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Research Article

Design and deployment of digital health interventions to reduce the risk of the digital divide and to inform development of the living with COVID recovery: a systematic scoping review

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Abstract

Background: Digital health interventions can support health-related knowledge transfer, for example through websites or mobile applications, and may reduce health inequalities by making health care available, where access is difficult, and by translating content to overcome language barriers. However, digital health intervention can also increase health inequalities due to the digital divide. To reach digitally excluded populations, design and delivery mechanisms need to specifically address this issue.

This review was conducted during the evolving COVID-19 pandemic and informed the rapid design, deployment and evaluation of a post-COVID-19 rehabilitation digital health intervention: 'Living with COVID Recovery' (LWCR). LWCR needed to be engaging and usable for patients and to avoid exacerbating health inequalities. LWCR was introduced as a service into 33 NHS clinics, was used by 7679 patients, and evaluation ran from August 2020 to December 2022.

Objective: To identify evidence-based digital health intervention design and deployment features conducive to mitigating the digital divide.

Methods: Cochrane Library, Epistemonikos, National Institute for Health and Care Excellence Evidence, PROSPERO, PubMed (with MEDLINE and Europe PMC) and Turning Research into Practice; OpenGrey and Google Scholar were searched for primary research studies published in English from 1 October 2011 to 1 October 2021.

Setting and population: Adults who were likely to be affected by the digital divide, including older age, minority ethnic groups, lower income/education level and in any healthcare setting.

Interventions: Any digital health intervention with features of design and/or deployment intended to enable access and engagement by the population of focus.

Comparators: Any or none.

Outcome measures: Any related to participants' access and/or use of digital health intervention and/or change in digital skills and confidence.

Analysis: Data from studies that met the inclusion criteria were extracted, narratively synthesised and thematically analysed.

Results: Twenty-two papers met the inclusion criteria. Digital health interventions evaluated included telehealth, text message interventions, virtual assistants, self-management programmes and decision aids.

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Design themes included: Co-development with end-users, user testing through iterative design cycles, digital health interventions that also helped improve digital skills and digital health literacy, tailoring for low literacy through animations, pictures, videos and writing for low reading ages; virtual assistants to collect information from patients and guide the use of a digital health intervention.
Deployment themes included: Free devices and data, or signposting to sources of cheap/free devices and Wi-Fi, text message interventions, providing 'human support', providing tailored digital skills education as part of the intervention and enabling peer/family support.
Limitations: Our search extended to late 2021, and there has been a massive increase in the literature following the pandemic. However, as our review was undertaken to inform the LWCR digital health intervention design and deployment, we have reported the results that informed this work. The studies included in the review were heterogeneous, so generalisability may be limited. Few randomised controlled trials assessed the digital health intervention's impact on digital health skills by using validated measures.
Conclusions: Using the design and deployment findings described above when developing digital health interventions may help overcome the digital divide. Beyond informing the LWCR digital health intervention development, the review findings have wider implications for the equitable design, delivery and evaluation of digital health interventions.
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Introduction

The COVID-19 pandemic led to very rapid widescale adoption of digitally delivered health care while also revealing the impact of systemic societal health inequalities.[1] COVID inflicted a 'double whammy', with deprived people, older people and those from ethnic minority groups getting sicker and more likely to die while, at the same time, making health care even less accessible for these groups.[2,3] Belonging to one or more of these groups (intersectionality) was a risk factor for experiencing disproportionately more severe illness and mortality.[4]

It also quickly became apparent that large numbers of patients would need rehabilitation following hospital admission for COVID-19. A large proportion of these patients and others, who were not hospitalised, went on to develop 'long COVID' with distressing symptoms, including breathing pattern disorders, anxiety and fatigue.[5–7]

In the context of an already stretched NHS in the UK, deploying its resources to the ongoing pandemic, combined with an increasing backlog of deferred treatment, it was clear that digitally delivered rehabilitation had the potential to help manage the demand for remote rehabilitation. The Living with COVID Recovery (LWCR) study was designed to deliver and evaluate remote rehabilitation for patients with ongoing severe symptoms immediately post hospital discharge and for people who developed long COVID through the development and deployment of a digitally delivered and supported rehabilitation programme.[8]

In brief, the LWCR system consisted of an app-based digital health intervention (DHI) with programmes to address the symptoms of long COVID, including self-management programmes for breathlessness, fatigue or anxiety, the most disabling symptoms of long COVID, along with a library of information about other common symptoms, for example brain fog.[8] The app supported self-management (a health coaching approach), regularly prompted users to complete patient-reported outcome measures (PROMs) questionnaires to populate a clinician-facing dashboard, allowing healthcare practitioners (HCPs), usually senior physiotherapists, to provide two-way support via app messages.

From the outset, the LWCR study team sought ways to mitigate the risk of exacerbating health inequalities resulting from low health literacy, low digital health literacy and the digital divide, terms which we define and describe in the next section. We needed to ensure the digital offer could be integrated into long COVID clinical pathways and would allow patients to receive adequate human support.[9]

Due to the fast pace of intervention development necessitated by the ongoing pandemic, an initial rapid literature review was conducted to ensure that the LWCR app's design, content and presentation of learning materials and PROMs would be accessible to people from a range of demographic groups and that the LWCR system could be equitably deployed in NHS clinics.

The rapid review expanded into a systematic scoping review[10] to bring together the evidence base of strategies to reduce the digital divide through design and deployment of the DHI in long COVID clinics and to support the app through iterative design cycles, a methodology based on a human-centred design approach, which uses a cyclical process starting with development of a minimal viable product or prototype, testing it, getting feedback from stakeholders, analysing the results and refining the product or process.[11,12]

We defined DHI as 'any service intended to improve physical or mental health, or to promote health improvement through, for example, lifestyle change, delivered digitally (formally or informally), such as via smartphone apps, social media, e-mail, SMS text message, using wearable technologies, video games (e.g. for motor or cognitive training), websites, or telehealth (e.g. remote consultations) but excluding telemedicine if this consists solely of remote monitoring without any input from the patient'.[10]

Health inequalities, health literacy and the digital divide

There are several overlapping definitions for the term 'health inequalities'. For this review, we used the King's Fund definition,[13] which builds on McCartney *et al.*'s definition of 'the systematic, avoidable and unfair differences in health outcomes that can be observed between populations, between social groups within the same population or as a gradient across a population ranked by social position'[14] and broadens it to include 'differences in access to health care, quality of care received, wider determinants of health such as housing and education, and opportunities to lead healthy lives, including differences in risky behaviours such as smoking', which brings in a social justice aspect, also expressed by the related term 'health inequity'.[15]

The term 'digital divide' describes 'the gap between people in society who have full access to digital technologies (such as the internet and computers) and those who do not', and it is a clear example of digital heath inequity. The digital divide is caused not only by lack of access to affordable and reliable internet and devices, including mobile phones, apps, etc., but also by the lack of skills and resources needed to use and benefit from such devices, which is compounded by a lack of trust or motivation to do so, or lack of saliency.[16] Ensuring 'equal opportunity for individuals to benefit from the knowledge and practices related to the development and use of digital technologies to improve health' is the focus of the World Health Organization global strategy on digital health 2020–5.[17]

Digital health literacy is a subtype of health literacy that is associated with poor health outcomes and is defined as 'the degree to which individuals can access, understand, and apply (digital) health information and services to make informed decisions about their health'.[18] It also refers to the need for digital health information and services to be designed to be usable and responsive to the digital health literacy of the populations they serve.[19]

Anticipating and addressing potential issues with design and usability are key to ensuring a diverse range of people can use DHIs. DHIs need to be engaging and simple to use on an ongoing basis if they are to produce their intended outcomes and avoid exacerbating the digital divide. Veinot *et al.*, in their 2018 health informatics perspective paper,[20] identified different levels of safeguards needed to reduce digital inequity, which they termed as 'universal precautions'. These included precautions to address access, resources and skills issues and also to overcome the 'literacy burden' of using DHIs by considering design and usability issues at development stage.

Rationale for conducting a systematic scoping review

We chose this methodology as the best way to provide a preliminary assessment of the size, scope and nature of the research evidence available and to synthesise the evidence base for ways to reduce the digital divide through design and deployment of DHIs. This methodology is best suited for pooling evidence from a wide range of sources, including grey literature and any studies missed from the search that might be included in relevant systematic reviews.[21,22]

Patient and public involvement

The LWCR study recruited 30 PPI representatives, of whom 2 were on the study steering group that met monthly. Two PPI representatives were members of the work package group that conducted this systematic scoping review. They did not conduct the review but commented on the review protocol and findings, and their contributions is acknowledged. All meetings took place on Zoom (Zoom Video Communications, San Jose, CA, USA), and PPI representatives received payment for their work and for attending meetings.

Methods

We used the Joanna Briggs Institute review methodology,[23] with guidance from Peters *et al.*[24] In brief, this covers clarifying the review's aims and research questions, searching appropriate evidence sources, charting data extracted from included publications, analysing the data and consultation with stakeholders, including patient and public involvement (PPI) representatives, to validate emerging results.

Aim and objectives

The aim of this systematic scoping review was to identify research that has evaluated features of DHI design and deployment, which are conducive to improving access to (and engagement with) DHIs by people from demographic groups likely to be affected by the digital divide.

The objectives of the review were to answer the following two research questions:

1. How can a DHI's design, and any digital skills' training for users integral to the DHI's delivery mechanisms, be optimised to reduce digital health inequalities arising from low digital health literacy?
2. How should the DHI be deployed to mitigate the digital divide?

Eligibility criteria

We included primary research studies of any design, published between 1 October 2011 and 1 October 2021, set in any part of the world, with participants aged ≥ 16 years and from the following groups: ethnic minorities, socially disadvantaged people and the elderly (aged > 65 years), as these groups have been identified as highest risk of digital divide.[25] We included population-based samples if participants from the groups of interest could be disaggregated. To be included, studies needed to focus on a specific DHI-containing element of its design or deployment that was intended to reduce the digital divide and measures reported needed to reflect these outcomes. We excluded reviews, opinion pieces, blogs and summaries as these did not fulfil the criterion of primary research. We also excluded those which were not published in English.

Decisions on whether publications retrieved should be included or excluded from further analysis were iteratively refined based on increasing familiarity with the literature, which was in line with systematic scoping review methodology. Following discussions at our regular team meetings, we made the following changes to inclusion criteria listed in the protocol.[10]

- We agreed to exclude studies that only described lists of barriers, or demographic characteristics of groups likely to be subject to the digital divide. These are likely moderators of digital engagement but were not the focus of this review and are well described in the literature.
- Equally, we excluded studies that assessed stand-alone interventions to increase people's digital skills outside the context of a DHI. Our research focus was on those studies that evaluated specific DHIs that incorporated purposeful facilitators for the DHI's use, built into the design or deployment mechanisms and reported results to show the effectiveness or acceptability of these measures.
- We agreed to include only those qualitative studies whose participants were actual or potential users of a specific DHI, for example to inform or co-design its development rather than those that explored barriers/facilitators to using DHIs in general.
- For grey literature, we would include only those that reported results of primary research, for example conference abstracts or reports by charities that described the results of studies carried out by the charity itself, not just summaries of the literature.
- We also excluded review articles because we were not doing a review of reviews. However, if the search identified any reviews that appeared highly relevant to our review, we would screen their included studies in case any eligible studies had been missed by our search.

The final list of eligibility criteria is shown in *Report Supplementary Material 1*, Table 1.

Evidence sources and search strategy

The following sources were searched: Cochrane Library, Epistemonikos, Europe PMC, MEDLINE, National Institute for Health and Care Excellence Evidence, The Grey Literature Network Service, PROSPERO, Turning Research into Practice Pro, Cumulative Index to Nursing and Allied Health Literature (Plus), PsycInfo® (American Psychological Association, Washington, DC, USA), Conference Proceedings Citation Index, Google Scholar, and OTseeker.

The search strategy was based on three categories: terms for health-related apps, terms for interventions/process and terms relevant to the priority demographic groups, which were combined using Boolean 'AND' to ensure that references captured contain at least one term from each category. The full search strategy is shown in *Box 1*.

BOX 1 Full search strategy

(app* OR ehealth OR mhealth OR telemedicine OR smartphone OR tablet OR computer OR internet OR wearable OR device OR technology) AND (interven* OR program* OR mitigate OR change* OR modif* OR implement* OR process* OR approach* OR facilitat* OR enabl* OR barrier) AND (ethnic minorit* OR disadvantage* OR underserved OR elderly OR geriatric OR older) AND ('digital divide' OR 'digitally excluded' OR 'digitally-excluded' OR 'digital exclusion' OR 'low digital health literacy' OR 'low ehealth literacy' OR 'low e-health literacy').

Limits:

Date range: 1 October 2011–1 October 2021.

Adults aged 16+ years.

Published in English.

Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews[26] was used to record processes of selection, deduplication and screening for inclusion.

Twenty-five of the hits were randomly selected and screened for inclusion or exclusion by the members of the review team, with 92% agreement. We divided the remaining hits between the team to screen, with reasons for exclusion being documented, and any disagreements were resolved by consensus among the study team. Publications that met the inclusion criteria were not subject to quality appraisal, as this is not recommended for scoping reviews, where the focus is on eliciting as complete a picture as possible of current knowledge about the subject of interest.[27]

Data extraction and charting

Data were extracted from full-text items that met inclusion criteria into a Microsoft Excel® (Microsoft Corporation, Redmond, WA, USA) spreadsheet under the following headings:

1. Author(s)
2. Year of publication
3. Origin
4. Publication type
5. Funding source
6. Stakeholder involvement
7. Population and sample size
8. Name of the DHI (including any comparator and details of duration)
9. Purpose of the DHI
10. Outcome measures relating to design and deployment features intended to facilitate use by people from demographic groups of interest (including effect sizes if reported and qualitative data if collected)
11. Key conclusions that related to the review question

Collating, summarising and reporting results

A narrative synthesis and thematic analysis[28] of the findings from the included studies were conducted by one member of the team (FLH). Emerging results were discussed in team meetings prior to wider consultation with the LWCR steering group.

Results

The initial search resulted in 1245 hits. The grey literature search identified very few relevant hits, so further searches were not conducted due to time and resource constraints.

After removing 942 duplicates, 303 hits were screened by title and abstract. Of these, 119 did not meet the inclusion criteria, leaving 184 publications for full-text review. From these, 165 were excluded because they did not meet the inclusion criteria for one or more of the following reasons: 64 were review articles (not primary research); 62 had no details of DHI design or deployment mechanisms intended to help reduce the digital divide; 7 publications had no focus on a specific DHI; and 3 papers had a focus on participants who were aged < 16 years, college students or healthcare professionals, respectively. This left 19 publications that met the inclusion criteria for our study. However, of the 64 review articles we screened out, 6 had a focus that was highly relevant to our review, so we screened their included papers. From one of these reviews,[29] three studies fulfilled the inclusion criteria for our review and so were added to the included studies.

In total, 22 papers were included in the systematic scoping review. The selection process is shown in *Figure 1*.

Characteristics of included studies

The characteristics of the included studies are summarised in *Table 1*, and further details for each of the included studies are given in *Report Supplementary Material 2*, Table 2.

Settings and designs

Most were conducted in the USA (13/22). The others were carried out in Canada, Mexico, Philippines, Uganda, Burkina Faso, Cambodia, the Netherlands and UK, and there was one multicentre study conducted in Spain, Italy, Greece, the Netherlands, Slovenia, France,

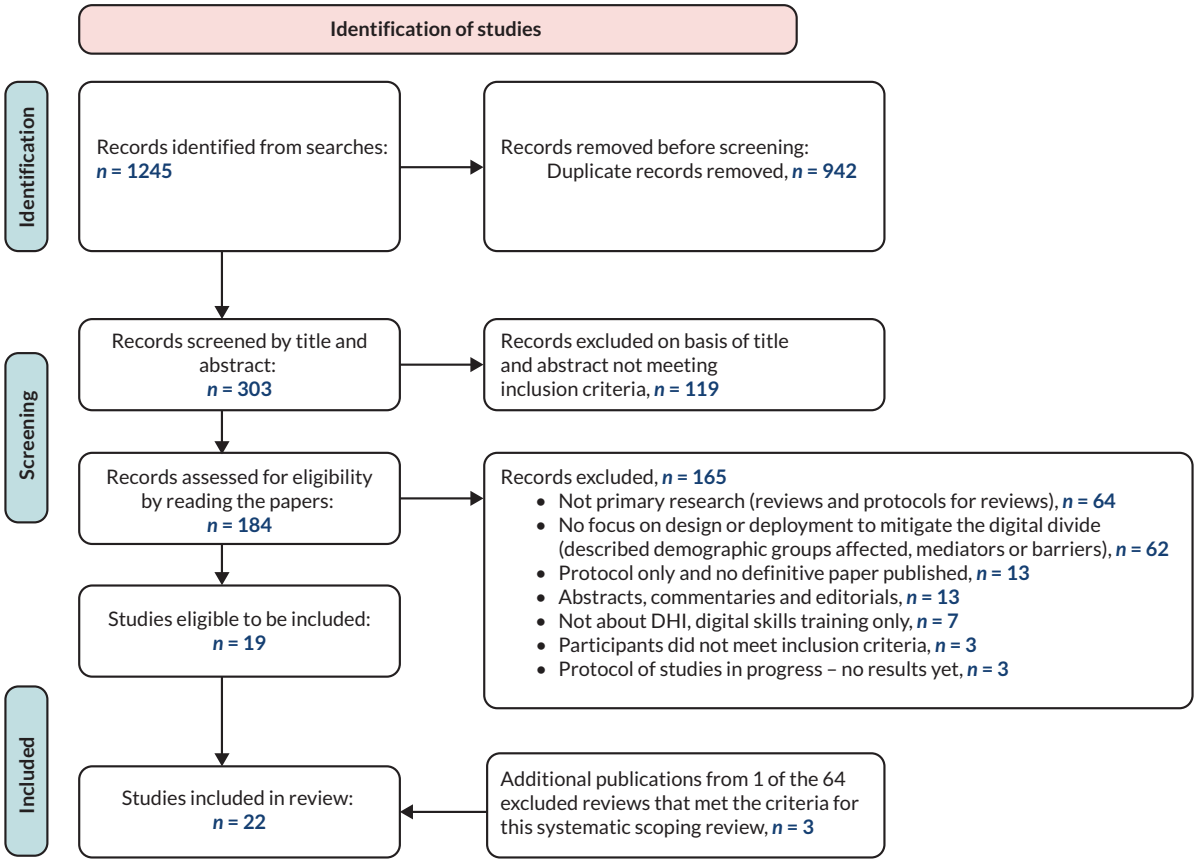


FIGURE 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.[30]

Serbia and Israel. There were eight randomised controlled trial (RCTs), eight qualitative studies, three were mixed-methods, one was cross-sectional and one was a pre–post single-arm study, source of study. The studies were all published between March 2013 and August 2021.

Participants

Most of the studies focused on older adults (10/22), including two studies with caregivers for older adults, who were mainly elderly themselves. One study recruited low socioeconomic status (SES) older adults and another enrolled older African American patients. There were six studies where participants were low SES adults (6/22), three recruited adults living with human immunodeficiency virus (HIV) in under-resourced settings, two focused on minority ethnic groups and one on homeless adults who were war veterans.

Digital health intervention categories

A wide range of DHIs were identified, which we categorised into four groups: e-health learning programmes to help patients use specific DHI, patient portals (PPs) or decision aids (n = 10); text messaging interventions (n = 7); telehealth interventions (n = 3) and virtual assistants (n = 2). The DHIs for each category are described in more detail in *Box 2*.

BOX 2 Digital health intervention categories

Decision aids/self-management e-health programs:

1. 'mPATH', a novel iPad decision aid app program (mobile Patient Technology for Health) aimed at increasing uptake of colorectal cancer screening among low SES older people in North Carolina, USA.[31]
2. 'T-PeP' an e-learning program (theory-based, PP) developed for older adults to learn to use PPs to manage their health.[32]
3. Videos about accessing and using an online PP, aiming to increase digital health literacy in English and Spanish speakers of lower SES living in San Francisco, USA.[33]
4. 'URHealth' smartphone DHI developed and customised for people living with HIV in New York and New Jersey, USA.[34]
5. Unguided web-based DHI targeting complaints such as sleep problems, stress and worry (complaint-directed mini-interventions), with nurse-led facilitation for low SES people, in the Netherlands.[35]
6. A DHI with a web portal for older people in Quebec, Canada, which aimed to mitigate the digital divide through participatory-facilitated sessions.[36]
7. 'VOCALE', an online DHI promoting problem solving about health management (Virtual Online Communities for Older Adults in Louisville and Kentucky, USA).[37]
8. 'ehcoBUTLER', a multiuse digital platform with apps to help elderly people access the internet in order to improve their health, independence and quality of life.[38]

Table 1 Summary of included studies' settings, study designs and participants

Region/ settings	USA (n = 13)	Burkino Faso (n = 1)	Canada (n = 1)	Cambodia (n = 1)	Mexico (n = 1)	Multicentre (n = 1) Spain, Italy, Greece, the Netherlands, Slovenia, France, Serbia and Israel	The Netherlands (n = 1)	Philippines (n = 1)	Uganda (n = 1)	UK (n = 1)
Study designs	Qualitative (*n* = 9)		RCT (*n* = 8)	Mixed-methods (*n* = 3)		Cross-sectional (*n* = 1)		Pre–post single arm (*n* = 1)		
Participants	Older adults (*n* = 10), including: • Two studies with caregivers for older adults (mainly elderly themselves) • One study with low SES older adults • One study with older African Americans			Low SES adults (*n* = 6)		Adults in under-resourced settings (low- or middle-income countries) (*n* = 3)		Minority ethnic groups (*n* = 2)		Homeless adults (*n* = 1)

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9. 'Active Brains', a web-based programme to support dementia-protective behaviours in older people recruited from general practices in the UK.[39]
10. 'PREPARE for your Care', a multimedia interactive e-health tool for diverse older adults in San Francisco, USA, to increase their engagement with advance care planning.[40]

Text messaging interventions:

11. 'TEXT', a bidirectional text messaging for antiretroviral therapy adherence among non-urban substance users with HIV in Virginia, USA.[41]
12. 'TEXT', as above, but aiming to reduce the proportion of missed HIV clinic visits.[42]
13. A text message intervention for people diagnosed with HIV in Uganda.[43]
14. A self-management and text message program for adults with type 2 Diabetes mellitus targeted at low SES groups in Mexico City, Mexico.[44]
15. An app-based text messaging service aiming to increase physical activity among patients with type 2 diabetes and depression and lower SES backgrounds in San Francisco, USA.[45]
16. A text messaging intervention in Burkina Faso, which aimed to improve adherence to antiretroviral medication and retention to HIV clinics.[46]
17. A peer education text messaging program aiming to improve adherence to evidence-based treatment for people with diabetes and hypertension in Phnom Penh and four other rural districts in Cambodia, provided by MoPoTsyo, a Cambodian NGO.[47]

Telehealth interventions:

18. A care management programme for homeless veterans in Los Angeles, USA.[48]
19. A telehealth programme for older adults in rural areas of the Philippines.[49]
20. Web-based mobile health information interface for older African American patients and their doctors in Ohio, USA.[50]

Virtual assistants:

21. An embodied conversational agent community-based virtual health educator for older adults in San Jose, California, USA.[51]
22. 'VICKY' (Virtual Counselor for Knowing Your Family History), an animated computer character designed to collect detailed family health histories from a diverse, vulnerable patient population with low health literacy and low reading age in Boston, USA, with English- or Spanish-language versions.[52]

Design and deployment features likely to help reduce the digital divide

Design and deployment features that intended to reduce the digital divide were assessed for 'positive impact'. Examples of positive impact in the results reported by RCTs and mixed-methods studies included improvements in the knowledge or self-management of a health condition, including clinical measures such as glycated haemoglobin;[44] increased levels of lifestyle factors such as physical activity;[51] increased adherence to recommended treatment;[34] increased self-efficacy or patient activation measures;[34] increased, e-health literacy measures;[32–34] increased ability to use online PPs;[32] greater use of online training materials;[33,34] and higher satisfaction scores in intervention groups versus controls.[35]

Positive impact described in the qualitative studies and mixed-methods studies included participants mentioning aspects of the intervention that facilitated their use, such as in-person training, prompts and use of persona to design the DHI;[37] usability testing in which participants reported their acceptance and liking of the intervention,[40,53] for example quotes like 'the language was very easy to understand' and 'pictures made the visuals good and easier to understand';[40] Think Aloud interviews with positive feedback for DHI features that were easy to use, for example 'like turning a page of the book';[39] and feedback from participants in text messaging intervention studies, suggesting that they liked the intervention and found it to be acceptable.[40,41,53]

The results of the individual studies were synthesised into design and deployment themes to answer the two main objectives of the review. The themes are described below.

Design features

Design features with positive impact could be divided into three categories: involving end-users in the design process and in user testing of the DHI, tailoring the presentation/interface and content and using virtual assistants. These design features are shown in *Box 3* and described further in the section below.

BOX 3 Design features associated with positive impact

Involving end-users in the design process and in user testing:
- Co-creation with end-user and user testing/Think Aloud, e.g. information/self-help web portal (n = 3).
- Use of focus groups with target users when planning to design DHI/e-health interventions (low SES, minority ethnic group and chronic diseases) (n = 3).

Tailoring the presentation/interface and content:
- Interactivity, e.g. e-health tool which focuses on advance care planning (n = 1).
- Tailoring to low SES, low education or reading levels and options for translations (n = 3).
- Use of pictures/videos (n = 1).
- e-Learning self-help programme: how-to use module in the intervention, a moderated discussion board, virtual library and human support (n = 3).
- iPad decision aid/self-management learning programs delivered via video (n = 2).
- Telehealth care management programme with healthcare professional feedback (n = 1).
- Use of text messages, e.g. condition-specific/self-care programme (n = 3).

Using virtual assistants:
- Embodied conversational agent virtual adviser (n = 1).
- Virtual counsellor (n = 1).

Involving end-users in the design process and in user testing

The studies that involved end-users in the design process and undertook user testing with Think Aloud

methodology were viewed positively by the participants. For example, a diverse group of caregivers of functionally dependent older persons in Quebec, Canada, took part in a series of workshops to inform the design of a DHI to facilitate the process of help-seeking for older people. The authors found that participation of end-users of the DHI in the development of the tool was an integral part of the design process and that 'compliance with the desired eHealth literacy level, the help-seeking process, and cultural context, were integrated into the eHealth tool by the co-designers' discourse and, more importantly, by the caregivers themselves'.[36] For example, relating to the content of the DHI, one caregiver participant of a Think Aloud session conducted as part of the study was quoted, 'The text is very heavy. The first thing I would do is click on the video'. There was also a suggestion by caregiver participants that alternative versions of the information in a DHI should be provided for people who do not have access to the internet or devices: 'we need a paper version'.

Involving end-users in Think Aloud interviews to inform a prototype web-based 'Active Brains' for community-dwelling older adults in the UK was reported by the study's authors as having improved the usability of the intervention (a programme to support dementia-protective behaviours for older people). Participants gave feedback on the layout and usability of the intervention and made positive comments about the uncluttered web pages with only a few 'necessary buttons' were 'like turning a page of the book'.[39]

Tailoring

Greater levels of uptake and usage were seen in those studies that tailored content for low literacy levels/illiteracy through use of animations,[39] pictures,[34,38,44] videos[31,33,36,38,40] and writing for a low reading age.[31,40,49]

In a questionnaire study that recruited elderly participants in the Philippines, 'effort expectancy' was found to be the most likely influence on their future use of a telehealth intervention, suggesting 'elderly respondents are most likely to adopt Telehealth interventions if they experience no difficulty in using the system'.[49] The use of a touch screen interface, an uncluttered visual display, narrated content with feedback and verbal navigation commands built into the DHI's interface were found to enhance usability for older people in a study evaluating a novel iPad decision aid that was designed to increase the uptake of colorectal cancer screening among low SES older people.[31] Using large text and clear iconography was also found to improve readability for older people.[37] A clear layout was also recommended by older participants in a qualitative study using a web-based intervention to support dementia-protective behaviours.[35] For example, in a Think Aloud session, one participant in the study noted 'I immediately look at this page and find it untidy and as a, not a struggle, but as a barrier there to reading it clearly and understanding it. I'm struggling to find what to click to go to next'.

Virtual assistants

The use of virtual assistants to collect information from patients and guide use of DHI was received well by the two studies that tested them with older people. In the RCT of an embodied conversational agent (ECA),[51] use of the ECA led to greater increases in 4-month self-reported minutes of walking per in the virtual advisor arm (mean increase of 253.5 ± 248.7 minutes/week compared to the wait list control group's mean increase of 26.8 ± 67.0 minutes/week; $p = 0.0008$), and the intervention was rated as acceptable by participants [mean score of 5.7 out of 7 (±0.67) across the 19 program acceptability scale items]. In the RCT conducted with a diverse, vulnerable, older patient population with low reading age and low health literacy,[52] the participants randomised to the virtual counsellor were significantly more likely to complete a family history questionnaire compared to those randomised to a web-based questionnaire (97% vs. 51%; $p < 0.0001$) and were more likely to divulge sensitive subjects, such as alcohol use or addiction, than they were to genetics counsellors.

Deployment features

Deployment features that were found to improve uptake fell into four main themes: taking steps to improve access (to devices and/or internet); providing human support integrated into the deployment strategy for recruitment and use of the DHIs; digital skills training as part of the DHI delivery; and addressing trust issues. These features are summarised in *Box 4* and described in more detail below.

BOX 4 Deployment features associated with positive impact

Improving access:
- Providing internet access ($n = 1$).
- Providing devices ($n = 2$).

Human support:
- Training nurses to recognise and assist low SES patients ($n = 1$).
- Involving research assistants ($n = 3$).
- Peer/family support (especially for elderly people) ($n = 4$).

Digital skills education as part of the DHI implementation:
- Interactive group-based educational sessions ($n = 2$).
- Web-based training programme ($n = 4$).
- How-to videos on accessing and using an online PP; in-person tutorial more effective than self-guided link ($n = 1$).
- Information and communication technology training within the DHIs ($n = 3$).
- Tailoring education to low SES/low education or reading level and translations ($n = 2$).

Addressing trust issues:
- Text messages as a way of maintaining confidentiality (n = 1).
- Voice messages more likely to 'communicate trust' than text messages alone (n = 1).

Improving access

Two studies provided participants with free devices,[34,42] one of which was a text messaging intervention. The six other studies text messaging studies did not do this because they considered that basic mobile phone ownership was sufficiently widespread even in places with inconsistent cellular or internet service, as participants could usually receive text messages without difficulty.[41–45,47] However, the authors of one of the studies found that voice messages had the advantage of increasing accessibility for persons with limited literacy, vision and smartphone access.[47]

Human support

Increased access and use of DHI were seen if 'human support' was part of the implementation package, such as in one study in which nurses were trained to proactively identify lower SES patients so they could provide them with extra guidance and help.[35] Other studies used research assistants,[33,43,45] community centre staff or volunteers[51] and peer educators[34,38] to help with downloading apps, accessing the internet, setting up logins, using a DHI and for sorting out technical difficulties. In these studies, if participants needed further help (for example in one of the studies with virtual advisors, five participants in the intervention arm experienced minor difficulties, such as forgetting their login information or difficulties in printing out information) this was reported to need only a few minutes of staff time to sort out, because staff were on site.[51] In the study with older adults in the Philippines, participants said they were more likely to use a telehealth DHI if they had social support from family members.[49] Family support to use a DHI was also recommended by participants in a co-design study for a DHI for older people, incorporating Think Aloud and qualitative interviews.[36]

Digital skills education as part of the digital health intervention implementation

Other features that helped uptake and use, with positive impacts on the primary outcomes examined, included tailored digital skills education as part of the intervention,[32,37,44] for, in the RCT, which trialled a 3-week e-learning program that was developed to help older adults learn to use PPs to manage their health, the intervention group showed greater improvements than controls for outcomes relating to PP knowledge (p = 0.019) and self-efficacy (p = 0.003).[32]

Addressing trust issues

Trust issues were mentioned in the context of the two studies that examined text message interventions. Texts were seen as a way of maintaining confidentiality and contributed to DHI acceptance in a study conducted among people living with HIV in Uganda.[43] However, the use of voice messages was perceived by older people as more likely to 'communicate trust' than text messages alone in a peer education program delivered via mobile-based text messaging in Cambodia.[47]

Discussion

This review has synthesised the evidence available in the early days of the COVID-19 pandemic, when LWCR was being developed, regarding key strategies for optimising the design and deployment of DHIs to mitigate the effects of the digital divide. In summary, the findings suggested a two-pronged approach. Firstly, to use features that explicitly increase the motivation of people at risk of the digital divide to engage with digital devices, health information and services delivered online and through DHIs and to develop their digital literacy skills. Secondly, to improve the digital health literacy of the HCPs and administrative staff who are involved in implementing the use of any DHI in healthcare settings and to encourage and enable them to support people to register with and use a DHI as part of their 'treatment programme'.

Key findings

For the design of DHIs, a key finding of the review was that user involvement from the start is vital, preferably through co-design and user testing. This approach has been shown to improve health equity in research, and in the context of digital health, requires active collaboration between patients and researchers to make the intervention more user-friendly and acceptable.[12] The intervention itself needs to be culturally appropriate and available at a low reading age, with translations, if possible, and animations or video content to help with engagement and use by people with low literacy levels. Including tailored digital skills education as part of the intervention appeared to improve participants' digital skills.

Usability considerations described by the studies with older people can be extended to anyone with low literacy/digital health literacy. For example, Think Aloud evaluations with older people identified universal design solutions to make them easy to use, such as

uncluttered web pages, judicious use of colour, keeping text to a minimum, clear formatting and simplifying the interface.[35,37]

For the LWCR intervention, we used these findings to design the app and deployment strategy. We developed a range of user personas based on patients admitted to hospitals in London during the pandemic to ensure that people from different demographic groups would be able to use the intervention and to identify potential difficulties they might find. We then user-tested the DHI with PPI representatives and adapted it in response to their feedback over multiple iterations. The LWCR development journey is described in more detail in Blandford *et al*.[54]

For deployment, although some studies provided free devices, this may not always be an option for publicly funded health services, and certainly this was not an option for the LWCR study. However, we suggested clinics signpost patients to charities for free or low-cost devices and data, and to Digital Champions support, where available.

Many of the included studies made the point that mobile phone ownership is becoming widespread, so text messaging interventions can be useful as they do not need costly data or the infrastructure of fast and reliable internet access. Most impactful was 'human support', especially for older people. The studies that provided members of staff or peer supporters to help the patient with the technical aspects of using a DHI found this only required a few minutes of staff time if they are already on site.[51]

Staff may not have sufficient digital skills or confidence themselves, so digital skills training can help staff accept and implement DHI in healthcare services. Taking account of staff ways of working, skills and attitudes towards DHI is important for the successful implementation of DHI in healthcare services, as reported in our LWCR implementation substudy.[55]

If staff are not available to support users to use a DHI, a family member or partner can help, but older people are less likely to develop digital skills if they rely on family members.[47] These results suggest that there may be a role for community hubs where people can access support with digital technologies.

Strengths

This review is one of the first to examine how the design and deployment aspects of DHIs can be optimised to address the digital divide. Its strengths include the JBI methodology that we followed for the review,[27] which allowed us to assess the extent of the relevant literature. We developed a comprehensive and systematic literature search strategy, which was peer-reviewed by an information specialist, as recommended by Peer Review of Electronic Search Strategies guidelines.[56] In addition, four members of the team screened 25 test papers randomly selected from the initial hits, achieved high inter-rater reliability, and all decisions on the exclusion and inclusion of publications were taken at regular review team meetings.

Our findings align with the *Framework for Digital Health Equity*, published by Richardson *et al.* in 2022[57] and can be mapped on to the levels corresponding to steps that can be taken at individual, interpersonal, community and societal levels to improve digital health equity. The design considerations we identified map onto the individual level: tailoring the interface and usability to appeal to a diverse group of end-users, allowing people with low literacy/health literacy and low digital health literacy to use the DHI, as advocated by Veinot *et al.* in their 2018 paper,[20] which called for a 'universal precautions' approach to digital health literacy, including using plain language, visuals and minimising text-based input.

Deployment of DHI using 'human support', either through family or peer support or through healthcare staff, maps onto the interpersonal level of the framework. Healthcare professionals may need specific training to recognise individuals who need more support to use a DHI as part of their treatment map to the interpersonal level, but time needs to be built into consultations for explanations and clarification and to facilitate the means for patients to improve their digital health literacy, as suggested by Busse *et al.*[58] in their overview of approaches to improve digital health literacy in person-centred health care.

Virtual assistants deployed through local centres also fit with the interpersonal and community level, while enabling people to access free or low-cost devices and reliable low-cost data and Wi-Fi are examples of deployment mechanisms that map onto the community level (e.g. through charities or local libraries). Societal-level policies include interventions that enable low-income groups to access devices, data and training to develop digital skills and confidence.

Limitations

We acknowledge that our search extended to late 2021, and there has been a massive increase in the literature

regarding inequalities since the COVID-19 pandemic. However, we wanted to situate the review in the context of the LWCR DHI design and deployment and to report the results that informed this work. We also acknowledge that the fast pace needed to develop the LWCR DHI, and the need to make the intervention available for clinical use as soon as possible, meant that we had to be pragmatic in our consultation with stakeholders. We therefore limited this to presenting emerging, and final, results to members of the LWCR steering committee for validation and feedback. The steering committee members included HCPs, digital health experts and PPI representatives, but they were arguably less impartial than the larger group of independent stakeholders we had initially planned to consult.

The studies included in the review were heterogeneous, so generalisability may be limited. Most of the studies focused on elderly populations as opposed to lower SES or inclusion health groups, potentially due to 'societal' implementation barriers, with wider SES barriers being harder to tackle in a research study.

Only a few of the included RCTs assessed the impact of the interventions on digital health skills using validated measures, for example eHEALS.[59] The qualitative and mixed-methods explored participants' motivation to use the DHIs being evaluated, their satisfaction with the DHIs and facilitators that helped them use the DHIs rather than the DHIs' impact on participants' digital skills and confidence specifically.

Application of the review findings in the LWCR intervention

The results of this review were critical for the success of the LWCR study at a time of great need: the early days of the COVID-19 pandemic. Its findings informed the iterative design and implementation of the intervention, helping the LWCR developers and study team take steps to mitigate the digital divide by incorporating the review's recommendations into the design of the LWCR programme. Co-design with, and user testing by, PPI representatives led to the patient-facing app being more usable and acceptable. Findings also helped the intervention's deployment into clinical practice. For example, clinic staff provided human support to introduce the LWCR DHI to patients and to check in with patients by in-app messaging. Trusts also provided access to devices as needed and signposted patients to help with digital skills.[60] Beyond benefitting the LWCR programme, these results have wider implications for designers, policy-makers, practitioners and researchers. We need to take 'universal precautions' to enable equitable access and use of DHIs by a diverse range of people.

Implications and recommendations for developers of digital health interventions, policy-makers, commissioners, clinical practitioners and researchers

Although the findings of this review were informed by a relatively small number of studies, they reinforce the persuasive argument for following the 'universal precautions' approach suggested by Veinot *et al.*[20] Where possible, developers, commissioners and providers need to consider these precautions for reducing the digital divide in the development and deployment of DHIs through their design and as part of their implementation in healthcare services.[20]

For developers, the recommendations are to co-design DHIs with a diverse group of end-users from the outset and throughout if feasible by using iterative cycles of user testing and redesign so that the product is acceptable and usable for the end-users. In the design, culturally and linguistically adapted content should be made available. User testing can ensure the DHI has clear navigation, with easy-to-read content that uses plain language. Using animation, visuals, such as pictographs, and minimal text can help users with low literacy. The functionality of the interface can support users to improve their digital skills. Further help can be included by signposting to external resources, for example human support or virtual assistants from the outset, with the assumption that any end-user may need support to use the DHI.

Our recommendations for commissioners and providers of healthcare services are to include criteria for digital services and products through the procurement process such that they avoid introducing or worsening health inequalities and include mechanisms to mitigate the digital divide. Equity impact assessments are one way to ensure that new services meet the needs of diverse groups, and these can be used by organisations that commission DHIs.[61]

For clinicians, we suggest an assumption from the outset that patients will need digital literacy support to use healthcare DHIs. Pragmatically, where funds allow, this help could come from non-clinical staff such as administrators or staff in social prescribing roles, given that healthcare professionals are likely to have less time within time-limited consultations to help with these aspects personally. Providing human support, or peer support, to help patients subject to the digital divide to, for example download apps to their devices and to sign up to the DHI,

will be more effective than just signposting them to other services, for example for digital skills training. Factoring in additional staff time for this help represents a hidden cost of using some digital technologies and should be included in any service cost calculations.

Recommendations for researchers are to include in their digital health research people who are likely to be subject to the digital divide. Participants' digital skills and confidence should be assessed by validated measures at baseline and follow-up, not just usage and acceptability measures. Design and deployment aspects of DHIs need to be evaluated to investigate how these considerations can improve digital literacy and mitigate the digital divide.

Conclusions

The COVID-19 pandemic worsened existing health inequalities and shone a light on the digital divide. Since then, there has been an acceleration of plans to move to a default 'digital first' delivery of health care, and there has been a corresponding increase in the number of publications reporting the results of research studies focusing on strategies to mitigate the digital divide. We have presented a summary of these strategies, with a particular focus on features of DHI design and deployment that are conducive to improving access engagement for people from demographic groups likely to be affected by the digital divide.

Additional information

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BOX 5 The LWCR collaboration

Co-Investigators

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Data-sharing statement

To request access to the underlying research data, please contact Dr Fiona Hamilton at f.hamilton@ucl.ac.uk.

Ethics statement

Ethical approval was not required for this systematic scoping review. The main research project which this review informed (reference NIHR132243) received ethical approval from East Midlands – Derby Research Ethics Committee (reference 21/EM/0160); IRAS ref: 288199 – on 23 July 2021.

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Disclosure of interests

Full disclosure of interests: Completed ICMJE forms for all authors, including all related interests, are available in the toolkit on the NIHR Journals Library report publication page at https://doi.org/10.3310/GJHG1331

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List of supplementary material

Report Supplementary Material 1
Table 1: Inclusion and exclusion criteria

Report Supplementary Material 2
Table 2: Included studies by DHI type and date published

Supplementary material can be found on the NIHR Journals Library report page (https://doi.org/10.3310/GJHG1331).

Supplementary material has been provided by the authors to support the report and any files provided at submission will have been seen by peer reviewers, but not extensively reviewed. Any supplementary material provided at a later stage in the process may not have been peer reviewed.

The supplementary materials (which include but are not limited to related publications, patient information leaflets and questionnaires) are provided to support and contextualise the publication. Every effort has been made to obtain the necessary permissions for reproduction, to credit original sources appropriately, and to respect copyright requirements. However, despite our diligence, we acknowledge the possibility of unintentional omissions or errors and we welcome notifications of any concerns regarding copyright or permissions.

List of abbreviations

DHI	digital health intervention
ECA	embodied conversational agent
HCP	healthcare practitioner
HIV	human immunodeficiency virus
LWCR	Living with COVID Recovery
PP	patient portal
PPI	patient and public involvement
PROMs	patient-reported outcome measures
RCT	randomised controlled trial
SES	socioeconomic status

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