of mental health problems. Compared with other clinical areas, there has been considerable development of digital health interventions in mental health. Using review of published literature in combination with expert opinion from interviews, we consider why this area is viewed as amenable to digital intervention, its success so far and potential for the future.

Evidence from reviews

The literature search identified 27 reviews of digital technology in mental health areas (see Appendix A). Of these 27 reviews, four were deemed to have sufficient evidence of a positive impact of the technology. The remaining reviews found many encouraging and promising research but failed to demonstrate statistically significant effects. The four reviews that found positive impacts were in three main fields: electronic screening and brief intervention for hazardous drinking, internet delivered CBT for reducing anxiety and other disorders, and internet-based treatment of eating disorders.

Screening and brief interventions to reduce problem drinking

Brief interventions have been shown in RCTs to reduce excessive drinking. A high quality Cochrane review and meta-analysis of 21 RCTs found that face-to-face screening and brief intervention (SBI) reduced alcohol consumption compared with a control group.[1] Electronic SBI (eSBI) has the potential to offer greater flexibility and potentially reach a larger proportion of the population in need. In a systematic review and meta-analysis by Donoghue et al, eSBI was also found to be effective at reducing alcohol consumption. Seventeen studies were included in the meta-analysis which examined the effectiveness ofrandomized controlled, parallel group trials comparing eSBI with a control intervention. The analysis found a statistically significant reduction in weekly alcohol consumption after three months compared to a control, indicating eSBI is an effective intervention.[2]

Digital delivery of cognitive behavioural therapy

NICE guidelines recommend cognitive behavioural therapy (CBT) as a treatment for anxiety disorders. Internet cognitive behavioural therapy (iCBT) has been developed in order to increase accessibility to CBT and to overcome some of the issues surrounding face-to-face CBT, which has seen a substantial increase in demand and a shortage of trained practitioners leading to long waiting

lists. Andrews et al found that internet delivered CBT (iCBT) was superior to both waiting list control and active control groups in reducing anxiety.[3]

An additional systematic review and meta-analysis by Andersson et al compared face-to-face CBT and guided internet delivered CBT (iCBT) for psychiatric and somatic disorders.[4] The review included 13 randomised controlled trials in a number of areas and found that the two treatment formats were equally effective. The authors conclude that more studies are required before firm conclusions can be drawn but the results indicate that guided iCBT is a promising treatment option.

Internet-based treatment for eating disorders

A systematic review of twenty one studies for treatment of eating disorders found that internet based treatment resulted in improved outcomes compared with waiting list controls. Internet based treatment was deemed more effective for individuals with less co-morbid psychopathologies. Higher levels of compliance were associated with more improvements in eating disorder symptoms. The review found that compliance rates varied across the twenty one studies but that the inclusion of face to face assessments and therapist support appeared to enhance compliance.[5]

Summary of areas with established effectiveness

Although these four reviews are in different areas of mental health, they have a number of factors in common. First, all the treatments have an existing evidence base. Rather than being a novel digital product, the digital intervention provides a new platform for delivering a treatment that uses the same evidence-base as that delivered by a health professional. Electronic versions have been developed from the face to face intervention in a bid to overcome limited access to therapists. Whilst in trials there is evidence for effectiveness there is often poor compliance. Longer term compliance can be addressed using guided support or including face to face contact in addition to the digital intervention, rather than using the technology in isolation.

Registered clinical trials

The ISCRTN directory was searched for trials starting or taking place from 2011.Eight were identified (see table 1), seven were trials of treatment for specific conditions: addiction, anxiety, schizophrenia, agoraphobia, psychosis and stress; one was a preventative intervention trying to increase positive feelings in everyday lives. One is currently ongoing, seven have been completed but according to ISCRTN website only one has published results, the iChill Project.[6] This multi-centre study found that the online therapeutic intervention for the prevention and treatment of generalised anxiety disorder was not effective in reducing anxiety levels.

Available interventions recommended by the NHS

Table 2 lists digital interventions which are currently endorsed in some way by the NHS. The NHS Choices website lists six online mental health services. These include Big White Wall, FearFighter,

Leso digital health, Kooth, Silvercloud and Sleepio. Slightly less visible, but within the CBT pages on the NHS Choices website is also Beating the Blues.

Expert opinion on digital health and mental health

We interviewed a number of experts in mental health generally, and in digital health specifically, including academic researchers and product developers.

Our interviewees confirmed that digital health interventions have been demonstrated to be effective in treating a range of different mental health problems, with the majority of products aimed at mild to moderate conditions. There are currently few or no evaluated products for psychosis or other severe and enduring mental illness. This prompted one interviewee to question whether the areas of mental health with the largest burden were being targeted. There is a balance to be struck between investing in products that help those whose symptoms may be relatively mild, but where prevalence is extremely high; and those much smaller numbers facing much more severe mental health problems.

One of our (clinical) interviewees commented that hit is "*hard not to do harm in mental health, and very easy not to do any good*". This perhaps underpins the fact that many digital interventions are based on evidence based existing interventions, essentially new delivery methods rather than novel products.

Digital interventions in mental health can be used within a care pathway with clinician support or can be entirely self-directed. As a standalone treatment, digital products lack the therapeutic alliance that is considered essential for the beneficial effects of therapy: many people also prefer therapy from a person rather than an app.[7] Most digital interventions were believed by some of our interviewees to have poor compliance, with high dropout rates and low completion (this was confirmed in our review). A number of the experts we interviewed suggested that the future of digital products are as an addition to current therapy, perhaps reducing the number of face-to-face contact sessions, but not completely replacing the essential therapeutic relationship.

One area where it was suggested that digital products would be useful is preventing relapse. Real time monitoring has the potential to capture mood and trigger an alert to a health professional if the symptoms cross a specified threshold.

Ongoing research

MindTech (http://www.mindtech.org.uk/) is one of eight NIHR health technology co-operatives. The group has identified four areas of unmet need and has potential solutions for target conditions (see summary table below). They are also developing a useful toolkit for appraising digital mental health products (http://www.mindtech.org.uk/digital-mental-health-toolkit.html)

MindTech areas of research

Clinical problem/ unmet need	Potential technology solution	Target conditions
Poor engagement, treatment adherence/ missed appointments	• Apps • SMS text messaging • remote video-consultation • On-line therapy	• All conditions
Time consuming, delayed & inaccurate assessment, diagnosis and prediction	• Objective computerised assessment of mood, attention/cognition & movement • Machine learning	• ADHD, ASD • Depression • Dementia
Relapse prevention Treatment optimisation Maintaining independence	• Real-time Personalised ambient monitoring (PAM)	• Bipolar disorder • ADHD • Dementia
Limited efficacy of non-pharmacological interventions	• Serious Games: computerised cognitive and social communication training • Virtual reality • Avatar therapy • Neuromodulation	• PTSD, phobia • ADHD, ASD • Depression, psychosis

Source MindTech

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2. Donoghue K, Patton R, Phillips T, Deluca P, Drummond C. The effectiveness of electronic screening and brief intervention for reducing levels of alcohol consumption: a systematic review and meta-analysis. Journal of Medical Internet Research. 2014;16(6):e142.

3. Andrews G, Newby JM, Williams AD. Internet-delivered cognitive behavior therapy for anxiety disorders is here to stay. Current Psychiatry Reports. 2015;17(1):533.

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6. Christensen H, Batterham P, Mackinnon A, Griffiths KM, Kalia Hehir K, Kenardy J, Gosling J, Bennett K Prevention of Generalized Anxiety Disorder Using a Web Intervention, iChill: Randomized Controlled Trial. J Med Internet Res 2014;16(9):e199

7. Mayor S, Sixty seconds on …. CBT apps.BMJ 2016;354:i4835

Table 1: Registered Trials of digital interventions in mental health

ISRCTN	Trial title	Description	Funder and website/publications
ISRCTN15315334	Positive Psychology Smartphone Application.	This study is aiming to increase positive feelings in people's everyday lives. Provision of short positive psychology activities to individuals will increase levels of positive emotions relative to a control group.	Unilever
ISRCTN67177737	Healthy Mind: A study of a web and smartphone stress management tool.	This study will disseminate 'Healthy Mind' a digital stress management intervention that is available as both a stand-alone Android application and a stand-alone website ('Healthy Paths').	EPSRC www.healthymindweb.lifeguidewebsites.org
ISRCTN34966555	Active Assistance for Psychological Therapy (Actissist): Using mobile technology to deliver cognitive behaviour therapy for psychosis.	The ACTISSIST project seeks to develop a mobile phone application (app) to deliver a CBT intervention to people with early psychosis. In this phase of the research (phase 3 of 3) participants will be randomly assigned to one of two conditions. Over a 12-week period participants will either receive the Actissist app, or a symptom monitoring app (ClinTouch). The principal aim of this phase is to assess the feasibility and acceptability of delivering a CBT intervention via a mobile phone to people with early psychosis.	MRC https://www.ncbi.nlm.nih.gov/pubmed/26357943
ISRCTN98453199	Evaluating the effectiveness of "Agoraphobia Free": A novel mobile application for treating Agoraphobia	The aim of this study is to examine whether the agoraphobia-specific mobile intervention ("agoraphobia-free") is more effective than the generic, control intervention ("stress free").	Nominet Trust (UK)

ISRCTN15399617	Improving the continuity of care in schizophrenia through an intervention delivered via mobile phones and internet: a pilot study	Is an aftercare intervention delivered via mobile phones and internet a feasible add-on to treatment as usual for patients with schizophrenia?	Center for Psychotherapy Research, University Hospital Heidelberg (Germany)
ISRCTN10515845	Alcohol and disadvantaged men: developing a brief intervention for delivery by mobile phone	Can a brief intervention delivered by mobile reduce heavy drinking among disadvantaged young to middle aged men?	NIHR
ISRCTN76298775	The iChill Project: can generalised anxiety disorder be prevented and treated using e-health interventions?	The effectiveness of online therapy for the prevention and treatment of generalised anxiety disorder: a multicentre randomised controlled trial	National Health and Medical Research Council (NHMRC) (Australia): https://www.jmir.org/2014/9/e199/
ISRCTN15853981	Using a smartphone application as an adjunct to counselling in substance misuse treatment.	The Application to Improve Motivation (AiM) has been developed to help users improve their motivation to make and maintain a desired health behaviour change, such as drinking, smoking and exercise. This study aims to explore the utility and potential impact of this smartphone application used alongside routine clinical practice for people being treated for substance misuse.	Investigator initiated and funded, Kingston University and St George's, University of London

Table 2: Existing digital interventions endorsed by the NHS, and associated evidence

Product	Description	Related Publications
FearFighter™ http://fearfighter.cbtprogram.com/	Nine step online program for anxiety and phobias Made by CCBT Ltd. Claims to reduce time in therapy by 80% and financial savings by up to 50%. Originally approved by NICE but approval was later withdrawn. Available on the NHS in some areas with a referral. Available privately, £129 for the silver version which is self-guided, £229 for gold which includes support from a healthcare professional.	McCrone , Marks IM, Mataix-Cols D, Kenwright M, McDonough M. Computer-aided self-exposure therapy for phobia/panic disorder: a pilot economic evaluation. Cognitive Behaviour Therapy. 38(2):91-9, 2009. MacGregor AD, Hayward L, Peck DF, Wilkes P. Empirically grounded clinical interventions clients' and referrers' perceptions of computer-guided CBT (FearFighter). Behavioural & Cognitive Psychotherapy. 37(1):1-9, 2009 Jan Kaltenthaler, E, Brazier, J, De Nigris, E, Tumur, I, Ferriter, M, Beverley, C, Parry, G, Rooney, G, Sutcliffe, P. Computerised cognitive behaviour therapy for depression and anxiety update: a systematic review and economic evaluation. Health Technology Assessment (Winchester, England). 10(33):iii, xi-xiv, 1-168, 2006 Sep. Schneider AJ, Mataix-Cols D, Marks IM, Bachofen M. Internet-guided self-help with or without exposure therapy for phobic and panic disorders. Psychotherapy & Psychosomatics. 74(3):154-64, 2005. Marks, I M, Kenwright, M, McDonough, M, Whittaker, M, Mataix-Cols, D. Saving clinicians' time by delegating routine aspects of therapy to a computer: a randomized controlled trial in phobia/panic disorder. Psychological Medicine. 34(1):9-17, 2004 Jan Kenwright, M, Liness, S, Marks, Reducing demands on clinicians by offering computer-aided self-help for phobia/panic. Feasibility study. British Journal of Psychiatry. 179:456-9, 2001 Nov.
Sleepio https://www.sleepio.com/	CBT for insomnia Evidence based model Online tailored techniques with continuous support Team based at University of Oxford Sleepio part of Big Health	Espie, C.A., Kyle, S.D, Williams, C., Ong, J.C., Douglas, N.J., Hames, P., Brown, J.S.L. (2012). A randomized, placebo-controlled, trial of online Cognitive Behavioral Therapy for chronic Insomnia Disorder delivered via an automated media-rich web application. *SLEEP 35*, 769-781.

Big White Wall https://www.bigwhitewall.com	Online community, support and help by sharing Guided by trained professionals Free in many areas via NHS, employers and universities	Ongoing evaluation with MindTech. http://www.mindtech.org.uk/projects/133-derbyshire-integrated-digital-mental-health-service-project-the-big-white-wall-and-reboot-study-online-peer-support-and-therapy-for-people-experiencing-common-mental-health-problems-mood-disorders-theme.html
Ieso Digital Health http://uk.iesohealth.com/	One to one therapy via typed conversation Trial funded by BUPA	Kessler D, Lewis G, Kaur S, et al. Therapist-delivered Internet psychotherapy for depression in primary care: a randomised controlled trial. Lancet. 2009;374(9690):628–34
Kooth **https://www.kooth.com**	Online counselling for young people Access via smartphone Available in certain areas Service provided by Xenzone	
Silvercloud http://www.silvercloudhealth.com/	Started as research project – Trinity College Dublin Support programs for range of mental and behavioural health issues: depression, anxiety, eating issues, OCD. Available via NHS	www.silvercloudhealth.com/research/publications
Beating the blues http://www.beatingtheblues.co.uk/	Computerised CBT for anxiety and depression Recommended by NICE 2006 NB NICE now recommends any cCBT programmes that meet certain criteria.	Proudfoot, J., Swain, S., Widmer, et al. (2003b). The development and beta-test of a computer-therapy program for anxiety and depression: hurdles and preliminary outcomes. Computers in Human Behavior, 19, 277-289 Proudfoot, J., Goldberg, D., Mann, et al. (2003a). Computerized, interactive, multimedia cognitive behavioural therapy reduces anxiety and depression in general practice: a randomised controlled trial', Psychological Medicine, 33, 217-227.

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Case study: Digital health and older people

Background

Life expectancy is increasing. In 2014 18% of the population were over 65 and over. Those over 75 made up 8% of the population, and this proportion continues to increase[1]. Older people are the highest users of NHS services,[2] mainly due to their high risk of suffering from sometimes multiple chronic diseases.

Technology to reduce problems of ageing can take many forms. Examples include tools to aid communication with family and friends, reducing social isolation; or to improve communication with health professionals. Technology can help with everyday living needs. Smartphone apps can aid memory, provide medication reminders and apps to keep a record of health outcomes.

There are many opportunities, but also potential challenges. Older people are often viewed as 'hard to reach' with technological solutions; digital exclusion prevents many older people using online services and apps. There is an increase in technology and particularly smartphone use in this population, (18% of over 65s have a smartphone, and this figure is increasing,[3] but it compares with around 70 per cent of the general population).

Our interviewees and findings of our review suggest that technology has to offer something *additional* to traditional methods in order for it to be adopted by this more reluctant group.[4] To be taken up widely, it also needs to be simple and user friendly. To increase adoption, there needs to be more involvement with users at the design stage and more research on implementation.

Review findings

Our literature search identified three reviews examining digital technology for older people. All three highlighted the promise the technology has, but that a much stronger evidence base is required regarding how technology can be used by and promoted to older people.

A review of older adults and mobile phone use for health by Joe and Dimitris identified ten areas where mobile phones were used for health.[5] These included activities of daily life, chemotherapy symptom management, palliative care symptom management, and use in heart failure, COPD, diabetes, falls, osteoarthritis and dermatology. The research studies identified were however mostly small feasibility studies. The review found that whilst most of the research and products in these different areas was promising, future larger scale evaluations would be required.

Some of the promising interventions included using mobile phone cameras to log activities of daily life. This was a step further in a study involving Alzheimer's patients, where a smartphone camera was programmed to take photos every five minutes throughout the day. These were then turned into a slideshow which improved patient recall. Two studies in the review examined using mobile phones as tracking devices for wandering patients, using the GPS functions of the phones. The phone was a reliable tracking device, but compliance was noted to be low as there were difficulties ensuring the patient carried the phone with them at all times. Mobile phones were also used to collect symptom data for chemotherapy and palliative care patients, triggering an automatic health professional intervention if thresholds were reached. Mobile phones were used in a similar way in a study looking at heart failure patients; mobile phone monitoring alerted the healthcare provider if a patient showed sign of worsening symptoms.

Falls are a leading cause of injury and hospitalisation amongst older people; they are also a major source of fear and loss of independence. Fall detection devices are used to alert carers. A study included in the review by Joe and Demitris examinedthe use of accelerometers built into phones to detect falls. Those built into phones were found to be comparable to stand alone accelerometers but again compliance is a potential difficulty. Casilarie et al examined the technical ability of mobile phones for fall detection,[6] finding that much of the research in this area failed to appreciate that mobile phones are used for more than a single app. The battery life and computing power are all affected by other applications. Although the direct functions of the apps were evaluated, the practical application in normal daily life has not been evaluated. The authors suggested more involvement from older people in the development of the technology in order to make it more useable in real-life settings.

Morris et al[7]examined the effect of smart technology to enhance social connectedness in older people who live alone. Eighteen publications were identified of which fourteen reported positive outcomes in aspects such as social support, isolation and loneliness. The technology included web based support, self help and discussion groups, integrated computer programs and Nintendo Wii. There were promising results, but the variety of outcome measures limited the direct comparison of study outcomes.

Ongoing trials

The search of the ISCRTN register identified three trials that were aimed at older people, in dementia, falling and care homes. Two of these trials are still ongoing but one has completed and has published the results. The iStoppFalls trial compared an exercise program using Microsoft Kinect and a control group who were provided with educational material. The exercise program reduced physiological fall risk in the study sample and additional subgroup analyses revealed that those intervention participants with better

adherence also improved in postural sway, stepping reaction, and executive function. Again, this trial is not pragmatic, and uses intermediate outcomes rather than a truly meaningful patient-centred outcome measure (such as reduction in falls or fear of falling).

Other ongoing research

The Care City Innovation Test Bed is one of seven test beds announced by NHS England. It consists of three clusters piloting technology for older people, each considering three technologies.[8] The purpose is to look at the technologies in real-life settings. The project is a two year programme investigating whether particular technologies can reduce the pressure on NHS services and improve quality of life. The products are all currently available.

One cluster will consider technologies for long term conditions, specifically Health Navigator, AliveCor and Kinesis. Health Navigator (http://health-navigator.co.uk/) uses nurse-led coaching over the telephone to help people manage their own care. AliveCor (https://www.alivecor.com/en/) is a monitor designed to detect abnormal heart rhythms to diagnosis atrial fibrillation. (https://www.nice.org.uk/advice/mib35/chapter/technology-overview). Kinesis (http://www.kinesis.ie/) is a tool for identifying people's risk of falling; it is intended to assist those assessing fall risk by providing a risk score.

Another cluster is for people suffering with dementia, specifically MyBrainBook, HealthUnlocked and Join Dementia Research. MyBrainBook (http://mybrainbook.com/login) is an online tool where people with dementia and their carers can stay aware, informed and in touch by storing photos and music or talking to their family. HealthUnlocked (https://healthunlocked.com/) is a social network app that provides peer support for people with dementia and their carers. Join Dementia Research is a site where anyone with or without dementia can register to take part in research on dementia treatments. (https://www.joindementiaresearch.nihr.ac.uk/)

The final cluster is concerned with carers and families. The technology used is supportspace® (http://www.careinnovation.co.uk/supportspace), a multi-platform app that connects personal budget and direct payment recipients with service providers and the social care agency that administers payment. Canary (https://www.canarycare.co.uk/) is a monitoring and notification system that works using a set of sensors in the home that will enable families to know if their relative is active. The other technology being trialed is Saint Bernard (http://www.stbernardlocation.com/) which is a GPS based emergency location service for use with some dementia patients, so that family members can be alerted if they wander a specified distance from their home.

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Trials

ISCRTN Number	Trial	Summary	Funder and website/publications
ISRCTN86537017	The ATTILA Trial: Assistive Technology and Telecare to maintain Independent Living At home for people with dementia.	A randomised controlled multi-centre clinical trial. We will compare the effects of an assessment followed by access to a suite of assistive technology and telecare (ATT) services with assessment and a control intervention; limited to the fitting and checking of smoke detectors; on the time that people with dementia who are at high risk of institutionalisation can be maintained in independent living. Health Technologies being assessed: Commercially available ATT devices that we and others have successfully piloted to promote independent home-living for people with dementia.	**HTA** Leroi I, Woolham J, Gathercole R, Howard R, Dunk B, Fox C, O'Brien J, Bateman A, Poland F, Bentham P, Burns A, Davies A, Forsyth K, Gray R, Knapp M, Newman S, McShane R, Ritchie C, Does telecare prolong community living in dementia? A study protocol for a pragmatic, randomised controlled trial., Trials, 2013, 14, 349, doi: 10.1186/1745-6215-14-349. http://www.ncbi.nlm.nih.gov/pubmed/24152600
ISRCTN15932647	iStoppFalls– information and communication technologies (ICT) based system to predict and prevent falls	The intervention group will receive an ICT system comprising of the PC, a set top box (STB), a Microsoft Kinect console, an Senior Mobility Monitor (SMM), and a Tablet to conduct the iStoppFalls programme on their own home television. The programme comprises exergames with strength and balance exercises. Both the intervention and control groups will receive educational material. This includes information about fall risk (e.g., general health, falls, fear of falling, eating, medication, environment, emergency plan, exercise, checklists and quiz). .The control group will undergo no exercise programme, but will be asked to conduct their regular activities during the course of the study.	**European Commission** Gschwind YJ, Eichberg S, Ejupi A, de Rosario H, Kroll M, Marston HR, Drobics M, Annegarn J, Wieching R, Lord SR, Aal K, Vaziri D, Woodbury A, Fink D, Delbaere K, ICT-based system to predict and prevent falls (iStoppFalls): results from an international multicenter randomized controlled trial, Eur Rev Aging Phys Act, 2015 , 12, 10, doi: 10.1186/s11556-015-0155-6. http://www.ncbi.nlm.nih.gov/pubmed/26865874
ISRCTN11972147	SPEC study: evaluation of a technology-enhanced,	The principal study question is whether the Systems for Person-centered Elder Care (SPEC), a technology-enhanced, integrated care model, as compared to usual	The Korean Ministry of Health and Welfare through Korean Health Industry Development Institute (KHIDI)

	integrated care model in nursing homes	care, will improve quality of care for frail older adults in nursing homes.	

Case Study: Digital Health in China

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Summary

Digital Health involves the use of digital media, mobile devices and internet based-technologies to deliver services and information related to health and social care. It has been highlighted as a cost-effective way to improve access and increase quality of modern healthcare. Digital health covers four key areas, namely, electronic records, social media, mobile and wearable devices and the collection of big data for analytics. This case study explores the rapidly evolving market of digital healthcare in China in the following areas: trends affecting digital health; overviews of the digital health care landscape and opportunities; and challenges to the deployment of digital health. The UK digital health market faces similar drivers and challenges as its China counterpart, including providing high-quality of healthcare for all individuals, delivering the services to the growing ageing population, helping people with chronic medical conditions and reducing the cost of healthcare. In this case study, we also investigate China's experience of digital health relevant to the UK and explore the collaboration opportunities between the two countries.

Introduction: the market for digital health in China

There are three primary trends affecting digital health in China: demographics and increasing life expectancy, technological innovation and government incentives. First, digitally enabled care has the power to improve the quality of healthcare, especially for people who have limited access to medical facilities. China has more than 1.3 billion people, 47% of whom live in rural areas. However, over 80% of the medical institutions are concentrated in fast growing urban areas. Although China launched its systemic health care reforms in 2009, with the aim of providing universal, affordable and equitable healthcare, for those living in rural China accessing quality healthcare is still difficult. Moreover, the percentage of people aged 65 or over in China will increase from 12% in 2013 to 34% in 2050. Population ageing with longer life expectancy and more chronic disease will increase the burden on the already overloaded healthcare systems. Chronic disease can result in significant losses to society and the economies. As of 2012, chronic disease was responsible for 86.6% of deaths and 70% of the total disease burden in China, with cardiovascular disease, cancer and chronic respiratory disease the leading causes.

Mobile and internet technologies bridging the distance, time and expectation gap between patients and health care providers are being seen as an effective means of addressing the challenges in China's healthcare reform, such as the nationwide shortage of doctors (1.8 physicians per 1000 people), lack of healthcare coverage, overburdened city hospitals and underfunded rural health facilities.

In the UK, improving care and support needed for people with long-term conditions is also one of the biggest challenges facing the NHS. Around one in three people in England have one or more long-term conditions, which accounts for nearly 50% of all GP appointments, 64% of all outpatient appointments, 70% of all inpatient bed days and 70% of hospital and primary care spend.[1]

In China, as in other parts of the world, the widespread adoption of new technologies has encouraged the implementation of a digital health care revolution. The internet provides a platform for millions of daily online transactions and commutations, moving China into the ranks of the leading countries in digital transformation. In 2016, 721 million internet users were recorded, and China has 675 million mobile users, over 1/3 of the global total. The average daily use of the internet is 3 hours and 45 minutes. On average, five billion searches every day are made through Baidu, and hundreds of millions of messages are communicated by WeChat. With an internet penetration of 52.2% and social media penetration of 47%, more people can expect to be able to digitally track, manage, measure and improve their goals for health and wellbeing.

In the UK, more than 70% of people now own a smartphone, and 80% of the population access the internet regularly. The penetration of digital technologies within the health care system is already high. 75% of people search for health information online, 50% use digital technology to self-diagnose, 80% would monitor their chronic condition using a mobile app, and 90% would use a service to ask a clinician questions.[2] Moreover, the UK is a pioneering user of digital information technology in primary care, particularly EHRs, eReferrals and telecare. The NHS spine is one of these applications, which handles more than 150 million transactions every single month. The NHS England's e-Referral service is another key application which offers patients to book their hospital and clinic appointments with a choice of hospitals, date and time online or by phone. Today, 100% of UK doctors are computerised, 97% of GPs report to use electronic medical records, and 50% of hospital trusts use electronic clinical records.[3] With information in digital form, the healthcare systems have also generated large volume of data, e.g. Hospital Episodes

Statistics (HES). Such datasets provide the UK with a strong underlying base and great potential for healthcare analytics and academic research.

Another fast growing digital health market is mHealth. There is a high consumer demand for mHealth apps in the UK, but adoption has been slow and is subject to a number of barriers, including the lack of standards for data protection, privacy and security, difficult to monetise and the lack of reimbursement mechanisms, and no clear standard regulations. The Accelerated Access Review process has been undertaken to improve this situation.[4]

The government of China, in a move to increase access to care, improve health outcomes and reduce costs, has intensified its efforts to boost digital health care. For example, the government offers lower barriers to entry to e-commerce in business approval procedures, relaxing the restrictions on online pharmacies, allowing some hospitals to run pilot remote clinics and encouraging private investment from foreign capital. This increasingly favourable regulatory environment has encouraged the Chinese digital healthcare market to grow at an exponential rate. According to estimates by the Boston Consulting Group,[5] the value of the market measured by the spending on digital health care was $3 billion in 2014 and is expected to reach $110 billion by 2020. Meanwhile; the UK is at the forefront of the implementation of digital technologies. Much of this has been supported by the government. Since 1980s, the NHS has committed to digitise healthcare records. In recent years, the government has refreshed their digital health strategies to accelerate adoption of electronic health records in secondary care, mHealth and data analytics.

Although there are considerable differences between China and the UK, improving quality of life for hard-to-reach people remain mutual challenges facing both countries. Digital health has the potential to increase the reach, reduce healthcare system costs and improve health outcomes, which provide huge potential opportunities for collaboration between the two counties.

Adoption of digital health technologies

Digital health, empowered by new technology, is changing every aspect of health and social care, concerning patients and hospitals, from the delivery of health care to the management of public health. Figure 1 provides an overview of the digital health care landscape in China. At the forefront of these is electronic health record (EHR) which documents a patient's lifetime health information in a digital format. The

adoption of the EHR in China has grown rapidly due to the government incentives and financial support. As of 2014, about half of tertiary hospitals, 30% of urban health centres and 20% of rural hospitals reported using EHR. By 2020, the government plans to increase the coverage in tertiary hospitals to 80% and to at least half in urban health centres and rural hospitals. This provides great opportunities for both regional and international EHR service suppliers, including IBM, Dell, Cisco, Siemens, Baidu, the Alibaba group, Tencent, Neusoft, Yonyou, B-Soft, Winning, Founder, and Jiangsu Zhongkang.

The EHR system acts as a clinical data repository which can help to exchange medical information and coordinate care across the health care sectors. It opens up new ways for patients, carers and healthcare professionals to access data and information more easily and improves the quality of healthcare.

First, individuals can review their own health records, make an appointment, check in and record a diagnosis online. This allows patients to better manage their health and engage with care providers, using patient facing technologies, such as wearable devices, apps, online communities and patient portals. For example, mHealth allows patients to access and manage their health by mobile devices. The number of health apps has increased rapidly, reaching over 2000 in 2016. The adoption of apps has doubled in the last two years (2015-6): 32% of smartphone users have one or more health apps on their devices. The most common category of mobile apps is for online appointment booking and payments apps (see Figure 2). 59% of those who use mHealth have already said that apps can replace visits to doctors or nurses. ChunyuYisheng, a smartphone app with 48 million active users and 60,000 registered physicians, enables patients to communicate with physicians at anytime, anywhere without any charge.

Case example 1: The Wireless Heart Health project, using3G smartphones to monitor patients with cardiovascular diseases (CVDs) in rural areas.

According to the report on Cardiovascular Disease in China, about 230 million patients in 2011 were suffering from CVD. It is the leading cause of death, which kills more than 2.6 million Chinese per year.[1] The treatment and prevention of CVD place a huge burden on society and the economics. The World Bank reports[1] that reducing the mortality of CVD by one percent per year from 2010 to 2040wouldsave china more than $10.7 trillion. These have led to a greater focus on new digital technologies in order to enhance the prevention of CVD and reduce the cost. Life Care Networks and the Community Health Association China, along with Qualcomm Wireless research have initiated a project to use smartphones to monitor patients with cardiovascular diseases (CVDs) in rural areas. In this project, patients' data are collected and delivered to the Beijing Life Care Networks Call Center by a 3G cardiovascular-sensing smartphone. The call center offers uninterrupted patient monitoring, diagnosis, and consultation as well as treatment. Since the project was launched in 2011, more than160, 000patients have used its services. In 2011, 2172 items of data were sent by 1033 patients, 513 of the cases were identified as abnormal, and 208 patients were diagnosed for serious cardiovascular conditions.

Second, physicians can use digital based tools to review patients' records, help diagnose illness, make clinical and treatment decisions, share experiences, and have better access to professorial information, education, and training. DXY (DingXiangYuan, http://www.dxy.cn/), one of the largest social networks for physicians and health care professionals, provides a platform where physicians can report clinical findings to colleagues and discuss them. Their services cover: IDXY (a professional social network), BioMart (a biomedical business information platform), JobMD (a healthcare career platform) and DXY survey (a market research related service).

Third, the use of digital tools can help hospitals to balance their medical resources and improve the quality of management. Examples include Regional Healthcare Information Networks (RHINs), clinical pathways, patient flow management systems and the remote monitoring of patients with chronic disease. The RHINs are designed to connect higher ranking hospitals with local community health centers (CHCs) by two-way electronic referrals and coordinating diagnoses. In 2008, Beijing, Shanghai and Sichuan were selected as pilot regional health centers for the development of RHINs. The Shanghai Shenkang RHIS (http://www.shdc.org.cn/) includes 226

hospitals, 38 municipal hospitals, about 6000 outpatient centers, 5100 in-patient centers, and 2,900 testing centers. It has documented around 6150 million patient medical records. It has also been able to save some $1 million per year and reduce the average stay at the flagship hospital from 9.2 days to 8.4 days[6].

Finally, digital health is penetrating every aspect of healthcare across the value chain. The EHRs, the RHINs, and mobile and wearable technologies are generating vast streams of medical data. Such longitudinal big datasets, recording information about patients and diseases over time, are used to evaluate a range of health interventions. Big data analytics involves data collection, data analysis and finally data application. All the players who have a role in the digital health-care ecosystem will benefit from the use of big data, including pharmaceutical and medtech companies, academics and clinical research organisations, distributors and retailers, big online and technology companies, payers and patients. For example, big-data analytics on health outcomes will be valuable in helping clinicians to redesign clinical pathways and make evidence-based clinical decisions. For pharmaceutical companies, big data can help to make business decisions, enhance productivity in Research and Development, and reduce the cycle time and cost for developing drugs. Electronic supervision drug codes are being introduced to monitor each step of drug administration. E-commerce is transforming the market. According to a report from Deloitte[7], the pharmaceutical E-commerce market could reach $50 billion by 2020.

Case example 2: Alibaba's Ali health - 'Future hospital' plane
The Alibaba group is at the forefront of exploiting the opportunities for online hospitals. It aims to reshape the hospital service model and enable users to complete the entire hospital visiting process, includingregistration,online appointments and consultations, e-prescriptions and e-payments, online pharmacies and drug sales platforms, electronic report checking and health insurance. It has partnered with 180,000 medical clinics and 50 tertiary hospitals.

Challenges

Digital health plays an import role in improving the quality and outcomes of health and social care while at the same time reducing the cost.[8] Despite the rapid growth of China's digital health care market, it still lags behind the leading countries regarding the extent of its adoption. A variety of barriers to the wider adoption of technology enabled care are still to be surmounted during the implementation of the digital healthcare reform. Regulatory uncertainty, for one thing, is a major challenge. China has no clear regulation for health digital applications associated with the outstanding speed of its development. According to the report from Deloitte,[9] digital health products developed from a technological perspective are market-driven. They are often developed without the involvement of patients and health care professionals and embody a conflict of interests. The lack of quality standards makes it very difficult for patients to choose the right applications for their health needs. Data connectivity and quality, together with privacy and the security of information are also major concerns with the adoption and integration of digital health. For example, the poor interoperability of EHR systems across hospitals makes data integration challenging. Skill gaps create another issue to address, seen in the shortage of staff with experience of large-scale health-care data management and the lack of education and training. Older people who have the highest rates of chronic disease, particularly in rural areas are the least likely ones to have electronic wearables and apps, even though these are particularly useful for patients to monitor and self-manage their health.

Despite such hurdles, it has been shown that the digital-based technology is a useful tool for making the entire healthcare system more effective. In China, it is considered the key to the most pressing challenges in healthcare systems: making healthcare more accessible, higher quality, faster and lower cost.

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Figure 1: Overview of digital health trends

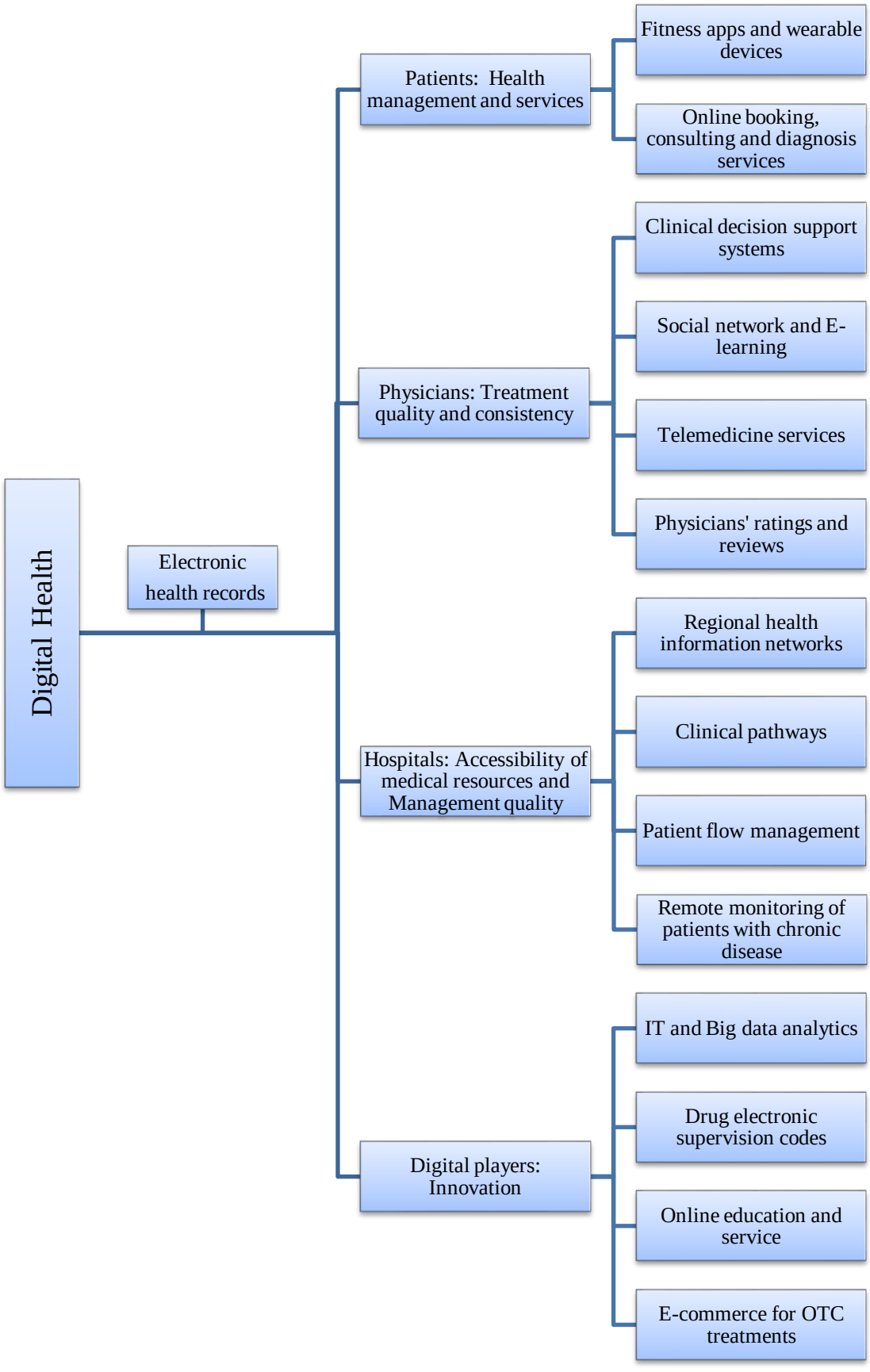
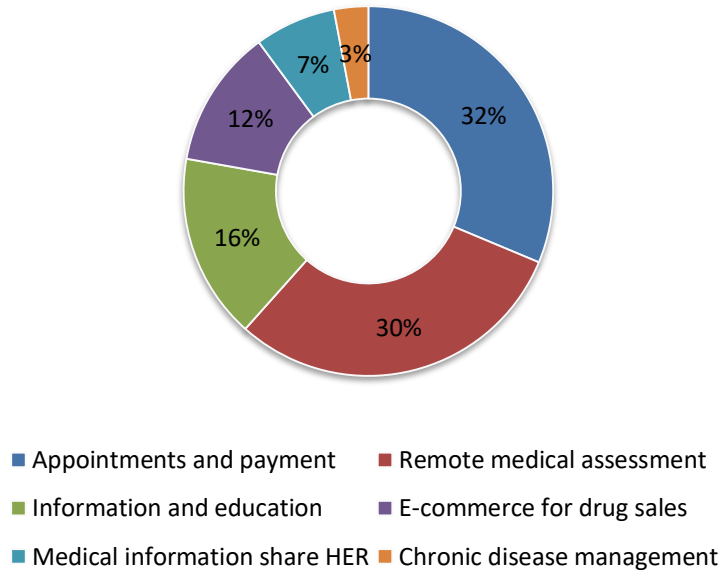


Figure 2. mHealth apps categories



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