Original Article

End-user and implementer experiences of mHealth technologies for noncommunicable chronic disease management in young adults: A systematic review

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Abstract

Background Chronic noncommunicable diseases (NCDs) such as asthma, diabetes, cancer and persistent musculoskeletal pain impose an escalating and unsustainable burden on young people, their families and society. Exploring how mHealth technologies can support management for young people with NCDs is imperative.

Objective We aimed to identify, appraise and synthesize available qualitative evidence on users' experiences of mHealth technologies for NCD management in young people. We explored both end-user (young people) and implementer (health policy makers, clinicians, researchers) perspectives.

Methods A systematic review and meta-synthesis of qualitative studies. Eligibility criteria included full reports published in peer-reviewed journals from January 2007 to December 2016, searched across databases including Embase, MEDLINE (PubMed), Scopus and PsycINFO. All qualitative studies that evaluated the use of mHealth technologies to support young people (aged 15–24 years) in managing their chronic NCDs were considered. Two independent reviewers identified eligible reports and conducted critical appraisal (based on the Joanna Briggs Institute, Meta-Analysis of Statistics Assessment and Review Instrument: JBI-QARI). Three reviewers independently, then collaboratively, synthesized and interpreted data through an inductive and iterative process to derive emergent themes across the included data. External validity checking was undertaken by an expert clinical researcher and for relevant content, a health policy expert. Themes were subsequently subjected to a meta-synthesis with findings compared and contrasted between user groups and policy and practice recommendations derived.

Results Twelve studies met our inclusion criteria. Amongst studies of end-users (N=7), mHealth technologies supported the management of young people with diabetes, cancer and asthma.

Implementer studies (N=5) covered the management of cognitive and communicative disabilities, asthma, chronic self-harm and Attention Deficit Hyperactivity Disorder. Quality ratings were higher for implementer compared with end-user studies. Both complementary and unique user themes emerged. Themes derived for end-users of mHealth included: 1. Experiences of functionality that supported self-management; 2. Acceptance (technical usability and feasibility); 3. Importance of co-design; and 4. Perceptions of benefit (self-efficacy and empowerment). For implementers, derived themes included: 1. Characteristics that supported self-management (functional, technical and behavior change); 2. Implementation challenges (systems level, service delivery level and clinical level); 3. Adoption considerations for specific populations (training end-users; specific design requirements); and 4. Co-design and tailoring to facilitate uptake and person-centered care.

Conclusion Synthesizing available data revealed both complementary and unique user perspectives on enablers and barriers to designing, developing and implementing mHealth technologies to support young people's management of their chronic NCDs.

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Keywords young people; implementation; musculoskeletal pain; mHealth; digital technologies; non-communicable disease; chronic; end-users; implementers; health policy

Introduction

Young people are digital natives and the portability and capabilities of digital technologies can act as a lever to connect them to health systems. This capability to connect is especially important for young people with chronic noncommunicable diseases (NCDs) during the critical transition from childhood to young adulthood [1, 2]. We have previously identified how mobile health (mHealth) technologies could support self-management of young people with persistent musculoskeletal pain who are making this transition [2, 3] and how to specifically address their self-management needs by improving access to disease information, strategies to manage symptoms and social support [4]. Self-management is well recognized as a fundamental component of chronic NCD care, denoting the active participation of people in their care with the aim of minimizing the impact of chronic disease on physical health status and functioning and enabling people to cope with the psychological effects of illness [5]. Core self-management skills include problem solving, decision making, resource utilization, forming patient-health professional relationships, taking action and self-tailoring, all skills that can be feasibly be supported by appropriate mhealth technologies as highlighted in findings from a recent systematic review on this issue [1]. Furthermore, the use of mHealth technologies as an enabler to self-management is an intuitive choice for young people, given the high rates of internet usage globally, with rates nearing 100% for the Millennial generation in many of the world's largest economies [6]. Young people are also more likely than older generations to own a smartphone in virtually every country [6]. Digital technologies can also provide a potential mechanism to help mitigate care disparity [7] reaching across high, middle and low-income economies [8] to enable the delivery of integrated, holistic information about chronic NCD management [9].

While the use of mHealth technologies, including mobile applications ('apps'), to support self-management of NCDs has also grown substantially [10], the evaluation of their quality and

safety and outcomes indicate that significant evidence-practice and policy-practice gaps remain [1, 11, 12]. In particular, there is a dearth of high quality evidence on the use of mHealth technologies to support young people's self-management of their persistent musculoskeletal pain conditions [2, 13]. Recent efforts address some of these gaps, providing evidence for how mHealth 'apps' can improve the access of young people with chronic pain to disease information, facilitate symptom management and social support [4] and support their self-management of cancer pain [14, 15]. In the context of other young people's use of mHealth to support their management of other chronic NCDs (asthma, diabetes, cancer), findings from a recent systematic review indicate the need for more high-quality studies targeting the development, evaluation, use and effectiveness of mobile 'apps' [1]. One significant issue common to mHealth interventions is that they fail to be fully embedded into real world settings and scaled up, with many studies being conducted as pilots or feasibility trials [1, 16]. Another key finding from this same review emphasized the critical role of co-design of mobile 'apps'. This means bringing together both end-users (here, young people) and implementers (policy makers or health professionals tasked with implementation), to ensure meaningful design and to facilitate strong engagement, adoption and sustained uptake [17]. Co-design includes consideration of factors such as feasibility, engagement, ease of use, ease of navigation, ease of understanding, satisfaction, acceptability, reliability, functionality, aesthetics, information quality and subjective quality [1, 14, 15, 18, 19].

The primary motivation for this systematic review was to inform appropriate mHealth resource design, evaluation and implementation, specifically targeted for young people with chronic NCDs including persistent musculoskeletal pain. The experiences of young people with chronic NCDs diseases were considered more broadly, as the self-management of chronic conditions frequently overlaps and is associated with co- and multi-morbidities [20, 21] requiring similar core self-management skills [5]. To optimally inform implementation approaches, a comprehensive

understanding of users' experiences and perceptions is essential. Qualitative (including mixed methods) studies are likely to provide the richest insights and such perspectives and insights are recognised as a critical component of implementation approaches related to interventions and system-wide models of care [22, 23]. Additionally, as the implementation of new interventions is recommended to be a partnered process between end-users and implementers, identifying unique and overlapping user perspectives could lead to better shared decision-making and care integration [18].

This systematic review therefore had two key aims: i) to identify users' (end-user and implementers) experiences with mHealth technologies to support the self-management of young people with chronic NCDs; and ii) to identify what factors these users (end-user and implementers) perceived or experienced as facilitators or barriers to the uptake and/or implementation of mHealth technologies for young people with chronic NCDs.

Methods

This systematic review followed an a priori published protocol with detailed methods [13]. Our review is reported in accordance the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement checklist [24] and Enhancing Transparency in Reporting the synthesis of Qualitative research (ENTREQ) checklist [25] (Multimedia Files 1 and 2).

Eligibility criteria

Types of participants

This review considered all qualitative studies on young people (aged 15 to 24 years) with chronic NCDs ('end-users') which included technologies intended for use by patients [13]. Studies were included where ≥50% of the cohort met the age criteria or where the mean age range (rounded) of participants fell within the 15 to 24 year age range. Additionally, the experiences and perspectives of

'Implementers' (defined as including health service delivery providers, administrators, researchers, clinicians and policy makers) supporting young people with chronic NCDs were included and considered separately.

Chronic NCDs, were defined as conditions of long duration and generally slow progression, lasting 3 months or more and included, but were not limited to, musculoskeletal conditions, diabetes, respiratory conditions (such as asthma), cardiovascular diseases, mental health disorders and cancer [26].

Phenomena of interest

This review considered studies that evaluated the use of mHealth technologies to support young people manage their chronic NCDs [13]. To be included, studies needed to have evaluated users' (implementers and end-users): i) perspectives or experiences (i.e., perceptions of feasibility, engagement, ease of use, ease of navigation, ease of understanding, satisfaction, acceptability, reliability, functionality, aesthetics, information quality and subjective quality) of using mHealth technologies to support the management of chronic NCDs; and ii) factors that users (end-user and implementers) perceived or experienced as facilitators or barriers to the uptake and/or implementation of mHealth technologies for young people with chronic NCDs [13]. In this review, mHealth included any mobile device or service, such as mobile phones, Short Message Service (SMS), smartphones, personal digital assistants, and devices that work on wireless technology or Bluetooth-compatible devices [27]. Interventions delivered using a Web-based platform were included only if it was specified that the patient accessed the service via a mobile phone, or other mobile device.

Context

Studies carried out in any setting were considered. The rationale included the portable and accessible nature of mHealth technologies, which enables varied use not just within different care

settings by different patients, but extending across different contexts by the same patient (i.e. continuing to access and utilize the same smartphone app in the community (locally and remotely), in primary care and tertiary care settings).

Types of studies

This review considered primary research studies that used qualitative methods to collect and analyse data, including but not limited to phenomenology, grounded theory, ethnography, critical enquiry, participatory action research, and descriptive qualitative studies. The qualitative components of mixed-methods studies were also included.

Search strategy

A three-step search strategy was utilised in this review [13]. An initial limited search of MEDLINE (PubMed) and CINAHL and PsycINFO was be undertaken, followed by analysis of the text words contained in the title and abstract, and the index terms used to describe an article. A second search using all identified keywords and index terms was then undertaken across all databases including Embase, Medline (PubMed), Scopus, and PsycINFO. Two independent academic research librarians were consulted to provide feedback on the final search strategy. The search for Grey literature included ProQuest Dissertations and Theses, KT, Epistemonikos as well as health policy and non-governmental organisation literature, based on the research team's knowledge. Thirdly, the reference list of all included reports and articles were hand searched for additional studies. Studies published in English were considered for inclusion in this review. The search was carried out in December 2016 by a senior review methodologist (JC). Studies from 2007 were included to align with global access to 147 Wideband Code-Division Multiple Access; the standard found in 3G mobile telecommunications and available globally [28].

Initial keywords used were: chronic, long term, persistent, non-communicable, disease, respiratory, asthma, cystic fibrosis, lung disease, diabetes, cancer, heart disease, cardiovascular disease, pain,

muscular disease, joint diseases, musculoskeletal, kidney disease, young, adolescent, adolescence, eHealth, mHealth, mobile application, mobile health app, mobile health application, smartphone application, digital technologies, intervention, qualitative, experience, phenomenology, grounded theory, action research, implementation, implementer, end-user. The full search strategies are included in Multimedia File 3.

Screening and selection

Overview

Search results were collated in a reference database (Endnote X7 version 3.1, Thomson Reuters, NY), duplicates were deleted and initial screening of titles and abstracts was conducted by one reviewer (JC), followed by the retrieval of full texts. Full texts were then reviewed against the inclusion criteria by two independent reviewers (HS and JC) to confirm eligibility. Disagreements were resolved through discussion.

Assessment of methodological quality

Papers selected for retrieval were assessed by two independent reviewers (JC, HS) for methodological quality prior to inclusion using the standardized critical appraisal instrument for qualitative research from the Joanna Briggs Institute, JBI-QARI [29]. Studies were not excluded on the basis of quality ratings. Any disagreements were resolved through discussion until consensus was reached.

Data extraction

Data were extracted by one reviewer (JC) from papers included in the review using the standardized extraction tool from JBI-QARI [29]. A second reviewer (HS) also completed data extraction for 30% of articles to confirm congruence. The primary focus of data extraction was the identification of specific qualitative findings – reported themes, subthemes, and metaphors – related to the phenomena of

interest, which were subsequently synthesized as described below. Additionally, descriptive data, including details about the mHealth application(s), study methods, country of development, and age range of participants were extracted.

The credibility of findings was assessed based on how they were supported in the text [29], as follows:

- Unequivocal: findings accompanied by an illustration that is beyond reasonable doubt and therefore not open to challenge
- Credible: findings accompanied by an illustration lacking clear association with it and therefore open to challenge
- Unsupported: findings not supported by data.

Data synthesis

A meta-synthesis approach was used to organise and interpret pooled data [29]. Initially, three reviewers (JC, AMB, HS) familiarised themselves with the extracted data and independently developed preliminary categorisations. At a subsequent three-day workshop, these independently and deductively derived categories were presented, discussed and iteratively and inductively organised into consensus-based descriptive themes from which we derived new, higher-order themes that extended beyond the findings of primary studies. Findings were linked back to the research questions to ensure relevance and appropriate contextualisation. Themes were then subjected to a meta-synthesis to inform declarative statements that could be applied as an evidence-base to our research aims. Four members of the team (AMB, JC, MB, HS) participated in the meta-synthesis. Findings based on the experiences of end-users and implementers were meta-synthesized separately and compared and contrasted.

Based on consensus, a reporting framework was developed to reflect these synthesized findings. The reporting framework was populated with derived themes and supporting evidence from primary study findings. To ensure external validity, one member of the team (JS) with substantial clinical and research expertise in the development and implementation of digital technologies for young people with chronic conditions, provided independent feedback over the meta-synthesis process. Where relevant, findings and supporting evidence were adjusted to reflect a consensus decision and the reporting framework was refined. Finally, a systems and health policy expert (MB) was engaged to assist with final policy and practice recommendations, with a final round of independent review (JS) conducted as outlined above.

Results

Identification and selection

The initial search identified 4,046 potential studies (Figure 1), 1,193 studies were excluded as duplicates and 2,815 were excluded based on the review on their titles/abstracts. Overall, 38 studies were identified as potentially meeting the inclusion criteria based on review of their titles and abstracts. From these 12 studies were ultimately included [30-41]. Reasons for exclusion included, not being a research paper [42], not being qualitative or having a qualitative component [43-50], investigating the wrong phenomena of interest [51-53], not meeting the definition of mHealth [54, 55], the population being outside the target age band [19, 56-62], and the population being affected by a condition not considered to be a chronic NCD (for example, mHealth promotion interventions with no specific chronic NCD or lifestyle behaviours) [63-66]. Seven studies contributed findings on end-users [30, 31, 33-35, 37, 39], while five [32, 36, 38, 40, 41] reported on implementers.

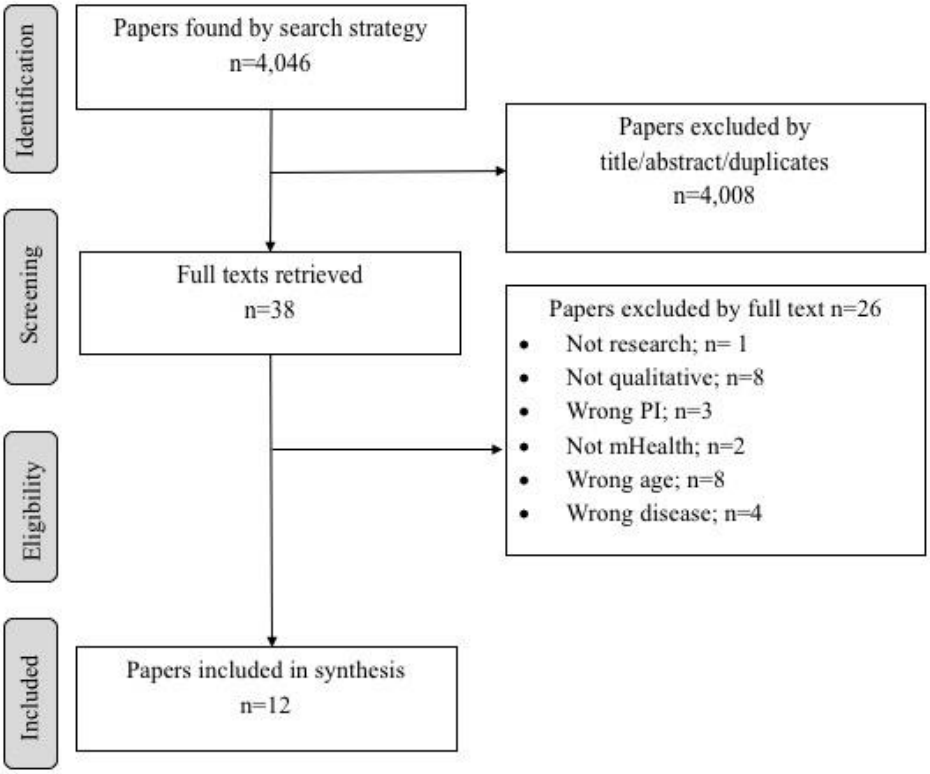

Figure 1. Flow diagram of study identification and selection, adapted from PRISMA flow chart. PRISMA=Preferred Reporting Items for Systematic Review and Meta-Analysis. PI=phenomenon of interest; mHealth=mobile health

Included study characteristics

Characteristics of included studies are described in Table 1 (end-user studies) and Table 2 (implementer studies). Amongst end-users, mHealth technologies were applied to aid in managing diabetes [30, 34, 35], cancer (chemotherapy symptom management) [31, 37], and asthma [33, 39]. Implementers included occupational therapists [32], speech language pathologists [32], nurses [36], physicians [36, 40], as well as medical [38, 41] and non-medical [38, 41] health care professionals assisting in the management of cognitive and communicative disabilities [32], asthma [36, 40],

chronic self-harm [38], and attention deficit hyperactivity disorder (ADHD) [41]. Studies on end-users were carried out in the United Kingdom (UK) [30, 37], United States of America (USA) [31, 33, 39], and Norway [34, 35], while studies on implementers were conducted in the UK [38, 41], USA [36, 40] and Sweden [32].

Table 1. Characteristics of included end-user studies

	Phenomena of interest	**Participants**	**mHealth technology used**	**Method/design[a]**	**Analytic approach**	**Setting**	**Geographic location**
End-user studies							
Ashurst 2014 [30]	Use of an app to help prepare for clinical appointments	Young people with type 1 diabetes; age 16-25 years; mean age 20.3 years	Apps developed by young people with diabetes to facilitate agenda setting in clinic consultations, data logging and insulin dose calculation;	Open ended questions (email and online)	Inductive conventional content analysis; summative content analysis	Community	UK
Baggott 2012 [31]	Perceptions about using mobile oncology symptom tracker (mOST) and any technical difficulties they experienced	Adolescents and young adults with cancer; 13-21 years; receiving chemotherapy; mean age 18.2 years	A mobile phone-based electronic symptom diary (mOST);	Interviews and questionnaire	Not specified	Participants were receiving chemotherapy	USA
Carpenter 2016 [33]	How app features promote self-observation, self-judgment and foster positive	Convenience sample of 20 adolescents with asthma; 12-17 years; mean 14.7 years; >50% over 15 years	Two asthma self-management apps (one targeted to adults; one to children)	20-30 minute telephone interview with verbatim transcription	Framework synthesis based on a framework analysis (self-regulation theory)	Paediatric practice located in an urban area	USA

	self-reflection; outline how app features (as posited by self-regulation theory) could work synchronously to increase adolescents' asthma self-management and improve asthma outcomes						
Froisland 2015 [34]	To evaluate the effect of the designed tool with regard to empowerment, self-efficacy, and self-treatment	Adolescents with type 1 diabetes; 13-19 years; mean age 16.2 years; >50% over 15 years	A mobile phone based tool designed to capture and visualize adolescent food intake in order to affect understanding of calorie counting and facilitate doctor-adolescent communication	Semi-structured interview	Deductive approach based on empowerment theory	Pediatric clinic	Norway
Froisland 2012 [35]	Adolescent patients' experiences with two different mobile phone applications used for diabetes care	Adolescents with type 1 diabetes; 13-19 years; mean 16.2 years	An app that contained a visual/picture based diabetes diary to record physical activity and food eaten that communicated with the glucometer, and a web-based (accessed through mobile) SMS service to be	Structured interview (transcribed) with field notes	Inductive qualitative description influenced by phenomenology and hermeneutics	Paediatric clinics	Norway

			used to contact providers when faced with obstacles and receive educational messages				
Gibson 2010 [37]	Key benefits of The Advanced Symptom Management System (ASyMS-YG)	Young people receiving inpatient intravenous chemotherapy; 13-18 years; median age 15 years; >50% over 15 years)	ASyMS: through which patients can report chemotherapy related symptoms through mobile	Questionnaires and semi-structured interviews	Thematic analysis	Cancer units	UK
Rhee 2014 [39]	Feasibility and user acceptability of mobile phone based Asthma Self-Management Aid for Adolescents (mASMAA)	Adolescents with asthmas; Adolescent-parent dyads; 13-17 years; mean 15.1 years; >50% over 15 years	mASMAA which facilitates symptom monitoring, treatment adherence, and adolescent patent partnership	Focus groups with semi-structured questions (recorded and transcribed)	Content analysis	Clinical setting (including the emergency department and primary care clinics in a university medical center)	USA

[a] Qualitative design/study type is specified where explicitly stated within studies, otherwise descriptive detail is provided

Table 2. Characteristics of included implementer studies

	Phenomena of interest	Participants	mHealth technology used	Method/design [a]	Analytic approach	Setting	Geographic location
Implementer studies							
Buchholz 2013 [32]	Professionals' views of satisfaction, participation and involvement in daily life of adolescents and adults with communicative disabilities who tried text messaging with picture symbols and speech synthesis through smart phones	Four occupational therapists and 3 speech language pathologists who had worked with end-users (adolescents and adults with cognitive and communicative disabilities using the intervention)	Text messaging with picture symbols and speech synthesis in smartphones	Semi-structured interview with independent transcription	Retrospective qualitative analysis theory influenced by directed content analysis	Community setting	Sweden
Geryk 2016 [36]	The use of attitudes and preferences for asthma mHealth app features among parents and clinicians	20 caregivers and 6 clinicians involved in the care of adolescents with asthma	Two asthma self-management apps (one targeted at adults one at children)	Questionnaires and interviews	Thematic analysis	Paediatric practices	USA
Owens 2016 [38]	Barriers to recruitment and implementation of a text messaging intervention for adolescents who	Clinicians and service managers working in Child and Adolescent Mental Health Services (CAHMS)	An SMS text messaging service (TeenTEXT) that delivered scheduled or prompted personalized messages	Field notes and focus groups	Inductive thematic analysis	Child health and adolescent mental health services (CAHMS)	UK

	self-harm	with adolescents who self-harm					
Schneider 2014 [40]	Physicians' views on patient-provider communication with their adolescent asthma patients, mechanisms for relating better with patients, their use of mobile technologies, and willingness to integrate technology in patient care	Residents and attending physicians about mHealth use for adolescents' management of asthma	Mobile technology for patient care (no one specific tool/technology)	Interviews (with recording and transcription)	Constant comparative method using a priori codes	One pediatric group in an urban academic medical center	USA
Simons 2016 [41]	To explore patients', parents', and healthcare professionals' views regarding the use of RMT (remote monitoring technology) during medication titration for attention deficit hyperactivity disorder (ADHD)	Health care professionals working with people with ADHD	Remote monitoring technology for people undergoing ADHD medication titration which sent automated text messages (linking to questionnaires)	Exploratory cross-sectional focus group	Thematic analysis and charting were used to search for data patterns within and across participant groups	4 National Health Service mental health providers	UK

[a] Qualitative design/study type is specified where explicitly stated within studies, otherwise descriptive detail is provided

Methodological quality assessment

Table 3 shows the findings of the critical appraisal for studies of end-users (n=7) and implementers (n=5) respectively. Studies on implementers were scored as higher quality than those on end-users. This was particularly true for question 8 on the representation of participant voices, which were adequately represented for all five studies on implementers, but only for four of the seven studies on end-users. Researchers' cultural or theoretical backgrounds were inconsistently reported (question 6), while the impact of the researcher on the research was rarely addressed (question 7).

Table 3. Critical appraisal of the methodological quality of included studies

	Question number									
Users	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
End-users										
Ashurst 2014 [30]	Y	Y	Y	Y	Y	N	N	N	Y	Y
Baggott 2012 [31]	U	U	U	N	U	N	N	N	Y	U
Carpenter 2016 [33]	Y	Y	Y	Y	Y	N	N	Y	Y	Y
Froisland 2015 [34]	Y	Y	Y	Y	Y	Y	N	N	Y	Y
Froisland 2012 [35]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Gibson 2010 [37]	Y	Y	Y	Y	N	Y	N	Y	Y	Y
Rhee 2014 [39]	U	Y	Y	Y	Y	U	N	Y	Y	Y
Positive/7	5	6	6	6	5	3	0	4	7	6
Implementers										
Buchholz 2013 [32]	Y	Y	Y	Y	Y	N	N	Y	Y	Y
Geryk 2016 [36]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Owens 2016 [38]	Y	Y	Y	Y	Y	Y	N	Y	Y	Y
Schneider 2014 [40]	U	Y	Y	Y	Y	N	N	Y	Y	Y
Simons 2016 [41]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Positive/5	4	5	5	5	5	3	1	5	5	5

Y=Yes, N= No, U= Unclear. Q1: Is there congruity between the stated philosophical perspective and

the research methodology? Q2: Is there congruity between the research methodology and the research question or objectives? Q3: Is there congruity between the research methodology and the methods used to collect data? Q4: Is there congruity between the research methodology and the representation and analysis of data? Q5: Is there congruity between the research methodology and the interpretation of results? Q6: Is there a statement locating the researcher culturally or theoretically? Q7: Is the influence of the researcher on the research, and vice- versa, addressed? Q8: Are participants, and their voices, adequately represented? Q9: Is the research ethical according to current criteria or, for recent studies, and is there evidence of ethical approval by an appropriate body? Q10: Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data? [29].

Data analysis and meta-synthesis

Results of the meta-synthesis are presented below. Data are presented as a synthesized finding with supporting themes and component subthemes (for a summary of themes/subthemes, see Table 4). Results are reported separately for end-users and implementers. Examples of supporting evidence are provided in text boxes along with statements about level of credibility. Data were subsequently examined for complementarity, indicating both common and unique user themes, which subsequently informed recommendations for policy and practice. Full supporting data and original findings are presented in Multimedia files 4 and 5.

Table 4. Summary of themes and subthemes derived for end-users and implementers

User group	**Themes**	**Subthemes**
End-users	Functionality of mHealth	• mHealth functionality to support

	technology	self-management • mHealth functionality to support young person-centered clinical encounters
	Acceptance of mHealth technologies	• Perceptions of technical usability • Perceptions and experiences around acceptability and feasibility
	The importance of co-design	• Intra-personal factors • Extra-personal factors
	Perceptions of benefit	• Self-efficacy • Empowerment
Implementers	mHealth characteristics that support young people's management of NCDs	• Functional aspects of design that support end-users' management • Technical characteristics can help their delivery of clinical care • mHealth can support positive health behavior change
	Implementation challenges	• Micro level factors • Meso level factors • Macro level factors
	Adoption of mHealth technologies in a specific young population	• The need for training of end-users • The need for design to facilitate uptake and match social context or peer expectations.
	Co-design and tailoring	• Importance of co-design • Tailoring to end-user needs

End-users' experiences and perspectives

Theme 1. Functionality of mHealth technology

End-users perceived the functionality of mHealth technologies as important. Specifically, sub-themes related to i) functionality as an important enabler to supporting self-management, and ii) person-centered clinical encounters (Textbox 1).

mHealth functionality to support self-management

The functionality of mHealth technologies was perceived as supporting young people's self-management of a range of NCDs including asthma, diabetes and cancer. Specifically, the functionality offered by mHealth technologies assisted young people in managing their conditions in a number of different ways. This included:

- monitoring their health status and symptom triggers via graphical charting [33] and sign/symptom awareness using self-checks [33, 37, 39]
- improving their comprehension and understanding of their health condition [34]
- providing reminders about medication adherence [33]
- providing ready access to automated tailoring of personal health information related to the management of their condition(s) [33]
- providing relevant information, support and reassurance about planning for emergencies and safety issues through prompting timely communication with health professionals [35, 37, 39]

mHealth functionality to support young person-centered clinical encounters

The functionality of the mHealth technologies supported a young person-centered clinical encounter by enabling accurate and immediately available clinically-relevant personal data at a consultation [30], providing a record of clinical health information to treating practitioners (portability and

accuracy of data over a cumulative period of time) [33], and enabling end-users to direct the focus of the clinical encounter [37].

Textbox 1. End-user experiences of mHealth (theme)

mHealth functionality to support self-management (sub-theme)

- I used the symptoms, triggers, and notes, cause—because with the symptoms, it can—it pretty much tells how—like what I'm feeling at that time like throughout the day and the triggers is like if I have a flare up or, uh, an attack or—then it'll—it'll help, it'll show like what—what caused it in the notes because it just—I can just put down everything that happened throughout the whole day. Carpenter 2016 *Page 515, column 2* (Unequivocal)
- "Like it—it really did help me out, um, and to know about the progress of my-of my asthma… it let me like know more of how my asthma was going during the weeks and—and days." Carpenter 2016 *Page 513 column 2* (Unequivocal)
- "The triggers, um, I thought it was good because it would help you keep track of like what triggered it before, so you would know to stay away from it or stay indoors if it's like a certain type of plant blooming or something. And it would help you, uh, remember that for the future years, so you could, um, remember to stay away from it." Carpenter 2016 *Page 514 column 1* (Unequivocal)
- "The chart, cause I can like sc-, I can watch it, I can scale my asthma and I can see if it's worse or if it's getting better, or if it's really serious I need to do something about it, it helps me. Um-hum." Carpenter 2016 *Page 514 column 1* (Unequivocal)
- "And I always remember to take my medicine easier with this app so I think that will help out. Because if I could continue to take my medication on sort of, uh, a consistent flow it makes it easier. And so overtime, I think it will help me control my asthma." Carpenter 2016 *Page 513 column 2* (Unequivocal)

mHealth functionality to support person-centered clinical encounters (sub-theme)

- ''They'll [doctors and nurses] be able to know exactly what is happening.'' Gibson 2010 *Page 349, table 3* (Unequivocal)
- "I think that was good…so like if your doctor just wonders how you're doing when he doesn't see you, you could, you could send him the chart and he could see how you've been doing." Carpenter 2016 *Page 515 column 1* (Unequivocal)
- "I could give it to my school if there's a problem with my asthma, they can say, 'Oh, well she did send us this document saying that she has asthma, so we need to let her take her medicine,' so that's a good thing." Carpenter 2016 *Page 515 column 1* (Unequivocal)

Theme 2. Acceptance of mHealth technologies

End-users acceptance of mHealth technologies was related to two subthemes: i) technical capability (usability; how it's working now and how they perceived optimisation), and ii) acceptability and feasibility (Textbox 2).

Perceptions of technical usability

Users identified technical aspects of the mHealth technologies that affected usability and made suggestions for optimisation/improvement as it related to implementation at scale.

While mHealth technologies were perceived as useful to supporting their health needs [30, 35], especially for tracking functions such as data logging, dose calculation (insulin) and for agenda setting (identifying and remembering what to discuss at appointment in the context of diabetes) [30], participants also identified the need for specific technical adjustments to better support management of their condition(s) [30, 35]. This included bypassing the need for accessing SMS via an internet browser on the mobile phone, rather end-users preferred a capability to use direct SMS. Further, end-users also reported a preference for having a download availability of the software for use directly on their own mobile phones [35].

Perceptions and experiences around acceptability and feasibility

Users identified characteristics of mHealth technologies that aligned with their preferences for disease management support, specifically apps that were intuitive (self-explanatory and simple to understand) and provided practical self-management information that was immediately usable [30, 31, 35]. While some features were reported as not relevant/acceptable (e.g. a requirement to record peak flow for asthma management) [33], the use of mHealth technologies was still considered useful and feasible as end-users were able to adapt to and accommodate mHealth technology into their routines [39].

Textbox 2. Acceptance of mhealth technologies (theme)

Perceptions on technical usability (sub-theme)

- "The Diamob app didn't work at the end of the project. The glucometer with Bluetooth worked, but batteries ran out of power quickly." Froisland 2012 *ePub* (Unequivocal)
- Overall, reviewers indicated that the apps were worth trialling but a few felt improvements or amendments were needed before regular use. Ashurst 2014 *ePub* (Credible)
- "But what is cumbersome is that you have to access that Internet browser on the mobile. I would prefer to send normal SMS on the phone...that would make it even easier if you could access it using the usual SMS [on the phone]." Froisland 2012 *ePub* (Unequivocal)
- "I think it is a lot easier to understand and to have it explained when I can see things." Froisland 2012 (Unequivocal)

Perceptions and experiences around acceptability and feasibility (sub-themes)

- I think most people just don't want to do them [peak flows]. And you don't want to have to – because first, you have to, you know, use it. You have to use it three times and you really start coughing, hacking after you've used it. Most people don't like peak flows. And then in addition to actually having to do the peak flow, you – if you want to see how you're doing really, you have to document it. Carpenter 2016 Page 515, column 1 (Unequivocal)
- Adolescents were able and willing to make adjustment to their routines to accommodate mASMAA and became accustomed to interactions with mASMAA easily ("You get used to it and it becomes routine"; "I feel like it becomes normal, just like … an instinct to do it") Rhee 2014 *Page 67, column 2* (Unequivocal)
- "It is more about those messages and the information. It has been practical advice, easy to understand, simple facts that are very nice to know. It is better to have it in such small portions instead of reading a lot of information, then everything is poorly read and poorly understood. I liked the way the information was given." Froisland 2012 *ePub* (Unequivocal)
- Reviewers' felt the easiest to use apps were self-explanatory and simple to understand. The other apps were also considered easy to use but with some suggestions to improve the user-interface. Ashurst 2014 *ePub* (Credible)

Theme 3. The importance of co-design

End-users identified the critical importance of co-design of mHealth technologies which included subthemes based on intra and extra-personal factors considered important to end-users [30] (Textbox 3).

Intra-personal factors Competing time demands and inadequate knowledge of condition-specific triggers and value judgements (such as a perception of already adequate self-management) [33, 34] were cited as factors that needed to be considered in mHealth technology co-design.

Extra-personal factors Capacity for tailoring design and making technology more broadly acceptable for end-users were important considerations. Understanding disease-specific requirements and young people's needs around the use of technology for self-management [30] were deemed important, including design considered within the context of their specific peer or social setting [34].

Textbox 3. The importance of co-design (theme)

intra-personal factors (sub-theme)

- "I really don't know what my triggers are, so I really didn't use it that much." Carpenter 2016 *Page 514 column 1* (Unequivocal)
- "Because, like my asthma is well-controlled, so like a lot of the stuff here I don't really need, but maybe like other people who have it worse will like probably need it more." Carpenter 2016 *Page 515, column 1* (Unequivocal)
- "[…] one participant noted that she was too busy to use an asthma app." Carpenter 2016 *Page 515, column 1* (Credible)

extra-personal factors (sub-theme)

- […] much importance was placed on app design (not necessarily development) by diabetic peers because of a mutual understanding of the needs, condition and experiences in order for the apps to offer the most accurate features and details. Ashurst 2014 (Credible)
- Most adolescents in the study felt in charge of their own life, however they talked about acceptance as an important factor. Acceptance of own disease and treatment and also acceptance from important others like friends to treatment while in different social settings. Froisland 2015 *Page 545, Table 1* (Credible)

Theme 4. Perceptions of benefit

End-users perceived benefits in the use of mHealth technology that included the subthemes of self-efficacy and empowerment (Textbox 4).

Self-efficacy

End-users indicated that mHealth technologies were beneficial and positively influenced their internal sense of control, consistent with improved self-efficacy [34, 37, 39].

Empowerment

mHealth technologies were perceived by end-users as empowering their NCD self-management skills and knowledge. This was perceived as resulting in increased confidence and more positive perceptions about their ability to better manage their lives [33, 35], through improving their knowledge and accessibility to health providers [34].

Textbox 4. Perceptions of benefit (theme)

Self-efficacy (sub-theme)

- "[…] adolescents reported increased independence during the trial, as indicated in their improved self-management (e.g., taking medications) without parents' prompting." Rhee 2014 *Page 68, Column 2* (Credible)
- ''I felt in control and I liked that you could see if your temperature had improved.'' Gibson 2010 *Page 349, table 3* (Unequivocal)
- The direct contact with those they trust was reported as important. To know that they got an answer back, gave a feeling of acceptance and to be paid attention to. Froisland 2015 *Page 545, Table 1* (Credible)

Empowerment (sub-theme)

- "It has been pretty good to know that if I have an issue, then I can just send a message...Instead of calling Mom or Dad and ask them to call [the physician], and when they have the answer it might be an answer to something I was not wondering about." Froisland 2012 *Page 513 column 2* (Unequivocal)
- "It kind of keeps me to where I can see what I've done, instead of it just being in my mom or my doctor knowing how far I've come, where – if I'm getting better or worse, if I'm normal for myself or anything, I can kind of keep myself in check." Carpenter 2016 *Page 516, column 1* (Unequivocal)
- Positive response from people who know the disease is important to feel empowered. The SMS application increased the possibility for response directly from their health care

professional. Froisland 2015 *Page 545, Table 1* (Credible)

Implementers' experiences and perspectives

Theme 1. mHealth characteristics that support young people's management of NCDs

Implementers identified multiple components of young people's NCD management that can be supported by mHealth technologies (Textbox 5). Three sub-themes emerged: functional aspects of design that support end-users' management; technical characteristics that support clinicians' delivery of clinical care for young people; and how mHealth can support positive health behavior change.

Functional aspects of design that support end-users' management

Implementers identified a range of design features that were perceived to support end-users' management of their conditions. These included:

- tracking side effects and symptoms for clinical management [36, 40, 41]
- focusing the agenda for clinical appointments [36, 40, 41]
- reminders for medication adherence and to overcome supply problems [36, 41]
- enabling bilateral communication between end-users and clinicians [32, 36, 40]
- overcoming communication deficiencies [32]
- habituation of components of self-management (medication management and adherence [40])
- providing alerts for end-users and their clinicians about deteriorating health conditions [40]
- remote technology enabling social connectedness and access to health support (motivation, coaching and providing information to their treating physician) [32, 41].

Technical characteristics can help their delivery of clinical care

Implementers identified several technical features that they believed would assist their delivery of clinical care and optimize their engagement with end-users such as communication reminders (use of medicines, low peak flows) and focusing clinical encounters through more efficient preparation [36, 40].

mHealth can support positive health behavior change

Implementers perceived mHealth technologies to positively influence end-users to independently manage their condition and to facilitate positive health behavior change [32, 36, 40], through independent communication [32], age-related appeal [36] and providing positive feedback to end-users (e.g., improved asthma tracking, reminders for medication use and refills, peak flow assessment and communication to health professional [40]).

Textbox 5. mHealth technology characteristics that support young people's management of noncommunicable diseases (theme)

Functional aspects of design that support end-users' management (sub-theme)

- "This way you can look back over the previous 4 weeks or 3 months and focus on questions such as—"you scored sleep a 2 here, what was happening at the time that made it so unsettled?" It should help parents to be more productive in giving the information we need." Simons 2016 *Page 9, column 1* (Unequivocal)
- "Participants saw the potential for RMT to provide the ability to easily monitor symptoms, chart them over time, and identify any patterns or unusual behaviors. This would increase people's knowledge, self-awareness, and understanding of and confidence in dealing with their condition." Simons 2016 *Page 9, column 1* (Credible)
- The difficulties I come across, [are that] young people are on medication and they tend to run out at the end of the month and their behavior will go sky high, and it will take them a week to get all the medication back into their system. I think it would be really useful if somewhere in the app, say when they're...near the end [they receive a message saying] "You need to put in a request for repeat prescription." [HCP, Site 3] Simons 2016 *Page 10, column 1* (Unequivocal)

- ‘‘ .. . teenagers are busy and communication is limited and I think using technology will improve communication. They’ll listen more. I mean, I think they read their texts, you know, and I think reading a short text is much more beneficial and reminder systems on an everyday, I mean, doing something the same way for 2 weeks makes it a habit.’’ Schneider 2016 *Page 156* (Unequivocal)

- “He has great help from the synthetic speech and he is markedly disturbed when it doesn’t really sound like he wants it to” Buchholz 2013 *Page 92, column 1* (Unequivocal)

How technical characteristics of mHealth can help their delivery of clinical care (sub-theme)

- Clinicians felt that use of the app could lead to a better medical appointment both in terms of efficiency, patient-centered care, and decision making. Multiple clinicians expressed data security concerns (eg, insecure email) or differed in their preference for information delivery method [...] Geryk 2016 *ePub* (Credible)

- Multiple clinicians mentioned that appointment non-compliance is a problem, one stating that “[a]ny extra reminder that families have that they have an appointment I think is helpful.” Geryk 2016 *ePub* (Unequivocal)

How mHealth technology can support positive behavioral change (sub-theme)

- ‘‘I mean if everything is going well, you could give them sort of positive feedback just like: ‘‘Hey, keep up the great work.’’ If not, you could be like: ‘‘Are you taking your controller?’’ Schneider 2016 *Page 158* (Unequivocal)

- Clinicians generally had positive things to say about the apps as a self-management tool to help parents and adolescents including the following: “hands-on” and provides a “more interactive or fun way to check on their asthma.” Geryk 2016 *ePub (Credible)*

RMT=remote monitoring technology

Theme 2. Implementation challenges

Important challenges to implementation of mHealth technologies were experienced or perceived by implementers as extending across multiple levels of the health care system. This aligned with three sub-themes: challenges at the clinical level (micro); at the service delivery level (meso); and at a systems level (macro) (Textbox 6).

Micro level factors

Factors identified as barriers to implementation at the clinical level included accuracy of health indicator monitoring [36] and a limitation of task-specific capability for specific health conditions [32].

Meso level factors

At the organisational level, key factors identified as barriers included the internal regulatory environment of organisations [38], resource allocation (remuneration and funding) [40], issues with integration into the current work flow [38, 41], organisational climate and readiness for change [38], and interoperability with existing information and technology infrastructures [41].

Macro level factors

At the systems level, health information security and national or jurisdictional eHealth regulatory frameworks were highlighted as key challenges to implementation of mHealth technologies [36, 40].

Textbox 6. Implementation challenges (theme)

Technical features as barriers to implementation at the clinical (micro) level (sub-theme)

- This [technical asthma trigger] feature was more often criticized by parents and clinicians because of its lack of long-term monitoring and feedback capabilities. One clinician expressed the opinions of other participants when stating, “I don’t know what you’d [do] with it. Other than just be aware of it.” Geryk 2016 *ePub* (Unequivocal)
- “Basically he seems to think it’s good but he’s frustrated because he thinks ...he has very high expectations and to this point he doesn’t feel they have been met” Buchholz 2013 *Page 91, column 1* (Unequivocal)

Organisational level (meso) barriers to implementation (sub-theme)

- ‘‘The biggest thing is ... a time issue, lack of reimbursement … for adding additional duties.’’ Schneider 2016 *Page 157* (Unequivocal)
- “We see young people with severe mental health problems, including suicidal ideation, and I’m not sure it’s ideal for this group… Most self-harm is dealt with by family support workers and schools, and they are always looking for additional resources and tools to

help with it." Owens 2016 *Page 7, column 1* (Unequivocal)

- "The general perception within the team is that using TeenTEXT is too much of an extra burden on top of our existing workload." Owens 2016 *Page 6, column 2* (Unequivocal)
- "The organisation doesn't give clinicians any leeway. We need permission to try anything new and there are so many hoops to jump through before that happens." Owens 2016 (Unequivocal)

System level (macro) barriers to implementation (sub-theme)

- Clinicians felt that use of the app could lead to a better medical appointment both in terms of efficiency, patient-centered care, and decision making. Multiple clinicians expressed data security concerns (eg, insecure email) or differed in their preference for information delivery method [...] Geryk 2016 *ePub* (Credible)
- 'Oh, I would love to do it by electronic means. The problem is that then you run into all the HIPAA problems.'' Schneider 2016 *Page 157* (Unequivocal)

HIPAA= Health Insurance Portability and Accountability Act

Theme 3. Adoption of mHealth technologies in a specific young population

Implementers perceived the need for mHealth to be adaptable or tailored for vulnerable populations, referring specifically to young people with cognitive and communicative disability. Two subthemes emerged: the need for training of end-users; and the need for design to facilitate uptake and match social context or peer expectations (Textbox 7).

The need for training of end-users

In a single study, Bucholtz et al [32] identified that specific training of end-users is required to facilitate better uptake or adoption of mHealth technologies in this specific population.

The need for design to facilitate uptake and match social context or peer expectations

Design to facilitate adoption included a focus on mHealth technology supporting end-users 'blending in' and a capacity to streamline function with their existing technology (for example, software installed on end-users' own mobile phones). Additional considerations were devices that were

physically easy to handle, hardware designed to meet specific end-user needs (e.g., text messaging with symbols and speech synthesis), and devices that fit well into end-users' daily routines.

Textbox 7. Adoption of mHealth technologies in a specific young population (theme)

The need for training for end-users for some conditions and settings to facilitate adoption (sub-theme)

- "It has been easy to handle for him ...it has been easy also in terms of making adaptations (for the helper)" Buchholz 2013 *Page 91, column 2* (Unequivocal)
- "This is an aid that would be of help for a lot of people. I have many colleagues with clients who would need something similar maybe particularly adolescents that are becoming adults" Buchholz 2013 *Page 92, column 2* (Unequivocal)
- "Exciting a little more up to date ...modern ...or she would never have accepted it" Buchholz 2013 *Page 91, column 1* (Unequivocal)
- "Yes because if this software was installed in the regular phone I think she would use it more" Buchholz 2013 *Page 91, column 1* (Unequivocal)

Need for co-design to facilitate uptake and social currency (sub-theme)

- "It's important to find a situation where you really see the need of being able to text or a person you need to contact where a regular phone call won't work" Buchholz 2013 *Page 92, column 1* (Unequivocal)
- "Yes, it was very abstract I think so when we could show him something more concrete he grasped it better" Buchholz 2013 *Page 91, column 2* (Credible)

Theme 4. Co-design and tailoring

Implementers perceived specific characteristics of mHealth technologies that they considered important to support end-users' management of NCDs. Two sub-themes emerged: the importance of co-design and tailoring to end-user needs (Textbox 8).

Importance of co-design

Implementers identified the importance of working collaboratively with end-users to optimize functionality requirements as part of the early phase of development of mHealth technologies [32, 36, 38].

Tailoring to end-user needs

Implementers identified the need for the design of mHealth technologies to be adaptable to end-users, providing for tailored age-relevant design, content and functionality [36, 40] as well as meeting condition-specific requirements [32].

Textbox 8. Co-design and tailoring (theme)

Importance of co-design: implementers identified the importance of working collaboratively with end-users to optimize functionality (sub-theme)

- "She has great use of them and we have built upon her interests so she can easily reply to a text and she can also send a pre-designed text" Buchholz 2013 *Page 93, column 2* (Unequivocal)
- One clinician brought up the benefits of using the feature for "engaging with them [patients]" including jointly inputting information into the plan and/or discussing what patients have previously input to ensure they are getting the correct guidance, especially regarding emergency situations. Geryk 2016 *ePub* (Credible)
- "I like the fact that the messages are written by them, so they're supporting themselves… This fits with what we currently do, which is try and give them a sense of control." Owens 2016 *Page 5, column 1* (Unequivocal)

Need for technologies to be tailored to end-user's needs and contexts (sub-theme)

- "Yeah it's like that. He has started to use it more for face to face communication. . . not just the text-messaging function but more as a communication device" Buchholz 2013 *Page 94, column 1* (Unequivocal)
- "I think most of them engage in devices like this for entertainment, right? And so you want to have something that provides them an educational opportunity, um, but also something that they – they won't get bored with." Geryk 2016 *ePub* (Unequivocal)
- ''Don't forget to pretreat before you go out for soccer practice, or football practice,''

specific for that patient's sport I think would be even more, you know, something that's specific for that patient.'' Schneider 2016 *Page 158* (Unequivocal)

Policy and practice recommendations and implications

Based on our evidence meta-synthesis, we derived five key recommendations and described the associated policy and practice implications (Table 5). The use of mHealth in management of young people with chronic NCDs can support self-management and drive meaningful change in contemporary health ecosystems. However, identifying and resolving implementation challenges is critical to enabling sustainable scaling-up of mHealth solutions. These recommendations should help to inform appropriate resource design, evaluation and implementation in a way which all users will find acceptable and which health systems will find sustainable.

Table 5. Policy and practice recommendations and implications

Recommendations	**Implications**
1. mHealth technologies should be considered as a potential strategy or solution to enable self-management, to improve clinical encounters and to encourage positive health behaviors in young people with chronic NCDs	○ mHealth should be considered by consumers and stakeholders involved in the delivery of care as a complement to existing healthcare options, as a means to enhance care delivery and efficiency and to integrate into care pathways ○ To achieve this outcome, it is important to clearly identify end-users' needs and also to identify where and when in a young person's care pathway mHealth technologies could meaningfully affect capacity for self-management, improve clinical encounters and influence positive health behavior ○ Policy makers need to respond to the momentum around mHealth by considering current care pathways and support systems and identifying opportunities for integration of mHealth technologies to optimize co-care; to facilitate location-based care; and drive quality, safety

	and efficiency in care delivery
2. Design of mHealth technologies for young people with chronic NCDs should be a collaborative process involving partnerships with multi-stakeholders (for example, young people, health professionals, digital technology designers, service delivery, policy makers) to achieve meaningful co-design and to inform appropriate implementation approaches	○ A collaboration of relevant stakeholders needs to be engaged from inception and at all stages through planning, developing, testing, implementing and through continuous cycles of improvement (formative evaluation) for mHealth technologies ○ Importantly, different stakeholders may be needed at different stages and these stakeholders should be explicitly identified to align with requirements at each stage ○ From inception, processes should be informed by contemporary evidence and an appropriate implementation science framework ○ The outcome of this collaborative and evidence-informed approach should ensure that mHealth technologies have social currency and are contemporary, relevant and useful to young people
3. mHealth technologies for chronic NCD management in young people need to have functional capabilities that allow for tailoring to end-users' preferences and person-centered needs	○ Implementers need to undertake formative evaluations of mHealth technologies across the development and implementation stages in partnership with young people to ensure that functionality is responsive to their end-user needs, including changing developmental and NCD needs ○ These formative evaluation outcomes need to direct iterations of mHealth technologies

4. Implementation initiatives must consider whole-of-system readiness to adopt mHealth technologies. The use of contemporary mHealth toolkits for planning and scale is advisable [67]	○ At a health systems (*macro*) level, it is necessary to consider system readiness to support implementation and adherence. This requires identifying gaps and opportunities across the system to support implementation, including:
	  ○ current policy / strategy platforms
	  ○ workforce capacity building initiatives and priorities
	  ○ infrastructure and human resourcing
	  ○ strategic cross-sector partnerships

	○ alignment with existing policy, technological, legal, and regulatory frameworks. Compliance with information and communication technology regulatory frameworks is imperative ○ At the service delivery (*meso*) level it is necessary to consider: ○ organisational readiness for change (e.g.; culture, change management leadership, executive support, technophobia) ○ seamless integration of mHealth into existing and planned workflow ○ business modelling to capture value, cost effectiveness and sustainability ○ interoperability with existing information and technology systems ○ At the clinical (*micro*) level, implementers need to jointly assess, in partnership with health providers and end-users, the desired functionality, required accuracy of data capture and security associated with the use of proposed mHealth technologies
5. Implementers of mHealth technologies must undertake continuous cycles of improvement to maintain technical and functional optimization. The use of contemporary digital health monitoring and evaluation guidance is advisable [68]	○ Given the rapidly changing landscape of mHealth technologies, continuous technical updates are needed to address changes (to maintain platform compliance and security) ○ Planned review cycles are necessary to allow for iteration and optimization of content and functionality based on analytics data ○ A governance framework needs to be developed in advance of implementation, with the aim of addressing project management and guiding these review cycles ○ Dedicated resourcing is required to implement such a framework

Discussion

Main findings

This systematic review extends our understanding of users' experiences and perspectives of mHealth for chronic NCDs management in young people and highlights the specific enablers and barriers to implementation. The clear evidence of benefit for the use of mHealth technologies by young people for education, monitoring and the self-management of their chronic NCDs, often fails to sustainably translate into real world settings, consistent with reports that '*…benefits can only spring from effective implementation that credits interaction with human and organizational factors*" [69]. Our evidence synthesis provides novel insights to inform and guide actionable policy and practice recommendations on 'how' we can implement mHealth technologies to better support young people's management of their chronic NCDs. The key findings from this evidence synthesis also show both complementary and unique perspectives on the use of mHealth for chronic NCD management in young people. Collectively, mHealth technologies were perceived by users as supporting young people's self-management across a range of chronic NCDs including diabetes [30, 34, 35], cancer (chemotherapy symptom management) [31, 37], asthma [33, 39, 40], cognitive and communicative disabilities [32], chronic self-harm [38] and Attention Deficit Hyperactivity Disorder [41]. No studies were identified that specifically examined persistent musculoskeletal pain.

Complementary perspectives on the use of mHealth technologies to enable young people's management of NCDs were evident for a number of themes and sub-themes. These included: co-design of mHealth technologies; functional and technical aspects of mHealth technologies that were person-centered and which aligned with young people's current technology use (habits, routines and preferences); and which supported the delivery of clinical care and positive behavior change. The benefits of mHealth use were uniquely perceived by end-users (young people) as empowering them to more independently manage their chronic health conditions. Implementers

(specifically clinicians) perceived a great benefit in mHealth affording access to clinical data during consultations and as an enabler to support person-centered clinical encounters. Barriers to the uptake or adoption of mHealth technologies were uniquely identified by implementers as representing 'whole of system' (multi-level) factors, including at the clinical level (micro factors), at the organizational level (meso factors) and at the systems level (macro factors). Implementers also identified the need for specific design considerations for mHealth applications for a vulnerable population.

These complementary and unique perspectives highlight both the interdependencies and complexities encountered by different users interacting with a rapidly evolving digital health ecosystem. In order to interpret our findings and make meaningful recommendations for policy and practice, the use of a design and implementation framework that is plural and pragmatic helps to address such complex interdependencies between human characteristics (users), digital technologies and health systems. Figure 2 shows the application of such a framework to our synthesized findings (darker shading indicates themes and lighter shading, sub-themes). This Holistic Framework developed by van Gemert-Pijnen and colleagues [69] has been widely used to guide the design and implementation of eHealth technologies in chronic care management [16]. The framework allows for an inherently fluid, iterative and cyclical nature of design, implementation and evaluation of digital technologies. We focus on key domains relevant to our findings (contextual enquiry and value specification, design and implementation (operationalization)) [69]. Given the significant overlay between contextual enquiry and value specification in our data, these were collapsed into a single domain.

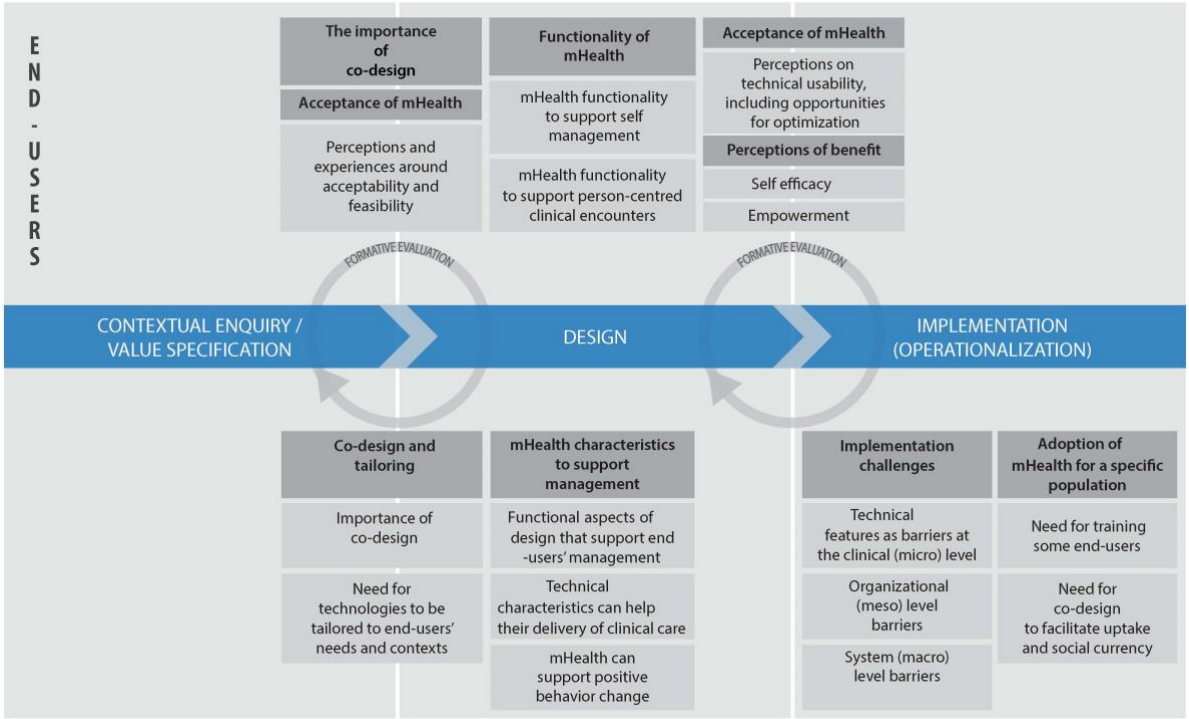

Figure 2. A representation of the review findings is mapped against relevant elements of the Holistic Framework [69] and applied here as a theoretical underpinning to guide our discussion. Themed categories for end-users are represented above the blue line and implementers below. Implementation phases are represented by the central blue line which indicates a left to right movement showing the continuous and iterative cycles of mHealth development. This includes phases from pre-development (enquiry/value specification), to design and implementation (operationalization), with formative feedback guiding iterations of mHealth technologies. Note, both complementary and unique user perspectives are evident.

Complementary users' perspectives on the importance of co-design

Co-design emerged for all users as a fundamental design principle and enabler to the uptake of mHealth technologies. The triangulation between user group perspectives is reflected in the mirroring of themes on co-design, as shown in Figure 2. These complementary perspectives related to i) the 'contextual enquiry and value specification' domain; and ii) the 'design' domain. For this

reason, co-design is shown in Figure 2 as overlapping both these domains. A formative evaluation loop guides iterations to mHealth technologies during this developmental phase; a step also identified in the primary studies as an important component of mHealth development. Involving end-users and other stakeholder user-groups was perceived as critical to ensuring a clear understanding of: i) what the end-user wants and needs to best support their self-management (user-friendly, acceptable, meaningful, safe); and ii) how mHealth technologies could be optimized to meet person-centered needs and support behavior change. Using participatory models of co-design to jointly develop digital technologies that is meaningful to end-users, aligns with current recommendations for development and implementation of digital technologies [16, 18, 69]. In a recent study published outside of our search dates, user-centred co-design principles were effectively applied to improve usability (easy to use, easy to understand, efficient to complete, and acceptable) of a real-time mHealth app for adolescents self-managing cancer pain [14].

Clarity was also deemed important by users around identifying who the required stakeholders would be, what specific roles they would undertake, and at what stages they would be needed. These findings are consistent with recommendations from a recent systematic review of mHealth for NCD management indicating a need for explicit identification of relevant stakeholders as a mechanism to help make sense of eHealth systems for users, to specify mHealth purposes and benefits, and to establish their value including identifying factors promoting or inhibiting engagement and participation [70].

Contextual enquiry allows for identification of factors relevant to guiding mHealth design that is acceptable and feasible for end-users; a theme that emerged from users reported in the primary studies in our review and more widely reported by others as a critical design factor [1, 70, 71]. Contextual factors from our review included value specifications such as the intended use of technology (self-management), the nature of the condition (e.g., NCDs, disease status, level of

impairment), the target population (young people), functional requirements (e.g., monitoring, medication titration, tracking, decision-support, goal setting, co-care) and the care setting (e.g., home, school, work, hospital). Similar factors have been identified in recent systematic reviews of mHealth technology use in NCDs [1, 18, 27]. Implementers' values were further reflected in their perspectives on the importance of the tailoring capabilities of mHealth to meet end-users' specific condition needs. Organisational needs did not emerge in this review as a key co-design value specification, although contemporary guidance on mHealth technology would suggest this is a critical pre-implementation factor [67, 69].

Users' perspectives on the importance of mHealth design characteristics

Emerging evidence supports use of mHealth for self-management to facilitate clinical interactions and to encourage positive health behaviors [16]. To promote use and adherence, mHealth design needs to reflect meaningful functionality for end-users [1, 4, 15, 27] and to make sense within the context of their daily lives [16]. Our findings support these recommendations with mHealth functionality identified as a critical design factor by both user groups (Figure 2).

End-users' perceived functional characteristics of mHealth technologies as helping their self-management adherence including self-tracking, condition self-monitoring (condition status and medication), self-observations providing for early warning of condition flare-ups, self-reflection, improving their understanding of their condition and providing reassurance by facilitating contact with their health professionals. Implementers' perspectives similarly recognized meaningful functionalities could assist adherence by leveraging off young people's habitual use of mHealth technologies. Functionality that extended reach to young people in remote settings, or to those with low accessibility was also perceived by implementers as important, an issue highlighted by us in a study of the gaps and needs of young people with persistent musculoskeletal pain [2] and consistent

with health policy in nations with large care disparity gaps created by geography, such as Australia and Canada.

Functionality characteristics that enabled person-centered care was identified by both user groups as important, including features that focused end-users on their condition status and helped them prepare for clinical encounters. From the implementer perspective, technical capabilities were perceived as enablers to supporting their delivery of clinical care. While protecting patient privacy, similar technical capabilities that supported person-centered care by facilitating bilateral communication and which helped the end-user focus the purpose of the clinical encounter, were perceived as important. Consistent with these findings, systematic review-level evidence indicates that person-centered care is a key enabler to adoption and adherence of mHealth technologies for self-management [16, 18]. This person-centered focus is also central to recommendations from contemporary health policy across all settings and economies [67, 68].

Implementers described mHealth technologies as helpful in supporting behavior change for young people with NCDs. For example, through sustained engagement of young people by monitoring of their health condition and by providing positive feedback as reinforcement for behavior change. Here, mHealth technologies may be utilized as a catalytic tool for driving sustainable management of NCDs [67, 68]. However, perceptions and actual outcomes around behavioral change do not necessarily align. More effort and focus is required to understand how mHealth technologies can be used to effect meaningful, sustained behavior change [27, 72]. This emerging area requires more than pilot or feasibility studies, arguing for more appropriately designed trials, longer term evaluation and real-world, population-based health monitoring [68, 69, 73].

Users' perspectives on mHealth technology implementation challenges and solutions

Technical issues associated with real world use of mHealth technologies impact usability and wider acceptance (end-users), scaling-up and sustainable implementation (implementers) (Figure 2). The need to address recognised technical issues and to optimize mHealth technologies in the 'readiness' phase of implementation highlights the critical role for rapid, continuous cycles of evaluation (formative and summative evaluation). Linking design refinements to improve end-user experience and to help drive adoption and uptake (i.e. implementation 'success') emerged as important for both user groups in our review. Judging 'readiness' and 'success' can help mitigate against implementation challenges and we have derived such a system-level framework which is described comprehensively elsewhere [23].

From the end-user perspective, mHealth applications that are readily accessible and downloadable onto young people's current mobile devices is an example of one such 'readiness' lever [2, 8], especially if applications align with end-users' habitual routines [16]. Implementers also highlighted the need for accurate disease monitoring and task-specific capabilities to support young people with unique NCD requirements. These perspectives again emphasize the importance of upstream 'readiness' contextual enquiry and value specification as integral to effective co-design and to supporting successful downstream implementation efforts [23].

While contemporary health policy reform agendas articulate the need for innovative use of mHealth for NCD management [7, 26, 74], currently very limited processes and frameworks exist to guide the development and implementation [17, 18, 75, 76]. This challenge resonates with the findings of our review. Many studies consisted of pilot projects or small-scale implementations with evidence of feasibility and acceptability (as per their study aims), however without extensive consideration of the implementation frameworks needed for building scale. Even with the application of theoretical frameworks to mHealth technologies to gauge scalability (for example, the use of normalisation

process theory; person-centered design and participatory methods of intervention development), significant barriers to implementation can still stymie uptake [38]. These same mHealth technology implementation challenges are articulated in reviews of older populations with NCDs [18, 72]. In the latter review by Matthew-Maich and colleagues [18], successful implementation of mHealth required addressing factors across the whole of health systems. Our review found similar 'whole of system' factors, including at the *micro* level (technical factors), at the *meso* level (organisational, culture, climate, environment, health workforce needs, work flow disruption, technophobia, natural fit for population and health condition, funding models) and at the *macro* level (regulatory frameworks, governance, flexibility) (Figure 2). These multilevel barriers emphasize the critical importance of taking a system-wide approach to supporting implementation (for comprehensive reviews on implementation, see Briggs et al [77, 78]). Such an approach involves the systematic identification of 'readiness' for implementation, as well as post-implementation evaluation of 'success' [23]. This approach aligns well with the Holistic Framework we have adopted here for the specific embedding of mHealth technologies within complex health ecosystems [16].

Moving mHealth from promise into policy and practice

It is hard to see a future without mHealth technologies as a complement to a rapidly evolving healthcare ecosystem. Digital disruption is here. Rather than focussing on barriers and challenges, perhaps we need to seek opportunities for embedding of mHealth within existing health systems where evidence for effectiveness is already well established (e.g., self-management [16]). Further value may be derived from identifying where in health systems, health services and clinical populations/interfaces, potential synergies can be identified that provide a natural 'fit' for implementing and building scale in mHealth use [72]. Here, mHealth can be viewed as a catalytic tool implemented to strengthen health systems [67, 79]. In lower and middle-income countries, factors such as a lack of infrastructure, health workforces, resources, and regulatory frameworks

have already driven innovative mHealth solutions; for example, using partnerships arrangements and modifications of existing mHealth technologies that can be readily and sustainably implemented [8]. Implementation guidance and enabling strategies to support mHealth initiatives more broadly is available, for example, in the mHealth Assessment and Planning for Scale Toolkit (MAPS) [67].

Beyond implementation, ongoing evaluation and monitoring of mobile and other digital health interventions, is deemed critical in order to inform health policy and practice [80, 81]. The World Health Organisation provides guidance in this regard from the collective learning of five years of engagement with various international lead agencies working to strengthen their digital health deployments, develop robust evaluations and scale up their activities nationally and regionally [68].

Strengths and limitations

The Holistic Framework adopted to underpin the interpretation of our review findings is based on extensive research on the uptake and impact of eHealth technologies and on models for development, implementation and evaluation [69]. The Framework also provides a level of construct validity to our findings. While consideration was given to alternate implementation frameworks [13] such as the Consolidated Framework for Implementation Research [82], Technology Acceptance Model [83], Normalisation Process Theory [70], none of these frameworks better satisfied the need for both an integrated whole of system approach and one specifically validated for eHealth applications.

The number of studies in this review provided sufficient data to interrogate our review questions and represented both end-users and implementers. The yield was not sufficient however, to enable meaningful sensitivity analyses to be undertaken based on criteria such as study quality, diseases, settings or credibility of findings. Most studies used mHealth ‘apps’ to support self- and co-management of young people with NCDs. End-users included young people in our age range of

interest, although were focused primarily on younger ages. Generalisability to other cultures and contexts was limited by the small samples and by cultural and socioeconomic specificity. Our results may not be transferable to low and middle-income economies, despite almost ubiquitous use of mobile phones. This represents a critical area of research need given the widespread use of mobile technologies in such global settings and the urgent need to address NCDs through health information and health connectivity at scale [84, 85]. Implementers were broadly representative of the whole of system, however health policy makers were not explicitly identified. While we did not include parents as implementers specifically in our search, for two [36, 41] of three possible studies that included parents, their perspectives were captured within pooled implementer data. Explicit parent perspectives may provide important additional insights especially for the younger end of our age range of interest. Data on experiences and perspectives about actual or potential risk and harm associated with use of mHealth technologies were limited, although these are very important factors to consider [86].

Most studies were of short duration, posing challenges for exploring implementation effectiveness and limiting longer term evaluation of outcomes. The quality of studies was variable and the use of reporting standards for qualitative research (such as the Consolidated Criteria for Reporting Qualitative Research [87]) was inconsistent, possibly suggesting a high risk of bias. This raises issues of confidence about internal validity and trustworthiness, making the data extraction, interpretation and the confidence in evidence, more complex. The confidence of reported findings could be readily addressed with the use of a reporting system such as Confidence in the Evidence from Reviews of Qualitative Research [88]. Another quality indicator that was insufficiently met for most studies, was the positioning of the researcher within the research, arguing again for improved reporting against standards. Some studies also provided secondary data interpretation without explicit quotations to support their interpretation suggesting potential researcher bias. Study designs that better align

with the rapid evolution of mHealth technologies are required as randomised trials are expensive, slow and do not accommodate the dynamic nature of digital technologies, issues also highlighted by others [15, 73].

Conclusion

Our evidence meta-synthesis revealed both complementary and unique user perspectives on enablers and barriers to designing, developing and implementing mHealth technologies to support young people's management of chronic NCDs. mHealth technologies should be considered as a tool to enable self-management, to improve clinical encounters and to encourage positive health behaviors. Developing mHealth technologies should involve a genuinely collaborative co-design process between end-users and implementers, with the capacity to tailor and adapt technologies to meet person-centered needs. This approach will help to ensure meaningful mHealth solutions for young people, while also supporting implementation efforts. Whole-of-system readiness to adopt mHealth technologies must be considered if implementation initiatives are to be successful and sustainable. Continuous cycles of improvement are needed to maintain technical and functional optimization ensuring that mHealth solutions remain relevant to young people. The use of contemporary frameworks that support digital health monitoring and provide evaluation guidance is advisable.

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inductive analysis. JC, HS, MB and AMB reflected on and interpreted the categorical themes to develop new themes and apply a meta-synthesis to inform declarative statements that could be applied as an evidence-base. JS provided external validation of the reporting framework. All authors (HS, JC, JS, MB, and AMB) provided input to policy and practice recommendations and contributed to drafting, revisions and final manuscript development. The authors wish to thank the staff at Joanna Briggs Institute for their assistance with study design (Micah Peters, Edoardo Aromataris and Craig Lockwood), and Diana Blackwood and Jayanthi Joseph (Senior Academic Librarians, Curtin University) for assistance with validation of the search strategy. AMB is supported by an NHMRC TRIP Fellowship (#1132548).

Conflicts of interest

No conflicts of interest to declare (HS, JC, JS, MB, AMB). Joanna Briggs Institute received grant funding to support developing and undertaking the search, screening abstracts, quality appraisal, data extraction.

Abbreviations

ASyMS-YG: Advanced Symptom Management System

HIPAA: Health Insurance Portability and Accountability Act

JBI-QARI: Joanna Briggs Institute, Meta-Analysis of Statistics Assessment and Review Instrument

mASMAA: Asthma Self-Management Aid for Adolescents

mHealth: mobile health

mobile oncology symptom tracker: mOST

NCDs: noncommunicable diseases

RMT: remote monitoring technology

SMS: Short Message Service

Multimedia Files

Multimedia File 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist

Multimedia File 2. Enhancing transparency in reporting the synthesis of qualitative research (ENTREQ checklist)

Multimedia File 3. Search strategy

Multimedia File 4. Themed categories for end-users' experiences of mHealth technologies

Multimedia File 5. Themed categories for implementers' experiences of mHealth technologies

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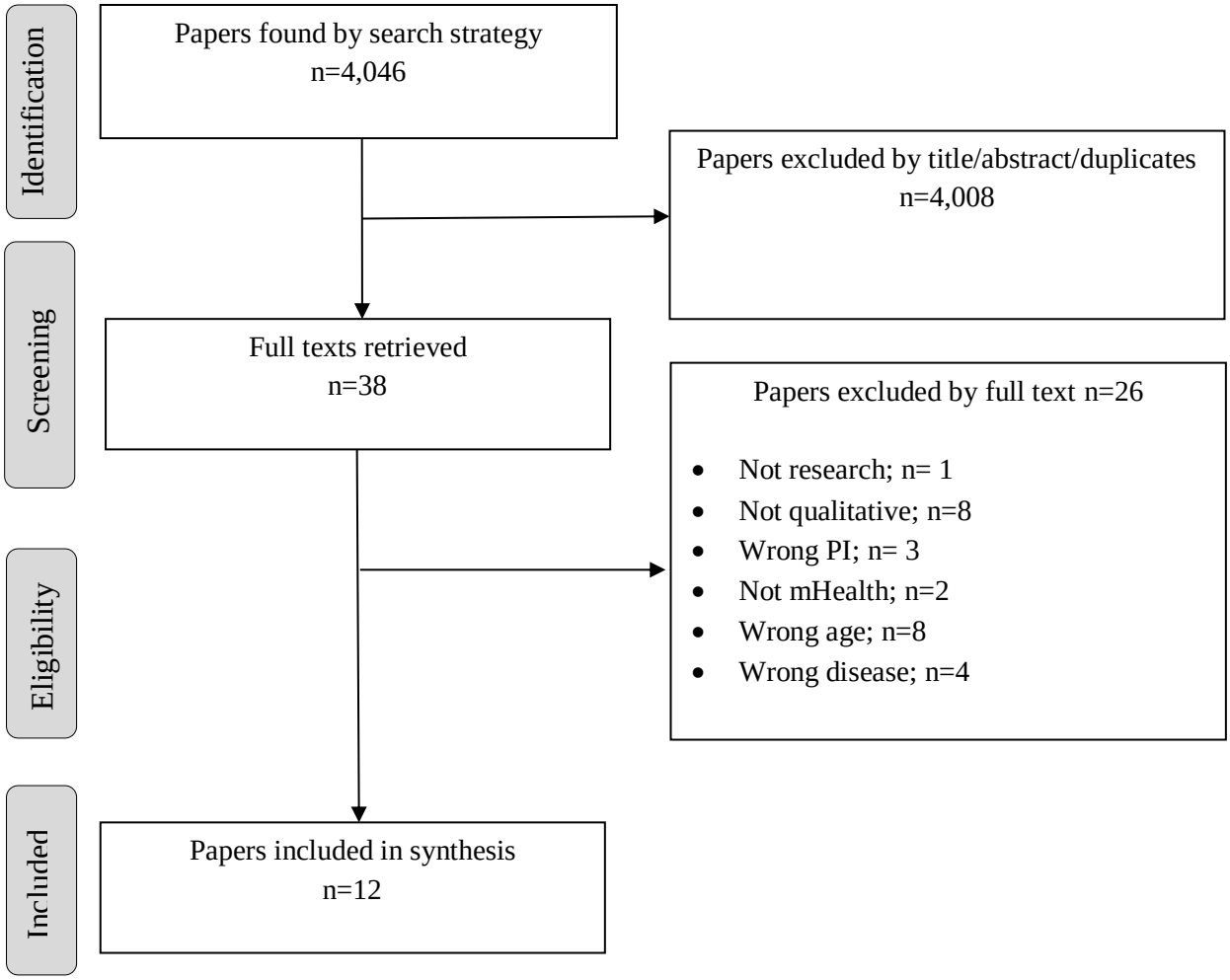

Figure 1. Flow diagram of study identification and selection, adapted from PRISMA flow chart. PRISMA=Preferred Reporting Items for Systematic Review and Meta-Analysis. PI=phenomenon of interest; mHealth=mobile health

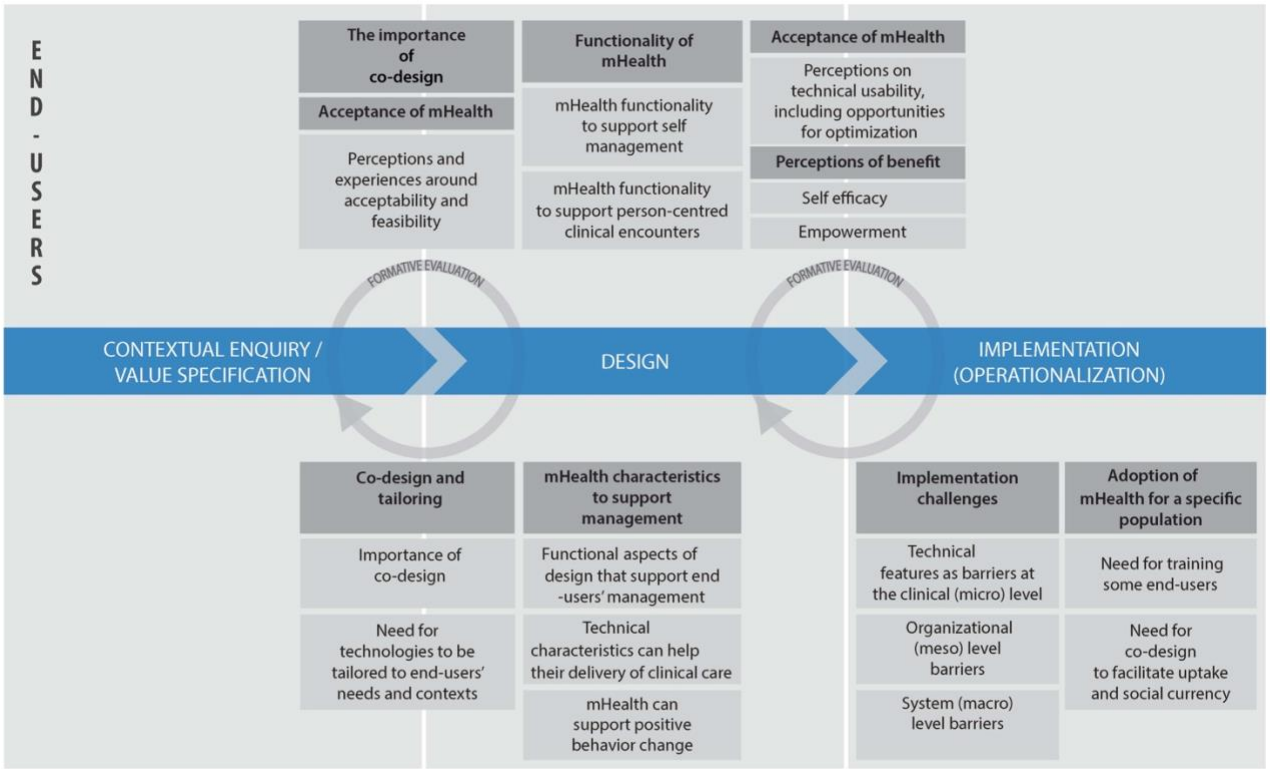

Figure 2. A representation of the review findings mapped against relevant elements of the Holistic Framework [69] applied here as a theoretical underpinning to guide our discussion. Themed categories for end-users are represented above the blue line and implementers below. Implementation phases are represented by the central blue line which indicates a left to right movement showing the continuous and iterative cycles of mHealth development. This includes phases from pre-development (enquiry/value specification), to design and implementation (operationalization), with formative feedback guiding iterations of mHealth technologies. Note, both complementary and unique user perspectives are evident.

No	Item	Guide and description	Reported on Page #
1	Aim	State the research question the synthesis addresses.	p2; p6
2	Synthesis methodology	Identify the synthesis methodology or theoretical framework which underpins the synthesis, and describe the rationale for choice of methodology *(e.g. meta-ethnography, thematic synthesis, critical interpretive synthesis, grounded theory synthesis, realist synthesis, meta-aggregation, meta-study, framework synthesis).*	p6-8
3	Approach to searching	Indicate whether the search was pre-planned (*comprehensive search strategies to seek all available studies)* or iterative (*to seek all available concepts until they theoretical saturation is achieved)*.	p8-9
4	Inclusion criteria	Specify the inclusion/exclusion criteria *(e.g. in terms of population, language, year limits, type of publication, study type).*	p6-8
5	Data sources	Describe the information sources used (e.g. *electronic databases (MEDLINE, EMBASE, CINAHL, psycINFO, Econlit), grey literature databases (digital thesis, policy reports), relevant organisational websites, experts, information specialists, generic web searches (Google Scholar) hand searching, reference lists)* and when the searches conducted; provide the rationale for using the data sources.	p8
6	Electronic Search strategy	Describe the literature search *(e.g. provide electronic search strategies with population terms, clinical or health topic terms, experiential or social phenomena related terms, filters for qualitative research, and search limits)*.	Supplemental File 1
7	Study screening methods	Describe the process of study screening and sifting *(e.g. title, abstract and full text review, number of independent reviewers who screened studies).*	p8-10

No	Item	Guide and description	Reported on Page #
8	Study characteristics	Present the characteristics of the included studies *(e.g. year of publication, country, population, number of participants, data collection, methodology, analysis, research questions).*	p12; Tables 1 and 2
9	Study selection results	Identify the number of studies screened and provide reasons for study exclusion *(e,g, for comprehensive searching, provide numbers of studies screened and reasons for exclusion indicated in a figure/flowchart; for iterative searching describe reasons for study exclusion and inclusion based on modifications t the research question and/or contribution to theory development).*	p11-12; Figure 1
10	Rationale for appraisal	Describe the rationale and approach used to appraise the included studies or selected findings *(e.g. assessment of conduct (validity and robustness), assessment of reporting (transparency), assessment of content and utility of the findings).*	p18-19
11	Appraisal items	State the tools, frameworks and criteria used to appraise the studies or selected findings *(e.g. Existing tools: CASP, QARI, COREQ, Mays and Pope* [25]*; reviewer developed tools; describe the domains assessed: research team, study design, data analysis and interpretations, reporting).*	p6, 9-11
12	Appraisal process	Indicate whether the appraisal was conducted independently by more than one reviewer and if consensus was required.	p9-10
13	Appraisal results	Present results of the quality assessment and indicate which articles, if any, were weighted/excluded based on the assessment and give the rationale.	p18-19
14	Data extraction	Indicate which sections of the primary studies were analysed and how were the data extracted from the primary studies? *(e.g. all text under the headings "results*	p9-10

No	Item	Guide and description	Reported on Page #
		/conclusions" were extracted electronically and entered into a computer software).	
15	Software	State the computer software used, if any.	p9
16	Number of reviewers	Identify who was involved in coding and analysis.	p10-11
17	Coding	Describe the process for coding of data *(e.g. line by line coding to search for concepts).*	p10-11
18	Study comparison	Describe how were comparisons made within and across studies *(e.g. subsequent studies were coded into pre-existing concepts, and new concepts were created when deemed necessary).*	p10, 19
19	Derivation of themes	Explain whether the process of deriving the themes or constructs was inductive or deductive.	p10
20	Quotations	Provide quotations from the primary studies to illustrate themes/constructs, and identify whether the quotations were participant quotations of the author's interpretation.	p20-33
21	Synthesis output	Present rich, compelling and useful results that go beyond a summary of the primary studies (e.g. *new interpretation, models of evidence, conceptual models, analytical framework, development of a new theory or construct).*	p19-37; Figure 2

Search strategy

Total: 4046
Duplicates removed: 1193
Final total: 2853

Pubmed

Filters: Year 2007, English
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Qualitative

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Chronic non-communicable disease

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Young people

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mHealth

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Qualitative

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Search Title, Abstract or Word in subject heading

Disease

Chronic OR long term OR persistent OR non-communicable OR respiratory OR asthma OR cystic fibrosis OR lung disease OR diabetes OR cancer OR heart disease OR cardiovascular disease OR pain OR muscular OR joint OR musculoskeletal OR kidney disease OR arthritis OR depression OR depressed OR anxiety OR anxious OR mental health OR schizophrenia OR fibromyalgia OR sickle cell OR disability OR disabled OR autism OR Asperger's OR adhd OR attention deficit hyperactivity disorder OR pulmonary OR cardiac OR ischemic OR renal OR neurological OR osteoarthritis OR osteoporosis OR ankylosing spondylitis OR psoriatic arthritis OR rheumatoid arthritis OR inflammatory arthritis OR lupus OR systemic lupus erythematosus OR juvenile idiopathic arthritis OR juvenile chronic arthritis OR back pain OR neck pain OR stress OR psychological

Search Title, Abstract or Word in subject heading

Young people

Young OR adolescent OR adolescence OR student OR students OR teenager OR teenage OR teenagers OR teen OR teens OR young adult OR young adults OR child OR children OR pediatric OR paediatric

Search Title, Abstract or Word in subject heading

mHealth

Search Title, Abstract or Word in subject heading

eHealth OR mHealth OR smartphone OR smartphones OR cell phone OR cell phones OR text messaging OR text messages OR digital technologies OR digital technology OR mobile OR mobiles OR wireless OR ICT

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Qual

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Search Title, Abstract or Heading word

Disease

Chronic OR long term OR persistent OR non-communicable OR respiratory OR asthma OR cystic fibrosis OR lung disease OR diabetes OR cancer OR heart disease OR cardiovascular disease OR pain OR muscular OR joint OR musculoskeletal OR kidney disease OR arthritis OR depression OR depressed OR anxiety OR anxious OR mental health OR schizophrenia OR fibromyalgia OR sickle cell OR disability OR disabled OR autism OR Asperger$ OR adhd OR attention deficit hyperactivity disorder OR pulmonary OR cardiac OR ischemic OR renal OR neurological OR osteoarthritis OR osteoporosis OR ankylosing spondylitis OR psoriatic arthritis OR rheumatoid arthritis

OR inflammatory arthritis OR lupus OR systemic lupus erythematosus OR juvenile idiopathic arthritis OR juvenile chronic arthritis OR back pain OR neck pain OR stress OR psychological

Search Title, Abstract or Heading word

Young people

Young OR adolescent OR adolescence OR student OR students OR teenager OR teenage OR teenagers OR teen OR teens OR young adult OR young adults OR child OR children OR pediatric OR paediatric

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mHealth

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EMTREE

Qualitative

‘qualitative research’ OR ‘semi structured interview’ OR ‘thematic analysis’ OR ‘ethnographic research’ OR ‘field study’ ‘personal experience’ OR ‘experience’ OR ‘discourse analysis’ OR ‘behavioral research’ OR ‘satisfaction’ OR ‘meaningful’ OR ‘perception’ OR ‘interview’ OR ‘comprehension’ OR ‘phenomenology’ OR ‘grounded theory’ OR ‘constant comparative method’ OR ‘open-ended questionnaire’ OR ‘action research’

Key words
Title, abstract

‘ethnology*’ OR ‘stories*’ OR ‘story*’ OR ‘content analys*’ OR ‘ethnographic*’ OR ‘observational methods’ OR ‘participant observation’ OR ‘field notes’ OR ‘experiences’ OR ‘narrative*’ OR ‘discourse’ OR ‘process evaluation’ OR ‘service need*’ OR ‘feelings’ OR ‘ethnopsychology’ OR ‘focus groups’ OR ‘behavioral research’ OR ‘behavioural research’ OR ‘narration’ OR ‘satisfaction’ OR ‘dissatisfaction’ OR ‘meanings’ OR ‘meaning’ OR ‘perspectives’ OR ‘perspective’ OR ‘perceived’ OR ‘perceives’ OR ‘perceive’ OR ‘perceptions’ OR ‘perception’ OR ‘views’ OR ‘view’ OR ‘qualitative’ OR ‘interviewed’ OR ‘interviewing’ OR ‘interviewer’ OR ‘interviews’ OR ‘interview’ OR ‘comprehension’ OR ‘opinions’ OR ‘opinion’ OR ‘expectations’ OR ‘expectation’ OR ‘thoughts’ OR ‘narratives’ OR ‘standpoint’ OR ‘standpoints’ OR ‘viewpoints’ OR ‘viewpoint’ OR ‘thematic analysis’ OR ‘phenomenol*’ OR ‘grounded theory’ OR ‘grounded studies’ OR ‘grounded research’ OR ‘constant comparative’ OR ‘constant comparison’ OR ‘field study’ OR ‘field studies’ OR ‘field research’ OR ‘biographical method’ OR ‘theoretical sampl*’ OR ‘open-ended’ OR ‘open ended’ OR ‘life world’ OR ‘life-world’ OR ‘conversation analysis’ OR ‘conversational analyses’ OR ‘theoretical saturation’ OR ‘thematic analys*’ OR ‘action research’

Disease

Emtree
‘non communicable disease’ OR ‘chronic disease’ OR ‘chronic pain’ OR ‘chronic patient’ OR ‘respiratory tract disease’ OR ‘asthma’ OR ‘cystic fibrosis’ OR ‘lung disease’ OR ‘diabetes mellitus’ OR ‘neoplasm’ OR ‘heart disease’ OR ‘cardiovascular disease’ OR ‘pain’ OR ‘muscle’ OR ‘joint’ OR ‘musculoskeletal disease’ OR ‘kidney disease’ OR ‘arthritis’ OR ‘depression’ OR ‘anxiety’ OR ‘mental health’ OR ‘schizophrenia’ OR ‘fibromyalgia’ OR ‘sickle cell’ OR ‘disability’ OR ‘autism’ OR ‘attention deficit disorder’

Key words

‘Chronic’ OR ‘long term’ OR ‘persistent’ OR ‘non-communicable’ OR ‘respiratory’ OR ‘asthma’ OR ‘cystic fibrosis’ OR ‘lung disease’ OR ‘diabetes’ OR ‘cancer’ OR ‘heart disease’ OR ‘cardiovascular disease’ OR ‘pain’ OR ‘muscular’ OR ‘joint’ OR ‘musculoskeletal’ OR ‘kidney disease’ OR ‘arthritis’ OR ‘depression’ OR ‘depressed’ OR ‘anxiety’ OR ‘anxious’ OR ‘mental health’ OR ‘schizophrenia’ OR ‘fibromyalgia’ OR ‘sickle cell’ OR ‘disability’ OR ‘disabled’ OR ‘autism’ OR ‘Asperger’ OR ‘adhd’ OR ‘attention deficit hyperactivity disorder’ OR ‘pulmonary’ OR ‘cardiac’ OR ‘ischemic’ OR ‘renal’ OR ‘neurological’ OR ‘osteoarthritis’ OR ‘osteoporosis’ OR ‘ankylosing spondylitis’ OR ‘psoriatic arthritis’ OR ‘rheumatoid arthritis’ OR ‘inflammatory arthritis’ OR ‘lupus’ OR ‘systemic lupus erythematosus’ OR ‘juvenile idiopathic arthritis’ OR ‘juvenile chronic arthritis’ OR ‘back pain’ OR ‘neck pain’ OR ‘stress’ OR ‘psychological’

Young adult

Emtree
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Keywords

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mHealth

Emtree
‘Telehealth’ OR ‘mobile application’ OR ‘smartphone’ OR ‘mobile phone’ OR ‘text messaging’

Keywords

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Search Title, Abstract or Keyword

Disease

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Search Title, Abstract or Keyword

Young people

“Young” OR “adolescent” OR “adolescence” OR “student” OR “students” OR “teenager” OR “teenage” OR “teenagers” OR “teen” OR “teens” OR “young adult” OR “young adults” OR “child” OR “children” OR “pediatric” OR “paediatric”

Search Title, Abstract or Keyword

mHealth

Search Title, Abstract or Keyword

“eHealth” OR “mHealth” OR “smartphone” OR “smartphones” OR “cell phone” OR “cell phones” OR “text messaging” OR “text messages” OR “digital technologies” OR “digital technology” OR “mobile” OR “mobiles” OR “ICT” OR “wireless”

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2007
English

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Qual

ethnolog* OR stories* OR story* OR content analys* OR ethnographic* OR observational methods OR participant observation OR field notes OR experiences OR narrative* OR discourse OR process evaluation OR service need* OR feelings OR ethnopsychology OR focus groups OR behavioral research OR behavioural research OR narration OR satisfaction OR dissatisfaction OR meanings OR meaning OR perspectives OR perspective OR perceived OR perceives OR perceive OR perceptions OR perception OR views OR view OR qualitative OR interviewed OR interviewing OR interviewer OR interviews OR interview OR comprehension OR opinions OR opinion OR expectations OR expectation OR thoughts OR narratives OR standpoint OR standpoints OR viewpoints OR viewpoint OR thematic analysis OR phenomenol* OR grounded theory OR grounded studies OR grounded research OR constant comparative OR constant comparison OR field study OR field studies OR field research OR biographical method OR theoretical sampl* OR open-ended OR open ended OR life world OR life-world OR conversation analysis OR conversational analyses OR theoretical saturation OR thematic analys* OR action research

Search Anywhere except full text

Disease

Chronic OR long term OR persistent OR non-communicable OR respiratory OR asthma OR cystic fibrosis OR lung disease OR diabetes OR cancer OR heart disease OR cardiovascular disease OR pain OR muscular OR joint OR musculoskeletal OR kidney disease OR arthritis OR depression OR depressed OR anxiety OR anxious OR mental health OR schizophrenia OR fibromyalgia OR sickle cell OR disability OR disabled OR autism OR Asperger$ OR adhd OR attention deficit hyperactivity disorder OR pulmonary OR cardiac OR ischemic OR renal OR neurological OR osteoarthritis OR osteoporosis OR ankylosing spondylitis OR psoriatic arthritis OR rheumatoid arthritis OR inflammatory arthritis OR lupus OR systemic lupus erythematosus OR juvenile idiopathic arthritis OR juvenile chronic arthritis OR back pain OR neck pain OR stress OR psychological

Search Anywhere except full text

Young people

Young OR adolescent OR adolescence OR student OR students OR teenager OR teenage OR teenagers OR teen OR teens OR young adult OR young adults OR child OR children OR pediatric OR paediatric

Search Anywhere except full text

mHealth

Search Anywhere except full text

eHealth OR mHealth OR smartphone OR smartphones OR cell phone OR cell phones OR text messaging OR text messages OR digital technologies OR digital technology OR mobile OR mobiles OR wireless OR ICT

Epistemonikus

Could not handle the long search string which had to be shortened

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1 study was eligible, but had already been found elsewhere (Stinson 2013 Journal of medical Internet research)

Qualitative

(ethnology OR ethnologies OR ethnographic OR ethnographical OR experiences OR narrative OR narratives OR discourse OR feelings OR focus groups OR narration OR satisfaction OR dissatisfaction OR meanings OR meaning OR perspectives OR perspective OR perceived OR perceives OR perceive OR perceptions OR perception OR views OR view OR qualitative OR interviewed OR interviewing OR interviewer OR interviews OR interview OR thematic analysis OR phenomenology OR phenomenological OR grounded theory OR grounded studies OR grounded research OR theoretical saturation OR thematic analysis OR thematic analyses OR action research) AND

Disease

(Chronic OR long term OR persistent OR non-communicable OR respiratory OR asthma OR cystic fibrosis OR lung disease OR diabetes OR cancer OR heart disease OR cardiovascular disease OR pain OR muscular OR joint OR musculoskeletal OR kidney disease OR arthritis OR depression OR depressed OR anxiety OR anxious OR mental health OR schizophrenia OR fibromyalgia OR sickle cell OR disability OR disabled OR autism OR Asperger OR adhd OR arthritis OR back pain OR neck pain OR stress OR psychological) AND

Young adults
(Young OR adolescent OR adolescence OR student OR students OR teenager OR teenage OR teenagers OR teen OR teens OR young adult OR young adults OR child OR children OR pediatric OR paediatric)

mHealth

AND (eHealth OR mHealth OR smartphone OR smartphones OR cell phone OR cell phones OR text messaging OR text messages OR digital technologies OR digital technology OR mobile OR mobiles OR wireless OR ICT)

KT Strategies Database

Database included 196 entries, hand searched 3/2/17, no hits obtained

Supplemental File 4

Themed categories for end-users' experiences of mHealth technologies

1. *Experiences of mHealth technologies functionality*

(a) mHealth functionality to support self-management

The functionality of the mHealth technologies supported self-management of a range of NCDs. These technologies enabled young people to improve their understanding of their condition, to monitor and track symptoms; to access early intervention and professional advice in a timely fashion in response to disease status; to support treatment adherence; to facilitate self-awareness/self-reflection of disease status; and to provide relevant information, support and reassurance about planning for emergencies and flare ups/exacerbation.

Finding	Illustration
Using a combination of self-management features is what seemed to have the strongest relationship with increasing self-observation and self-judgment among adolescents. Unequivocal	I used the symptoms, triggers, and notes, cause—because with the symptoms, it can—it pretty much tells how—like what I'm feeling at that time like throughout the day and the triggers is like if I have a flare up or, uh, an attack or—then it'll—it'll help, it'll show like what—what caused it in the notes because it just—I can just put down everything that happened throughout the whole day. **Carpenter 2016** *Page 515, column 2**
Participants also reported using the peak flow graphics to better self-judge their asthma. Unequivocal	"Like it—it really did help me out, um, and to know about the progress of my-of my asthma… it let me like know more of how my asthma was going during the weeks and—and days." **Carpenter 2016** *Page 513 column 2**
Adolescents linked the trigger feature to increased self-observation, in that they could track their exposure to triggers over time, which led them to engage in better environmental control behaviors. Unequivocal	"The triggers, um, I thought it was good because it would help you keep track of like what triggered it before, so you would know to stay away from it or stay indoors if it's like a certain type of plant blooming or something. And it would help you, uh, remember that for the future years, so you could, um, remember to stay away from it." **Carpenter 2016** *Page 514 column 1**

The convenience of being able to document information electronically and track progress over time were cited as benefits of this feature. Unequivocal	"because every time I enter it at the device, I wanted to go back to see how it was, all I have to do is go to the diary and see how it's been over a time period." **Carpenter 2016** *Page 514 column 1**
Adolescents appreciated being able to visualize how their asthma was changing over time. Unequivocal	I liked the chart. It kind of helped me see what I was, uh, how I've been doing over the course of time. Um, I normally didn't really monitor it that much, I kind of let my mom did it, and this way if I were using this, I could kind of tell myself how I was doing on my own. **Carpenter 2016** *Page 514 column 1*
The charting feature seemed to increase both self-observation and self-judgment, as adolescents liked to see if their asthma was getting better or worse. Unequivocal	"The chart, cause I can like sc-, I can watch it, I can scale my asthma and I can see if it's worse or if it's getting better, or if it's really serious I need to do something about it, it helps me. Um-hum." **Carpenter 2016** *Page 514 column 1**
This feature [self-check] was helpful for increasing adolescents' ability to self-judge their asthma severity Unequivocal	"I think it's really good because you get to take this test over and over again, and like over time, maybe your score might get, your score might get higher and your score might get higher and that might be a good thing. And you'd be really – and like I like the test because you can really see if your, your asthma is getting better." **Carpenter 2016** *Page 514 column 2*
Record of symptoms to see change and symptom patterns Unequivocal	''Can see how symptoms change for other cycles.'' **Gibson 2010** *Page 349, table 3*
Increased awareness of symptoms and triggers Unequivocal	"You could like share like [...] your symptoms with the machine or whatever and it helped you realize what your symptoms were – actually were. It's [...] sometimes you don't really um [...] like [...] realize that you've had symptoms – you actually have to think about it." **Rhee 2014** *Page 67, column 2*

Improved asthma self-management and medication adherence Unequivocal	"I feel like it could help you manage your asthma because it like tells you when like you're having flare-ups and what time of day and then that can help you find out why because you can reflect and think back what you were doing then or what you were exposed to." **Rhee 2014** *Page 68, Column 1**
Adolescents also discussed how they were able to take action to keep their asthma under control when the self-check feature result indicated that they were having problems. Unequivocal	"I think what this is, this is very good. It helps you, um, track it so maybe you can catch your – catch it before it gets bad, you know, saying, you know, my – I wrote down I have a lot of symptoms all this week. Maybe, maybe I should, you know, check and see if Ineed to start doing my Xopenex and, you know, maybe do more upkeep I guess." **Carpenter 2016** *Page 514 column 2*
Reminders helped adolescents with forgetfulness and helped them become more observant of their medication-taking behaviors. Unequivocal	"And I always remember to take my medicine easier with this app so I think that will help out. Because if I could continue to take my medication on sort of, uh, a consistent flow it makes it easier. And so overtime, I think it will help me control my asthma." **Carpenter 2016** *Page 513 column 2**
Adolescents liked having all the information about what to do in case of an emergency in one location that was easy to share with others, so they could get the support they need in case of an asthma attack. In this way, the plan was linked to both technical advice and social support. Unequivocal	"You know, you can just pull it up and say, you know, I have all the information and I have it with me. And maybe in the case of a flare, flare, really your friend can see it and say, oh, it says her emergency plan is to do this, this, and this, so I can help her do this, this, and this." **Carpenter 2016** *Page 514 column 2*
To see and reflect using pictures improves understanding and knowledge and affects self-treatment. Credible	The most important factor for coping was seen as control of improved daily glucose values. DiaMob was reported as giving them better insight into what causes changes in glucose measurements. They reported better coping and not least increased motivation to succeed. **Froisland 2015** *Page 545, Table 1*
Improved comprehension and increased feeling of managing the self-treatment. Credible	Told that they understood diabetes theory before start of the study. However, reported that the picture app changed their understanding of cornerstones of treatment. This was reported as giving them an increased feeling of being able to manage the disease. **Froisland 2015** *Page 545, Table 1*

Support and reassurance for young people/families from being monitored. Unequivocal	‘‘It would just sort of reassure them a lot of the time that what they are feeling is normal, and then if there is anything out of ordinary then someone’s gonna pick up on it quite quickly, and probably for their parents, it would put their minds at rest as well.’’ **Gibson 2010** *Page 349, table 3*
It provided a safety net that gave them a sense of protection because it made it easy for them to access their physician with questions and concerns. Unequivocal	"The fact that you have someone to support you—someone who knows the subject, and if you get into difficulties you can get an answer—it gives a certain feeling of security." **Froisland 2012** *ePub*
Early intervention Unequivocal	‘‘You can nip symptoms in the bud.’’ **Gibson 2010** *Page 349, table 3*
Accessibility of asthma-related advice Unequivocal	“I think it would help them just 'cause if they needed someone’s opinion or they didn’t know what to do they can text you and they’d send back a quick answer.” **Rhee 2014** *Page 68, Column 2*

(b) *mHealth functionality to support person-centred clinical encounters.*

The functionality of the mHealth technologies supported a person-centred clinical encounter by enabling accurate provision of clinically-relevant information to treating practitioners (portability, and accuracy of data over a cumulative period of time), and helped to set the focus the clinical encounter.

Finding	Illustration
Perceived Usefulness of App for Preparing for or setting the Focus of Clinic Appointment Credible	Over half of reviewers […] thought their chosen app was useful or very useful for preparing for or setting the focus of their clinic appointment. **Ashurst 2014** *ePub*
Improve health professional's knowledge and understanding Unequivocal	‘‘They’ll [doctors and nurses] be able to know exactly what is happening.’’ **Gibson 2010** *Page 349, table 3**
Aid communication in consultations with professionals	‘‘It can help them remember their symptoms because when you come in for the first day of a cycle, doctors always ask you about the symptoms over like the last cycle, and it’s

Unequivocal	sometimes kind of hard to remember what you had on each cycle. So if it's like stored in the thingy, then you can tell them a little bit.'' **Gibson 2010** *Page 349, table 3*
Adolescents liked that they could share the [school] form with their school nurse so he or she could know what medications they were taking. Like the emergency plan, the school form seemed most linked to social support and technical advice. Unequivocal	"I could give it to my school if there's a problem with my asthma, they can say, 'Oh, well she did send us this document saying that she has asthma, so we need to let her take her medicine,' so that's a good thing." **Carpenter 2016** *Page 515 column 1**
Teens thought the [Doctor] report "travels a lot better" than paper and is a nice way to summarize their asthma experience in a concise format to give to their providers Unequivocal	"I think that was good…so like if your doctor just wonders how you're doing when he doesn't see you, you could, you could send him the chart and he could see how you've been doing." **Carpenter 2016** *Page 515 column 1**

2. Acceptance of mHealth technologies

(a) Perceptions on technical usability (how it's working now and how they perceive optimisation)

Users identified technical aspects of the mHealth technologies that affected usability and made suggestions for optimisation/improvement as it relates to scalability and implementation.

Finding	Illustration
Although the participants described the applications as highly usable in general, they also identified particular problems that required resolution. Unequivocal	"The Diamob app didn't work at the end of the project. The glucometer with Bluetooth worked, but batteries ran out of power quickly." **Froisland 2012** *ePub**
[…] several participants indicated that the Web-based SMS system was unduly cumbersome. Unequivocal	"But what is cumbersome is that you have to access that Internet browser on the mobile. I would prefer to send normal SMS on the phone...that would make it even easier if you could access it using the usual SMS [on the phone]." **Froisland 2012** *ePub**
All the adolescent participants used the verb "to see" in relation to the first application's functionality. Unequivocal	"I think it is a lot easier to understand and to have it explained when I can see things." **Froisland 2012**

Intentions to Use Again and Recommend to a Friend Credible	Overall, reviewers indicated that the apps were worth trialling but a few felt improvements or amendments were needed before regular use. **Ashurst 2014** *ePub**
Useful App Features Credible	By app function, the most useful features reported in qualitative feedback were: for data logging apps (1) setting targets and viewing trends, (2) ease of recording and tracking data, and (3) data storage in one mobile location without need for logbook or pen/ paper; for the insulin dose calculation apps (1) simplicity and ease of use, (2) accuracy and trust of calculator, and (3) all in one calculation (carbs and insulin); for the notes/ agenda setting apps (1) the topic prompts to identity and remember what to discuss at appointment, (2) simple layout and ease of use, and (3) ability to document and review notes. **Ashurst 2014** *ePub**
The participants agreed that the applications were highly usable, but requested the possibility of downloading the applications to their own mobile phones in the future. Credible	With 1 exception, the participants indicated that if the applications were available for downloading to their own phones, they would continue to use the applications. **Froisland 2012** *ePub*

(b). *Perceptions and experiences around acceptability and feasibility*

Users identified characteristics of mHealth technologies that aligned with their preferences for management support, specifically apps that were intuitive (self-explanatory and simple to understand) and practical self-management information that was immediately usable. While barriers were identified, the use of mHealth technologies was still feasible as end-users were able to adjust to the use of mHealth technologies with their daily routines.

Finding	**Illustration**
Although adolescents thought electronically documenting information was convenient, other barriers could limit use of certain features, particularly the peak flow feature. Unequivocal	I think most people just don't want to do them [peak flows]. And you don't want to have to – because first, you have to, you know, use it. You have to use it three times and you really start coughing, hacking after you've used it. Most people don't like peak flows. And then in addition to actually having to do the peak flow, you – if you want to see how you're doing really, you have to document it. **Carpenter 2016** *Page 515, column 1**

mASMAA feasibility and acceptability Unequivocal	Adolescents were able and willing to make adjustment to their routines to accommodate mASMAA and became accustomed to interactions with mASMAA easily ("You get used to it and it becomes routine"; "I feel like it becomes normal, just like … an instinct to do it") **Rhee 2014** *Page 67, column 2**
All patients who were questioned reported that they would recommend the application to others Unequivocal	"… because it really helps to see how you've been doing too actually, not just like, you know, go on day by day. But it does help you see and reflect on how you're doing. And if you did something the other day that helped, will help you make you feel better and so on." **Bagott 2012** *Table 5*
Patients' preference for the use of the VAS or face scales to rate pain and nausea were fairly evenly divided. Credible	Those who preferred the VAS appreciated the opportunity to select a more precise level of pain or nausea, compared to only a few options on the faces scales. Those who preferred the faces scales commented that the diagrams depicted how they were feeling. **Bagott 2012** *ePub*
Ease of Use Per App Credible	Reviewers' felt the easiest to use apps were self-explanatory and simple to understand. The other apps were also considered easy to use but with some suggestions to improve the user-interface. **Ashurst 2014** *ePub**
[…] stated that they appreciated simple and practical self-management advice more than large amounts of information that was not relevant to their immediate situation. Unequivocal	"It is more about those messages and the information. It has been practical advice, easy to understand, simple facts that are very nice to know. It is better to have it in such small portions instead of reading a lot of information, then everything is poorly read and poorly understood. I liked the way the information was given." **Froisland 2012** *ePub**

3. The importance of co-design

End-users identified the critical importance of co-design of mHealth technologies. Both including (a) intrapersonal and (b) extrapersonal factors were highlighted as considerations for tailoring design.

Finding	Illustration
However, intrapersonal factors, such as inadequate knowledge of one's triggers, limited some adolescents' use of the [triggger and symptom tracking] feature	"I really don't know what my triggers are, so I really didn't use it that much." **Carpenter 2016** *Page 514 column 1**

Unequivocal	
[…] adolescents who felt like they were already doing a good job managing their asthma were less likely to spend time using the apps since they did not have symptoms or triggers they wanted to document. Unequivocal	"Because, like my asthma is well-controlled, so like a lot of the stuff here I don't really need, but maybe like other people who have it worse will like probably need it more." **Carpenter 2016** *Page 515, column 1**
[…] competing demands limited adolescents' ability to use the apps […] Credible	[…] one participant noted that she was too busy to use an asthma app. **Carpenter 2016** *Page 515, column 1**
The Importance of the Apps Being Created by YPD Credible	[…] much importance was placed on app design (not necessarily development) by diabetic peers because of a mutual understanding of the needs, condition and experiences in order for the apps to offer the most accurate features and details. **Ashurst 2014***
Social settings change action readiness with regard to acceptance of disease and self-treatment. DiaMob increased social acceptance Credible	Most adolescents in the study felt in charge of their own life, however they talked about acceptance as an important factor. Acceptance of own disease and treatment and also acceptance from important others like friends to treatment while in different social settings. **Froisland 2015** *Page 545, Table 1**

4. Perceptions of benefit

(a) *self-efficacy (locus of control)*

End-users identified that mHealth technologies positively influenced self-efficacy.

Finding	Illustration
Improved sense of control over asthma and its management Credible	"[…] adolescents reported increased independence during the trial, as indicated in their improved self-management (eg, taking medications) without parents' prompting." **Rhee 2014** *Page 68, Column 2**
Increased control for young people Unequivocal	''I felt in control and I liked that you could see if your temperature had improved.'' **Gibson 2010** *Page 349, table 3**

SMS solutions lower the threshold for contact and give adolescents a sense of "being in charge." Credible	The direct contact with those they trust was reported as important. To know that they got an answer back, gave a feeling of acceptance and to be paid attention to. **Froisland 2015** *Page 545, Table 1**

(b) *Empowerment*

mHealth technologies were perceived as empowering condition management by young people

Finding	Illustration
Positive feedback leads to mastery and increases empowerment. Negative feedback leads to opposition. Credible	Positive response from people who know the disease is important to feel empowered. The SMS application increased the possibility for response directly from their health care professional. **Froisland 2015** *Page 545, Table 1**
The participants also reported feeling empowered in that they could access the health care practitioner so readily Unequivocal	"It has been pretty good to know that if I have an issue, then I can just send a message...Instead of calling Mom or Dad and ask them to call [the physician], and when they have the answer it might be an answer to something I was not wondering about." **Froisland 2012** *Page 513 column 2**
Patients are empowered and can change their own lives when they are able to integrate knowledge and resources to take rational decisions. Through experience they are further able to evaluate the effectiveness of their decisions. Credible	DiaMob gave them a visual and tangible understanding of how physical activity, food intake, and insulin dosage, interact and affect postprandial glucose measurements. This gave them a new start to change the direction of their own treatment. SMS solution gave them a feeling of being in charge and closer to the health care practitioners. **Froisland 2015** *Page 545, Table 1*
Using the app also resulted in several positive self-reactions for adolescents, including feeling more confident that they could take more responsibility for managing their asthma, obtaining the support they need to manage asthma, and communicating more effectively with others about their asthma. Unequivocal	"It kind of keeps me to where I can see what I've done, instead of it just being in my mom or my doctor knowing how far I've come, where – if I'm getting better or worse, if I'm normal for myself or anything, I can kind of keep myself in check." **Carpenter 2016** *Page 516, column 1*

* indicates supporting quotes also included in full text paper
mASMAA= Mobile phone-based asthma self-management aid for adolescents; VAS=visual analogue scale; SMS=short message service; YPD=young people with diabetes

Supplemental File 5

Themed categories showing implementers' perceptions and experiences of mHealth technologies

1. mHealth technology characteristics that support young people's management of NCDs

(a) functional aspects of design that support end-users' management

Implementers identified a range of design features that were perceived to support end-users (young people's) management of their conditions. This included tracking side effects and symptoms, accessing information, motivation, alerts for deteriorating health condition, knowledge and self-awareness, habituation of components of self-management (e.g.; medication management), and enabling bilateral communication, and as overcoming communication deficiencies.

Finding	Illustration
Symptom Tracking to Improve the Quality of Clinic Appointments Unequivocal	"This way you can look back over the previous 4 weeks or 3 months and focus on questions such as—"you scored sleep a 2 here, what was happening at the time that made it so unsettled?" It should help parents to be more productive in giving the information we need." **Simons 2016** *Page 9, column 1*
Diary and chart features Credible	Most parents and clinicians believed the diary and chart were crucial features for management of the child's asthma. **Geryk 2016** *ePub*
Monitoring and Tracking Side Effects and Symptoms Unequivocal	Graphs would be useful for example for... patients who stop taking meds but parents and teachers say they have improved. It might help to have the parent and teacher graphs to see. **Simons 2016** *Page 10, column 2*
Supporting Greater Self-Management Credible	"Participants saw the potential for RMT to provide the ability to easily monitor symptoms, chart them over time, and identify any patterns or unusual behaviors. This would

	increase people's knowledge, self-awareness, and understanding of and confidence in dealing with their condition." **Simons 2016** *Page 9, column 1*
Medication Reminder Feature Credible	Most clinicians felt that the medication reminder feature would help their patients a lot, particularly with their controller medications, as they saw medication nonadherence as an important clinical issue. **Geryk 2016** *ePub*
Organization Aid Unequivocal	The difficulties I come across, [are that] young people are on medication and they tend to run out at the end of the month and their behavior will go sky high, and it will take them a week to get all the medication back into their system. I think it would be really useful if somewhere in the app, say when they're...near the end [they receive a message saying] "You need to put in a request for repeat prescription." [HCP, Site 3] **Simons 2016** *Page 10, column 1*
Time was an important factor in interaction Unequivocal	"You can send text messages at a time that suits you and at the pace that you need. That is a very positive thing" **Buchholz 2013** *Page 93, column 2*
Physicians believe that mobile technology could improve communication by reaching adolescents directly. Unequivocal	'' .. . teenagers are busy and communication is limited and I think using technology will improve communication. They'll listen more. I mean, I think they read their texts, you know, and I think reading a short text is much more beneficial and reminder systems on an everyday, I mean, doing something the same way for 2 weeks makes it a habit.'' **Schneider 2016** *Page 156*

School Form Feature Credible	Some parents and clinicians felt that communicating asthma care between various entities using the school form feature would be very convenient. **Geryk 2016** *ePub*
The use of mobile technology by physicians and patients turns this platform into a feasible, accessible, and acceptable outreach mode. Unequivocal	‘‘Teens probably most of them it would have to be some type of an e-mail or text messaging ‘cause I feel like most of our teen patients have access to that type of information. That, I think, is definitely a patient population who may be more willing to respond to you.’’ **Schneider 2016** *Page 157*
Physicians believe that repeated reminders assist adolescents in practicing and routinizing their asthma action plan and developing self-management skills. Unequivocal	‘‘Y’know, to use the Aero Chamber with it, y ’know, or something. But I think the best reminders will be, maybe, during cold season or something, to remember—just a reminder that said, y ‘know, to use your—‘‘These are the symptoms. Remember to use your Albuterol.’’ So, I think just reminders are going to be best for, maybe, just a little blurb related to the symptoms and for follow-up appointments. It might be for acute follow-up visits or it might be for routine visits.’’ **Schneider 2016** *Page 158*
Reliable, Trustworthy, and Tailored Information Unequivocal	I’m feeling dizzy—[the] advice would be to go to see your GP”. **Simons 2016** *Page 10, column 1*

The possibility to use remote communication affected the users' feeling of safety in daily life. Unequivocal	"She has found the courage to do things she didn't dare before ...for example she was scared to be home alone" **Buchholz 2013** *Page 93, column 1*
A Coach/Supporter/Motivator Unequivocal	[It] could have some information based on how long the process should take with messages such as "you may not be seeing any improvements yet, but stick with it"... or you could have messages to parents, such as "Derek might be struggling this week" **Simons 2016** *Page 10, column 1*
The speech synthesis was indispensible to users when listening to an incoming message. Unequivocal	"When she receives them, that's what has been the single most important thing for her in the phone" **Buchholz 2013** *Page 92, column 1*
Speech synthesis was important for the user in the construction of a message. Unequivocal	"He has great help from the synthetic speech and he is markedly disturbed when it doesn't really sound like he wants it to" **Buchholz 2013** *Page 92, column 1*
Physicians believe that alerts regarding a worsening asthma condition and the need for follow-up are crucial for reducing the number and severity of exacerbations. Unequivocal	''I would probably have—probably tie the—maybe a color scheme. If it comes over and the numbers are in the red then a response comes back in the red, too, that's basically saying, y 'know, instructions. ''You need to do this and this and—'' kind of like a little triage form. ''Do this and this. If not this, then you need to report to the ER.'' **Schneider 2016** *Page 158*

(b) *How technical characteristics of mHealth can help their delivery of clinical care*

Implementers identified several technical features that they believed would assist their delivery of clinical care and optimise their engagement with end-users through communication, reminders and focussing clinical encounters

Finding	Illustration
Communication /Information Sharing* Credible	Clinicians felt that use of the app could lead to a better medical appointment both in terms of efficiency, patient-centered care, and decision making. Multiple clinicians expressed data security concerns (eg, insecure email) or differed in their preference for information delivery method [...] **Geryk 2016** *ePub*
They perceived text messaging and e-mails as efficient and preferred communication channels to connect with patients […] Unequivocal	‘‘I am a big fan of texting. I would love to just get everything texted. If I could just text data to people all day I would save hours of time.’’ **Schneider 2016** *Page 156*
Doctor Appointment Reminder Feature Unequivocal	Multiple clinicians mentioned that appointment noncompliance is a problem, one stating that “[a]ny extra reminder that families have that they have an appointment I think is helpful.” **Geryk 2016** *ePub*

(c) *how mHealth technology can support positive behavioural change*

Implementers perceived mHealth technologies to positively influenced end-users to independently manage their condition and facilitate positive health behaviour change

Finding	Illustration
Monitoring and Supervision Credible	Clinicians generally had positive things to say about the apps as a self-management tool to help parents and adolescents including the following: “hands-on” and provides a “more interactive or fun way to check on their asthma.” **Geryk 2016** *ePub*
Physicians perceive positive feedback as essential for reinforcing behavior change and encouraging asthma control. Unequivocal	‘‘I mean if everything is going well, you could give them sort of positive feedback just like: ‘‘Hey, keep up the great work.’’ If not, you could be like: ‘‘Are you taking your controller?’’ **Schneider 2016** *Page 158*

The users' possibilities to manage things on their own increased with the use of TMSS Unequivocal	"It gives a direct contact that doesn't go through someone else and that in itself makes it a more independent way of communication" **Buchholz 2013** *Page 93, column 1*

2. Implementation challenges

(a) *Technical features as barriers to implementation at the clinical (micro) level.*

These included, accuracy of monitoring and limitation of task-specific capability.

Finding	Illustration
The device did not always live up to the users' expectations about how it should compensate for his or her communication difficulties. Unequivocal	"Basically he seems to think it's good but he's frustrated because he thinks ...he has very high expectations and to this point he doesn't feel they have been met" **Buchholz 2013** *Page 91, column 1**
Asthma Trigger Features Unequivocal	this feature was more often criticized by parents and clinicians because of its lack of long-term monitoring and feedback capabilities. One clinician expressed the opinions of other participants when stating, "I don't know what you'd [do] with it. Other than just be aware of it." **Geryk 2016** *ePub**
The speech synthesis was sometimes a subject of irritation. Unequivocal	"When we send texts to [him] we have to be careful with commas exclamation marks and question marks so that the synthetic speech will be clear" **Buchholz 2013** *Page 91, column 2*
Peak Flow Feature Credible	Clinicians expressed some reservations to patient peak flow use, including worrying about the adolescent obtaining an accurate peak flow reading. **Geryk 2016** *ePub*

(b) *Organisational level (meso) barriers to implementation.*

These included internal regulations, resource allocation (remuneration and funding), integration into workflow, organisational climate and readiness for change, interoperability with existing IT systems

Finding	Illustration
Physicians also raised reimbursement of services outside their routine responsibilities as a barrier. Unequivocal	‘‘The biggest thing is ... a time issue, lack of reimbursement … for adding additional duties.’’ **Schneider 2016** *Page 157**
Right intervention; wrong setting Unequivocal	“We see young people with severe mental health problems, including suicidal ideation, and I’m not sure it’s ideal for this group… Most self-harm is dealt with by family support workers and schools, and they are always looking for additional resources and tools to help with it.” **Owens 2016** *Page 7, column 1**
Access to Technology Credible	“This included access to mobile devices, especially ones that would support any new app/software (all groups); […]; and capability for interoperability with NHS hardware.” **Simons 2016** *Page 9, column 2*
Perceived burdensomeness and technophobia Unequivocal	“The general perception within the team is that using TeenTEXT is too much of an extra burden on top of our existing workload.” **Owens 2016** *Page 6, column 2**
Perceived Challenges of Incorporating RMT Into Clinical Care Unequivocal	HCPs were keen on receiving digital information that coincided with patients’ appointments, but noted that “if you start getting notifications about patients from another area clinic it will take up too much time” **Simons 2016** *Page 9, column 2*
Organisational gatekeeping Unequivocal	“The organisation doesn’t give clinicians any leeway. We need permission to try anything new and there are so many hoops to jump through before that happens.” **Owens 2016***
Context: CAMHS in crisis Unequivocal	“CAMHS is overwhelmed at the moment… It may have been the wrong time to try something new…There have been so many organisational changes. Managers have left, there’s been the introduction of Child IAPT1 services and there are high rates of sickness absence. Tis does affect our ability to get involved with new projects.” **Owens 2016** *Page 5, column 2*

(c) *System level (macro) barriers to implementation.*

These related to regulatory frameworks and health information security

Finding	Illustration
Communication /Information Sharing***** Credible	Clinicians felt that use of the app could lead to a better medical appointment both in terms of efficiency, patient-centered care, and decision making. Multiple clinicians expressed data security concerns (eg, insecure email) or differed in their preference for information delivery method [...] **Geryk 2016** *ePub**
Sharing medical information electronically or by the Internet potentially creates security risks. Unequivocal	'Oh, I would love to do it by electronic means. The problem is that then you run into all the HIPAA problems.'' **Schneider 2016** *Page 157**
Doctor Report Feature Credible	However, clinicians mentioned specific communication-related concerns including the Health Insurance Portability and Accountability Act (HIPAA) and security concerns, not wanting to be handed the report by families in clinic, or seeing the feature as impractical with difficulties getting it to interface well with office technology and to link to a patient chart. **Geryk 2016** *ePub*

3. Adoption of mHealth technologies in a specific young population

a) Implementers perceived the need for training for end-users for some conditions and settings to facilitate adoption. For features to encourage adoption included using existing technology and hardware, and physical ease of handling devices.

Finding	Illustration
Overall, the design of the devices seemed to be satisfactory, since it was easy for the users to hold, see and point at the screen. Unequivocal	"It has been easy to handle for him ...it has been easy also in terms of making adaptations (for the helper)" **Buchholz 2013** *Page 91, column 2**

TMSS was useful to be able to use mobile phone technology in daily life activities. Unequivocal	"This is an aid that would be of help for a lot of people. I have many colleagues with clients who would need something similar maybe particularly adolescents that are becoming adults" **Buchholz 2013** *Page 92, column 2 **
The possibility to be able to use the same technology as others in society was important. By succeeding in using the devices, the users had the opportunity to express their views independently. Unequivocal	"You might get a stronger self when you get to be a little more independent mainly with the texting but also using the calendar or the price calculator for keeping track of things" **Buchholz 2013** *Page 92, column 2*
It was important to blend in; to have a device that didn't look different from the every-man's. Unequivocal	"Exciting a little more up to date ...modern ...or she would never have accepted it" **Buchholz 2013** *Page 91, column 1**
There was wish for the software to be installed in the users' regular phones. Unequivocal	"Yes because if this software was installed in the regular phone I think she would use it more" **Buchholz 2013** *Page 91, column 1**

b) Features to encourage adoption included using existing technology and hardware, and ensuring design that supported ease of handling devices

Finding	Illustration
It was sometimes hard to know if and to what extent the users understood the purpose of the device before having gained experience of use. Credible	"Yes, it was very abstract I think so when we could show him something more concrete he grasped it better" **Buchholz 2013** *Page 91, column 2**
The training needed to be a part of daily activities and actual communication situations. Unequivocal	"It's important to find a situation where you really see the need of being able to text or a person you need to contact where a regular phone call won't work" **Buchholz 2013** *Page 92, column 1**

4. Co-design and tailoring

(a) importance of co-design: implementers identified the importance of working collaboratively with end-users to optimise functionality.

Finding	Illustration
The pre-designed phrases were valuable for initial training where the phrases served as suggestions for messages that could be sent. Unequivocal	"She has great use of them and we have built upon her interests so she can easily reply to a text and she can also send a pre-designed text" **Buchholz 2013** *Page 93, column 2**
My Allergies and Emergency Plan Feature Credible	One clinician brought up the benefits of using the feature for "engaging with them [patients]" including jointly inputting information into the plan and/or discussing what patients have previously input to ensure they are getting the correct guidance, especially regarding emergency situations. **Geryk 2016** *ePub**
Engagement in principle Unequivocal	"I like the fact that the messages are written by them, so they're supporting themselves… This fits with what we currently do, which is try and give them a sense of control." **Owens 2016** *Page 5, column 1**
Self-Check Quiz Feature Unequivocal	"[k]ids are involved. They are more willing to be self-advocates for themselves." **Geryk 2016** *ePub*

(b) Implementers identified the need for the design of mHealth technologies to be adaptable to end-users, providing for tailored content and function.

Finding	Illustration
[…] with time, the devices were also used for face to face communication. Unequivocal	"Yeah it's like that. He has started to use it more for face to face communication. . . not just the text-messaging function but more as a communication device" **Buchholz 2013** *Page 94, column 1**

Physicians believe that tailoring messages responsive to preferences about delivery mode, time, and content would increase youth's receptiveness to the intervention Unequivocal	''Don't forget to pretreat before you go out for soccer practice, or football practice,'' specific for that patient's sport I think would be even more, you know, something that's specific for that patient.'' **Schneider 2016** *Page 158**
Education Unequivocal	"I think most of them engage in devices like this for entertainment, right? And so you want to have something that provides them an educational opportunity, um, but also something that they – they won't get bored with." **Geryk 2016** *ePub*

* indicates supporting quotes also included in full text paper
TMSS=text messaging with picture symbols and speech synthesis; NHS=National Health Service