

Annual Review of Public Health

Multilevel Determinants of Digital Health Equity: A Literature Synthesis to Advance the Field

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Annu. Rev. Public Health 2023. 44:383–405

First published as a Review in Advance on December 16, 2022

The *Annual Review of Public Health* is online at publhealth.annualreviews.org

<https://doi.org/10.1146/annurev-publhealth-071521-023913>

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Keywords

digital health, health equity, social determinants of health, health technology

Abstract

Current digital health approaches have not engaged diverse end users or reduced health or health care inequities, despite their promise to deliver more tailored and personalized support to individuals at the right time and the right place. To achieve digital health equity, we must refocus our attention on the current state of digital health uptake and use across the policy, system, community, individual, and intervention levels. We focus here on (a) outlining a multilevel framework underlying digital health equity; (b) summarizing

five types of interventions/programs (with example studies) that hold promise for advancing digital health equity; and (c) recommending future steps for improving policy, practice, and research in this space.

INTRODUCTION

Digital health is now foundational to both public health and medicine, given that online and mobile platforms are central to accessing public health information and resources as well as the delivery of health care services (2). Because of the diffusion of digital approaches in all aspects of health, we use a broad definition of digital health for this article: “Digital health connects and empowers people and populations to manage health and wellness, augmented by accessible and supportive provider teams working within flexible, integrated, interoperable and digitally-enabled care environments that strategically leverage digital tools, technologies and services to transform care delivery” (90).

Within the field of digital health, there are disparities in both uptake and effectiveness of tools and platforms, with a range of evidence across settings and conditions (58, 78). More specifically, new innovations or programs can exacerbate underlying health disparities, as outlined in the “inverse care law,” which describes how well-resourced individuals are better positioned to be aware of and take up these interventions before less-resourced individuals, thereby widening gap(s) in health outcomes (48). This reality is misaligned with the goals of health equity, and it also reduces our ability to make a population-level health impact with digital health tools because it limits the reach of platforms to individuals and communities who might otherwise benefit the most (82). Thus, centering digital health equity as a primary goal within the field is critical to interrupting this cycle and reframing how we design, implement, evaluate, and spread digital health tools (32).

This article has three objectives to advance digital health equity: (a) to outline what is known about the current state of digital health access and use among marginalized populations across critical levels of influence (policy, system, community, individual, and intervention), (b) to focus in on five sets of interventions that hold promise for addressing disparities across these domains, and (c) to generate a set of future recommendations for public health and health care researchers and practitioners.

OUTLINING A MULTILEVEL FRAMEWORK FOR DIGITAL HEALTH EQUITY

We review here key literature and statistics that shape the current state of digital health use and existing barriers. We focus primarily on the United States within this summary, given the specific policy, organizational, and social structures in place, but believe the evidence also extends easily to other high- and middle-income nations worldwide. To outline the multiple levels of influence on digital health equity, we were guided by the socio-ecological model and the technology acceptance model to frame the evidence (21, 61). More specifically, we expand here on evidence within five levels of influence that have been consistently linked to digital health disparities: policy/structural drivers, system-level influences (such as public health and health care settings), community/social factors (such as the role of family and friends as well as community-based organizations), individual influences (such as skills and motivation), and finally the characteristics of the digital platforms themselves (such as usability and accessibility).

Policy and Structural Determinants

At the most foundational level, societal structures and policies are key determinants of digital health disparities. These structures influence digital health equity and the potential reach of digital health tools by limiting implementation, dissemination, and access to technology in already marginalized communities. In 2021, nearly 1 in 4 Americans still did not have home access to high-speed (specifically broadband) Internet connections, and nearly 1 in 6 Americans still did not own a smartphone, with clear inequities by income, age, and race/ethnicity (75). Even among those with a home broadband connection or a smartphone, about one-quarter worry about being unable to afford their Internet and cell phone bills over the next few months (60). For those who rely on federal assistance to access critically needed smartphones, the significant technical shortcomings of the Lifeline program—which provides low-income individuals with discounts on voice or broadband Internet service—including poor service coverage and limited monthly minutes, limit the usefulness of the program for the millions of Americans who could benefit (80).

In addition, in the United States there are no current federal regulations in place to prevent preferential installation of fiber broadband by Internet service providers only in high-income communities, thereby limiting access to high-speed Internet needed in low-income communities. This practice is known as “digital redlining” and parallels twentieth-century US federal, state, and local housing policies that mandated racial segregation (68). As health care delivery increasingly relies on digital tools requiring access to high-speed Internet, digital redlining ultimately limits care access and exacerbates health inequities in communities with already poorer health outcomes. For example, one recent study found that limited Internet access in communities was associated with higher rates of COVID-19 mortality (51).

Recent policy efforts have increased focus on expanding access to high-speed Internet for all Americans, most notably through the Affordable Connectivity Program, a long-term \$14 billion federal program for discounted broadband and computing devices enacted under the Infrastructure Act of 2022 and through renewal of a federal waiver for expanded eligibility of the long-standing Lifeline program. However, these policy mechanisms rarely link broadband or other Internet service provision directly to health initiatives or health care service delivery (80), even though digital access is clearly a foundational social determinant of health. Even more broadly, linking the policies involving determinants of health, such as utilizing a “health in all policies” approach (81), might better connect the concepts of digital access, inclusion, and health in the future.

Systems-Level Determinants

To achieve digital health equity, there must also be health care and public health system investment, given how critical these systems are in supporting individuals and communities in managing their health. Within these settings, digital equity requires availability of resources and a robust technical infrastructure. However, capacity within publicly funded systems to drive digital innovation varies; for instance, settings such as safety net health care and social services are least likely to have the digital infrastructure and staffing to support digital health innovation and/or implementation (70, 99). Collectively, these public health and health care systems are the most likely to serve marginalized communities in the United States, such as individuals with low income and those from racial/ethnic and linguistic minority groups (19, 40). As was brought to light during the COVID-19 pandemic, there is severe underinvestment in public health throughout the United States (16, 29), with clear needs for digital supports such as electronic data sharing between public health and clinical settings, digital communication with the public, and advanced technologies to support disease monitoring and reporting. Similarly, many public and community-based

health care systems were unable to leverage more sophisticated features of their electronic health records (EHRs) and other data systems to respond to the pandemic (43), resulting in disparities by socioeconomic status and race/ethnicity in the uptake of critical digital health care services such as video-based telemedicine encounters (1).

System-level funding barriers in the private health care sector can also drive digital health inequities. For example, private funding of digital health companies (e.g., mobile apps, devices/wearables) has grown exponentially within the past decade, up to a \$1 trillion investment, yet there are stark differences in which type of digital health products are brought to market and which entrepreneurs receive funding. Entrepreneurs of color and those developing digital platforms to support complex medical and social needs continue to receive smaller portions of funding (3, 64); for example, Latinx- and Black-founded companies account for only 2% and 1.3% of overall start-up investments, respectively (97, 100), compared with overrepresentation among white and Asian founders.

In addition to having sufficient funding and infrastructure, public health and health care systems require leadership and culture that support innovation to achieve digital health equity (87). For example, health system leadership must jointly prioritize health equity and innovation to achieve digital health equity. Metrics for innovation success often do not include an equity perspective, such as digital implementation of new platforms or services without clear goals for uptake among domains such as race/ethnicity, language proficiency, or age (50, 71, 88). Lack of coordination between health equity leaders and digital or innovation leaders can impede progress toward digital health equity (23, 54, 55, 88).

Finally, local skills to develop and implement digital approaches vary widely among health and health care systems. To pursue digital health equity, the frontline workforce must be adaptable and receptive to changes in workflow that come with new digital tools. Because digital tools often support ongoing work (such as in-person visits or service provision), it is vital to redesign workflows when improving existing digital infrastructure to get the most value from implementation (87). If properly integrated into routine practice, digitally enabled workflows can help health systems maximize efficiencies, enhance the quality and safety of services, and improve care coordination. To complement these workflows, reimbursement and incentives from payers to support and reinforce this work must also be aligned (95). Implementation gaps can arise when skills or support for developing workflows is insufficient—and this is particularly true in settings that serve marginalized communities who might need additional time and/or support to take up digital platforms.

Community-/Social-Level Determinants

At the next level, social relationships clearly influence the success of digitally enabled health and health care interventions (94). This domain is built on decades of public health research that documents social influences on the effectiveness of any intervention or program (8). Furthermore, it cannot be overstated that community and social factors play a particularly important role in reducing health inequities (102). Trust is essential for achieving digital health equity because societal structural barriers and historic injustices have specifically eroded trust for many communities, underscoring the need for all digital health programs and interventions to focus on trustworthiness and usefulness within their work, which are deeply rooted in social connections and context (15).

At the most foundational level within this community/social domain, there is a need to better understand how communities prioritize digital health platforms and programs to support health and wellness. It is critical to codevelop digital health solutions with marginalized communities often excluded from digital health research or implementation (12, 25), starting with designing for topics that are most relevant for these communities. Because digital health programs are often

attempting to optimize or enhance existing resources or services, it is critical to ensure that digital platforms are viewed from the outset as acceptable, important, and timely (106).

Next, even after the design is complete, social influences have a clear role in establishing both awareness of and trust in the digital health platform. At a local level, many community-based organizations are critical to spreading any health program within their communities (69), and these groups should be considered as core partners in the digital health ecosystem. For example, community-based organizations are intricately tied to health and wellness within specific neighborhoods or racial/ethnic or cultural groups, and digital health programs that build from these existing relationships will be much better positioned to make an impact (46, 67).

Finally, considering one-on-one interpersonal interactions within this domain, there are multiple relationships that influence both the use and the effectiveness of digital health solutions. The supportive accountability model helps to define how coaches and other supporters improve digital intervention adherence through trustworthiness, benevolence, and expertise (62), ranging from technical support to emotional support to expert support. Existing literature has considered the broad (but often overlooked) impact of caregivers on health outcomes and has provided additional evidence on the importance of loved ones in learning or trying new digital programs. This research also extends beyond family and friends: Evidence supports the role of trusted health care relationships [such as doctors and clinicians (66, 109), community health workers (74), or peers (31)] in recommending or assisting with health interventions. Therefore, any assumptions or descriptions about digital health solutions replacing in-person programs should be more appropriately framed as blending human and digital support to achieve the greatest impact while also improving reach and efficiency (47).

Individual-Level Determinants

At the individual level, there is more extensive behavioral research on digital health use and effectiveness. An individual's access to devices and data/Internet, as described above, is a core driver of digital health equity, given their foundational influence on who is able to take advantage of digital services and communication. Yet even with universal access to digital devices and data, abilities and motivational components at the individual level must also be considered (21); these include skills, usefulness, and acceptance of digital health tools (28).

One core aspect within this domain is the skills needed to use digital tools and platforms. UNESCO defines digital literacy as "the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital devices and networked technologies for participation in economic and social life" (4). This definition includes both cognitive and technical skills, and digital literacy is core to overall adoption of digital health interventions (10, 26). As stated above, when individuals are socially connected, they may also experience greater ease of use and fewer barriers to uptake from a support network (20, 37).

The usefulness of any digital health tool is also impacted by an individual's motivation. Individuals with worse health status who are unable to get their health needs addressed through other means may have greater motivation and interest in using digital health tools (72, 76). Health literacy (aside from digital literacy) can also impact whether individuals gain as much utility from using a digital health tool. For example, individuals with lower health literacy experience greater challenges when they seek and use online health information (7, 24, 59, 107); therefore, even if the user has adequate digital literacy skills, limited health literacy can impact the usefulness of a digital tool (108).

Individual acceptance of the digital tool is also affected by factors beyond ease of use and usefulness. One important factor is trust in the digital tool developer or whoever is recommending the digital health tool (13). Adoption of digital health tools, such as patient portals, is affected

by clinician recommendations and trust in individuals' primary care clinicians (56). Studies have found that, beyond trust, concerns about the privacy and security of personal data vary among individuals (45), especially when it is unclear where data are stored and who has access to the data.

Digital Health Intervention-Level Determinants

At the final level of influence, several features within the digital platforms themselves can support broader use across diverse end users. From the outset, it is critical that digital health products leverage approaches to ensure language and literacy accessibility in their platforms. For example, there is a dearth of digital health apps in either iOS or Android formats that are available in fully translated versions to support non-English-speaking populations (65, 79). Furthermore, clear guidelines for improving the readability of content should be adopted, such as writing text at less than a sixth-grade reading level and complementing written text with audiovisual features to support comprehension (11, 52).

Digital tools must also be straightforward and usable. Many users report feeling overwhelmed by the time it takes to review large quantities of health information as well as to vet the varying quality of health information and apps (93). In addition, the number and complexity of digital health platform features vary, from employing basic tools such as one-way text messaging, to engaging in conversations with chatbots that employ artificial intelligence and machine learning algorithms, to using wearables or apps to collect data about user behavior and/or to track health behaviors. These levels of complexity may themselves present challenges to uptake among certain populations, especially if they require active data entry or engagement from users (83).

Relatedly, many existing digital health features have not been explicitly designed to be usable for people with lower levels of digital literacy. Typically, the more features that a platform has, the more difficult it is for users of all background literacy levels (health and digital) to use (83). Therefore, it is crucial to integrate inclusive design methods that emphasize equity, simplicity, tolerance for error, and scaffolding approaches (107). Similarly, digital design must be completed in different digital environments and devices as well as for varying levels of Internet speed and availability. Identifying user needs and abilities to shape digital interventions can greatly increase their relevance in people's lives (53).

KEY INTERVENTION EXAMPLES TO ADDRESS DIGITAL HEALTH EQUITY DETERMINANTS

Given these existing multilevel influences on digital health equity, there are many components to consider when planning a public health or health care digital intervention to support inclusive and equitable uptake and effectiveness. Although addressing all levels of influence in each digital intervention or program may not be possible, previous work provides insights on how best to develop, implement, and evaluate digital health interventions across more than a single level of influence. In this section, we present evidence from both the peer-reviewed literature and the gray literature that centers around five major types of interventions or programs to advance digital health equity:

1. Interventions that employ digital health codesign to advance equity in usability, uptake, and/or effectiveness of digital health platforms;
2. Interventions that provide individual-level digital literacy support or training as a core program component;
3. Digital programs that leverage community/social relationships to support use;
4. Systems-level implementation of digital interventions or programs, specifically within safety net settings; and

5. Policies/programs that addressed structural barriers to digital health interventions, such as broadband access or devices.

The examples within this section are also summarized in **Table 1**. The included studies (*a*) utilized a multilevel digital intervention and/or implementation approach, (*b*) focused explicitly on health equity within the study population/setting or the digital intervention or program itself, and/or (*c*) employed novel or rigorous methods/processes that increased the generalizability of the work.

Interventions/Programs that Employ Digital Health Codesign to Advance Equity in Usability, Uptake, and/or Effectiveness of Digital Health Platforms

Digital health interventions need to be designed with the communities they hope to help and to meet real needs. Content experts have important knowledge (such as clinical or technical expertise), but users are experts in their own lives and on how to integrate digital tools with their ongoing needs and preferences. Codesign methods jointly conceptualize and develop digital products driven by the expertise of end users as well as those involved in their care, such as family members and health care staff (73). Codesign and user-centered design have parallels with community-based participatory research and other community-engaged methods that have been implemented more broadly (12).

Multiple examples from the published literature have outlined codesign work focused on marginalized and excluded communities (**Table 1a**). For example, one study partnered with community members to design a smartphone app to collect user experience related to walking and the built environment, with an explicit goal of feeding these data back to decision makers for consideration in evaluating possible community improvements (14). Other examples of codesign include studies outlining the longitudinal and iterative process of assessing feedback from users about both the content and early prototypes/features of digital health platforms, including the mix of traditional and design methods with an explicit focus on cultural relevance in all phases of work (41). Despite the imperative for participatory codesign in digital health, effectively engaging in the work is not without challenges. It requires strong community partnerships that take time to develop. It is also important to address cultural mismatches between developers and community organizations/users in the way each addresses problems (98).

These studies also present clear recommendations for the field. For example, studies often need to engage in more than a year of formative design and development to achieve relevant tools when working with people with limited health and digital literacy (6). In addition, codesign approaches must evolve in ways that match the experiences of underserved and marginalized populations. Methods that require abstraction and verbal communication (often linked to formal educational exposure) may not be relevant for all populations or studies (35). For example, open brainstorming is a common task to help users generate rank intervention content and methods based on preference; however, users with limited health literacy, English proficiency, and digital literacy sometimes have difficulty with the method (71).

Interventions that Provide Individual-Level Digital Literacy Support or Training as a Core Program Component

Another type of intervention with success in addressing digital health equity involves explicitly focusing on digital literacy skills through training or support programs. Many of the studies in this section (**Table 1b**), which focused on training programs, were small and delivered to a specific patient population (e.g., older adults or inpatients within a hospital setting).

Table 1 Example studies addressing digital health equity

Study	Study setting	Primary objective of digital platform/intervention	Study design/outcome(s)	Key findings/lessons for digital health equity
a. Interventions/programs that employ digital health codeign to advance equity in usability, uptake, and/or effectiveness of digital health platforms				
Papoutsi et al. 2021 (73)	Nationwide in the United Kingdom	Compare codeign in three case studies	Workshops with patients as well as providers to obtain feedback on tools. Pilot testing.	Case studies highlighted importance of codeigning technology alongside clinical practices and organization routines.
Brewer et al. 2020 (12)	African American churches in Rochester and Minneapolis-St. Paul, Minnesota, USA	Engage the community to develop a general health app	CBPR: Community members involved in the mixed-methods study design to incorporate community members in intervention development. FAITH! Partners designated to refine recruitment, implementation, and results dissemination.	Co-design process: Leveraged established stakeholders and trusted social networks, focused on understanding the social context of potential end users, integrated community engagement throughout, and gained an understanding of community partner's technology infrastructure.
Buman et al. 2013 (14)	Three senior, low-income housing sites in South San Francisco, Menlo Park, and San Mateo, California, USA	Develop and evaluate the utility of a computerized, tablet-based participatory tool designed to engage older residents in identifying neighborhood elements that affect active living opportunities	Formative testing. Participants used the tool to record common walking routes and geocoded audio narratives and photographs of the local neighborhood environment while navigating their usual walking route.	Tool was found to complement other assessments and can assist decision makers in consensus-building processes for environmental change.
Jackson et al. 2022 (41)	Prince George's and Montgomery counties, Maryland, USA	Design a prevention-focused, personalized mHealth, information-seeking smartphone app that is culturally appropriate and acceptable	One-year, multimethod participatory research process that engaged English-speaking African American and bilingual or Spanish-speaking Hispanic adults.	Community partnerships provided the chain of trust that helps Black, Indigenous, and people of color (BIPOC) participants feel comfortable participating in app research. CBPR principles yielded promising results to engage these populations in digital health research. Interactive design sessions uncovered participants' needs and development opportunities for digital health tools. Multiple design sessions with different methods provided an in-depth understanding of participants' preferences and needs.
Avila-Garcia et al. 2019 (6)	Safety-net hospital, San Francisco, California, USA	Inform development of text-messaging intervention to encourage physical activity	Focus group and individual interviews with English- and Spanish-speaking patients to integrate user feedback into intervention design.	Key barriers to use (pain and depression) were identified and addressed in the intervention, alongside technical requirements.
Nouri et al. 2020 (71)	Public-sector urban primary care clinics, San Francisco, California, USA	Assess relevance of user-centered methods for diverse patient pool	Semi-structured interviews, coding, and card sorting.	Engagement in design methods varied by digital and health literacy. Augmentation of card sorting with direct observation and audiovisual cues may be more productive in eliciting feedback for those with communication barriers.

(Continued)

Table 1 (Continued)

Study	Study setting	Primary objective of digital platform/intervention	Study design/outcome(s)	Key findings/lessons for digital health equity
Unertl et al. 2016 (98)	United States and Canada. Projects using CBPR	Case analysis of five studies implementing CBPR in health informatics work	Examined each case individually for success factors and barriers and identified common patterns across cases.	CBPR projects resulted in more relevant products that match community need. Challenges persist, including longer time frame and mismatch in style and culture.
b. Example studies that provide individual-level digital literacy support or training as a core program component				
Hoffman et al. 2020 (38)	Boston, Massachusetts, USA	Identify digital resources for hospitalized patients with serious mental illness to increase wellness, make informed decisions about apps, and use apps and data for behavior change	Exploratory group evaluation of apps culminating in the development of two training manuals.	Wide range of starting digital skills. Group training required flexibility to meet participants at current digital literacy level. Training can increase perception of the importance of using digital tools to access health information and increase confidence in finding health information online.
Lyles et al. 2019 (57)	Safety-net clinics, San Francisco, California, USA	Increase patient portal enrollment	Pre- and postevaluation of effectiveness of in-person training versus Web-based videos about patient portal navigation.	Both in-person and Web-based videos were better than no training. However, nearly 80% did not log in after training, suggesting a need for very intense training or significant improvement in usability of patient portals.
Watkins & Xie 2014 (103)	NA (review article)	Studies aiming to increase eHealth literacy	Systematic review. Collaborative learning and tailored content developed on the basis of NIH materials (both in person and Web based).	Review paper highlighted that there are few evaluations of health outcomes, few theory-based interventions, and few experimental study designs.
Lee et al. 2014 (49)	NA (review article)	Studies aiming to increase the ability to find reliable health information (workshops most common approach)	Review of in-person and Web-based trainings, both group and individual sessions.	Overall effort of workshops/trainings increased self-reported knowledge and/or skills.
Stein et al. 2018 (91)	King County, Washington, USA	Evaluate an intervention that teaches hospitalized patients at a safety net hospital how to access and use their EHR online portal	RCT of in-person patient portal education during admission involving registration, login, navigation of website, and review of discharge summary.	Education/training was effective at increasing portal use.
Fields et al. 2021 (30)	San Francisco, California, USA	To assess barriers to and facilitators of technology training implementation	Pilot involving community-based organization to evaluate the impact of technology training on older adults' loneliness, social support, and technology use in real-world settings.	Embedding training within existing community-based programs showed promise as a potentially sustainable mechanism to provide digital training to isolated older adults.

(Continued)

Table 1 (Continued)

Study	Study setting	Primary objective of digital platform/intervention	Study design/outcome(s)	Key findings/lessons for digital health equity
National Health Services, Widening Digital Participation, 2017 (92)	England, United Kingdom	Three-year program provided seed funding to (a) establish 20+ projects focused on specific patient populations in each community; (b) create a portal to promote digital skills (Learn My Way) and use of digital tools to promote health (Staying Healthy); and (c) support predigital skills	Help those without digital skills to access health information and support online. The program aimed to put the individual in charge of their health, with a long-term aim to also relieve pressure on frontline health services.	Projects reached 285,000+ people and specifically 53,000+ improved their digital literacy. 83% who used the digital skills portal reported feeling more confident about using online tools to manage their health; 33% who completed training reported fewer primary care visits. Governments can support widescale dissemination and innovation through establishing standard curriculum and collaborating with community-based organizations to reduce overall costs.
c. Example digital health studies leveraging community/social relationships to support use				
Nguyen et al. 2021 (69)	Community-based organizations, San Francisco, California, USA	Development of a digital health search/referral platform to connect community members with resources in their neighborhoods	Qualitative study focused on user needs and requirements for a digital health platform.	Community organizations are essential for tangible resource connections as well as overall social support and trust. Digital platforms must enhance existing human knowledge of community assets/needs.
Heisler et al. 2019 (36)	Urban VA clinic, Detroit, Michigan, USA	Peer coaching intervention for diabetes management, with versus without digital tool	RCT with glycemic control as primary outcome measure. Assessments at baseline, 6 months, 12 months.	Peer coaching was critical for improving outcomes, including detailed documentation of coaching implementation. Digitally enabled coaching may need longer-term use in future studies.
Roddy et al. 2022 (77)	Urban academic medical center and community clinics, Nashville, Tennessee, USA	Text messaging intervention to support diabetes management, with a specific subintervention that engaged family/adult supporters	Secondary analysis of RCT, with glycemic control as the primary outcome measure.	Family/adult support mediated the improvements in diabetes control postintervention. Future studies are needed to tease apart these influences.
Holt et al. 2019 (39)	African American churches in Metro DC area, USA	Evaluate and compare Web-based versus in-person peer coaching for preventive health behaviors	RCT evaluating cancer-related knowledge and screening behaviors between groups.	No significant differences in cancer knowledge or screening rates at 24 months by group were noted. Web-based coaching was as effective as in-person coaching, but process measures by arm were not reported.
Handley et al. 2021 (34)	Safety net settings, San Francisco Bay area	Examine fidelity and acceptability of coaching intervention by language of participants (English versus Spanish speakers)	Secondary analysis of RCT data to determine how in-person and digital support might have varied by participant demographics.	Intervention had high overall engagement and acceptability of coaching, with no differences in modality by participant language. Study emphasized importance of having a clear analytic plan to examine implementation outcomes based on the modality of coaching (digital versus in person) and key participant demographics.
d. Example studies focusing on systems-level implementation of digital interventions or programs, specifically within safety net settings				
Watkinson et al. 2021 (104)	England, United Kingdom	Measure system-level acceptance of health information exchange (HIE) and understand barriers to/facilitators of adoption	Mixed-methods study to examine differences in acceptance between user groups and care settings.	Social care users had lower acceptance and adoption. They also lacked the resources to properly use the HIE system.

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Table 1 (Continued)

Study	Study setting	Primary objective of digital platform/intervention	Study design/outcome(s)	Key findings/lessons for digital health equity
Velázquez et al. 2020 (10)	Safety net system, Boston, Massachusetts, USA	Rapid implementation of telepsychiatry to meet care needs for diverse patient population	Implementation study outlining change management processes used to implement services.	Multiple departments engaged to create patient-focused implementation. Core domains focused on during the intervention included people, process, technology, monitoring, environment, and equity.
California Health Care Foundation innovation fund, 2011 (17)	California, USA	Philanthropic investment program to specifically fund private-sector digital health companies with the potential to improve care quality for Medicaid patients	By 2021, the fund's portfolio served more than 5 million Medi-Cal enrollees at more than 250 hospitals and 100 clinics in California. Portfolio companies experienced an average 115% annual revenue growth.	It is vital and feasible to use capital investment for supporting private companies working in the Medicaid market.
Barnett et al. 2017 (9)	Los Angeles safety net hospital	Decrease wait time to see a specialist	Examine growth, usage, and outcomes of eConsult system implementation.	Rapid growth in eConsult use was shown within this study, resulting in decreased wait times to see a specialist. Health systems and plans partnered to solve a high-priority problem, achieving early implementation before more well-resourced settings.
Aulakh & Maguire 2021 (5)	Safety net systems nationwide	Provide guidance for safety net leaders and providers to improve digital health care services via innovation approaches	Learning collaboratives and peer learning for innovation are successful strategies for innovation in safety net settings.	Shared learning models across sites and settings (health care, community-based organizations) can increase impact. Phased implementation and support (technical assistance, training, networking) are critical.
Lyles et al. 2014 (54)	Safety net systems in California	Qualitative study of safety net leaders, focusing on drivers of innovation implementation	Examples of successful innovations alongside unique contexts for implementation.	Safety net leaders emphasized their approaches to centering equity and addressing highest priority topics, rather than supporting too many programs/pilots.

(Continued)

Table 1 (Continued)

Study	Study setting	Primary objective of digital platform/intervention	Study design/outcome(s)	Key findings/lessons for digital health equity
e. Example studies of programs that addressed structural barriers to digital health interventions, such as broadband access or devices				
Gujral et al. 2022 (33)	Rural USA	Assess the association between increased distribution of tablets during the COVID-19 pandemic and mental health service use and related outcomes	Retrospective cohort study. Loaned iPads to rural US Veterans from March 2020 to April 2021. Compared outcomes 10 months before tablet receipt and 10 months after tablets to controls.	Tablet distribution increased mental health care use, reduced suicidal behavior and ED visits. Findings are particularly relevant for rural veterans already engaged in mental health care.
Zulman et al. 2019 (110) Jacobs et al. 2019 (42) Sligham et al. 2020 (89)	Nationwide in the VA, USA	Evaluate implementation of tablet distribution to high-need veterans with health care access barriers	Retrospective cohort study. 2016 VA pilot distributed video-enabled tablets with 4G wireless or Wi-Fi to veterans with access barriers. Evaluated outcomes of tablet adoption and reach, as well as barriers to and facilitators of tablet use for telehealth.	Zulman et al. 2019: 80% of patients who received tablets used them; those who were older and who had fewer chronic conditions were less likely to use the tablets. Facility-level barriers to implementing the tablet program included staffing shortages and lack of staff training. Sligham et al. 2020: Lack of digital skills and poor Internet connection among patients in the study were associated with lower preference for video visits. Jacobs et al. 2019: Study demonstrated time and money savings for patients who live far away from the VA, have travel barriers, and do not have mental health diagnosis.
Whealin et al. 2017 (105)	Rural areas of the Pacific Islands	Evaluate veterans' perceptions of home therapy for PTSD through video-enabled tablets	VA pilot of tablets and secure Wi-Fi for home treatment of PTSD. Pre- and post-engagement questionnaire.	It is feasible to use tablets to deliver treatment to rural veterans of racial/ethnic minority ancestry; some patients still had privacy and connectivity concerns.
Davis et al. 2016 (22)	USA	Understand technical needs to support veterans after distribution of tablets for telemental health services	Assess workload and productivity of PTC in providing technical support to veterans. Survey veterans and providers during and after telemental health program treatment about the PTC's role.	For veterans with diverse digital literacy skills and mental health care needs, robust technical support is needed for successful use of devices and telehealth technologies. PTC should be a full-time contract employee to increase the availability of technical support.
Schueler et al. 2019 (84)	Homeless shelter network located in Chicago, Illinois, USA	Evaluate feasibility and acceptability of a remotely delivered mental health intervention with brief emotional support and coping skills training among young adults experiencing homelessness	Single-arm feasibility pilot trial, prepost intervention evaluation. Participants received mobile phone, service/data plan, one month of coaching. Assess session and program completion and acceptability based on satisfaction ratings.	The intervention demonstrated high rates of program completion and satisfaction among participants but little change on prepost measures of depression, PTSD, and emotion regulation. Study showed it is feasible and acceptable to provide technology-based mental health services to young adults experiencing homelessness.

(Continued)

Table 1 (Continued)

Study	Study setting	Primary objective of digital platform/intervention	Study design/outcome(s)	Key findings/lessons for digital health equity
Kazewman et al. 2021 (44)	Ontario, Canada	Improve access to primary care, adherence to public health directives, and adherence to self-isolation guidelines during COVID-19 pandemic	Provide free donated and prepaid cell phones to patients without a listed phone number who presented for care at the ED during COVID-19 pandemic. Protocol paper for pilot mixed-methods study, no data reported.	Study findings related to health outcomes are not yet available. Study design highlighted the importance of documenting the number and type of approach attempts to improve patient access to health care, information, and social services.
Moczygemba et al. 2021 (63)	Austin, Texas, USA	Assess the accuracy, acceptability, and outcomes of a GPS-mHealth intervention to alert community health paramedics when people experiencing homelessness were in the ED or hospital	Prepost design with assessments at baseline, one month, two months, three months, and four months post-enrollment.	There is limited accuracy for alerts from ED/hospital alerts back to community paramedics. Digital intervention showed decrease in depression symptoms and improved medication adherence among patients, demonstrating that cell phone provision can help individuals with complex medical needs and who are experiencing homelessness.
Chih et al. 2020 (18)	Appalachia (rural USA)	Better understand the landscape of connected cancer care management in rural America	Framework and proposed program to improve telehealth-enabled cancer care for rural America.	This program demonstrates the need for community-based participatory approach for human-centered design of digital cancer care, with foundational digital access at the core.

Abbreviations: CBPR, community-based participatory research; ED, emergency department; EHR, electronic health record; GPS, global positioning system; NA, not applicable; NIH, National Institutes of Health; PTC, peer technical consultant; PTSD, post-traumatic stress disorder; RCT, randomized controlled trial; VA, Veterans Affairs.

Despite the limited number of these studies, the example studies highlight a few key points. First, both health care organizations and community-based organizations can conduct trainings successfully. However, trainings conducted by community-based organizations tend to focus more broadly on digital health skills (30, 38, 92), whereas health care systems (and most interventional research studies) have focused primarily on increasing skills to access specific digital health tools (such as a patient portal or mobile health application) (57, 91).

The modalities with which training is delivered also vary, including Web-based videos or more intense in-person, one-on-one or small-group training (103). Studies have found all these modalities to be somewhat successful at increasing confidence and digital literacy for at least some of the participants; however, many studies have suggested that a large proportion of individuals need more intensive hands-on support to increase their digital literacy to a level where they can access digital tools.

Among studies focused on health platforms, digital literacy efforts have focused primarily on the use of patient portals, mobile health applications, or Web searches for online health information (49, 57, 91, 103). Very few studies have evaluated the impact of training on improving health outcomes or on long-term impacts of training, though some have shown some improvement in self-reported health behaviors (e.g., finding health information, using digital tools to engage with clinical team).

Digital Programs that Leverage Community/Social Relationships to Support Use

Because of the important role that social connections play within communities with regard to the awareness, use, and ultimate effectiveness of digital health programs, there is also a growing body of work that implements and evaluates a digital health intervention within social contexts (86). In many cases, these studies document processes and measure outcomes at an individual patient or community member level, as well as processes and outcomes that are specific to the caregiver or environment/setting in which the digital program or intervention was conducted. This work is critical to advancing our understanding of how we will blend digital and human support in future digital programs within public health and health care settings.

Table 1c documents studies from a range of community- or caregiver/provider-supported digital health platforms. Overall, these studies demonstrate the wide range of research on this topic: understanding community-based organization assets related to chronic disease management prior to developing a digital health resource platform (69), utilizing digital platforms to support peer coaching in clinical and community settings (36, 39), designing parallel text messaging programs to support both patients and caregivers/loved ones (77), and explicitly evaluating the implementation of digital and in-person support within an intervention (34). All the studies demonstrate—using either quantitative or qualitative results—that digital programs can be better tailored and/or easily delivered by leveraging implementation assistance from important social and interpersonal relationships.

However, the studies are less clear with regard to the generalizability of this work, given that there is wide variation in what type of social relationship was engaged (e.g., family versus peer coach versus community organization) and the specific approach to implementation (e.g., starting with in-person support and then adding human follow-up or vice versa, what pieces of the intervention required in-person support). Additional attention will be needed to tease apart the influence of the in-person/human support from digital support, given that we know how effective in-person support can be on health outcomes and are often striving to reduce the intensity of in-person support within digital programs.

Systems-Level Implementation of Digital Interventions or Programs, Specifically Within Safety Net Settings

Safety net health systems and public health settings are essential when implementing digital platforms to advance health equity. In **Table 1d**, we enumerate some example health system innovations that shed light on digital health equity. First, we present several examples of successfully implemented programs such as telepsychiatry/telemedicine (101) and the eConsult system (9), which demonstrate how aligned incentives and a focus on team-based workflows are essential. In addition, there are examples of private-sector initiatives (17) that demonstrate the importance of focusing on system-level investment (e.g., private investment into digital health companies working on products for the Medicaid market) to bridge the equity gaps in available products and tools. Finally, evidence from studies or collaboratives across multiple safety net settings demonstrates differences in local priorities and the need to engage frontline staff and adapt implementation as relevant (5, 54, 104).

Overall, these studies demonstrate that stakeholder engagement (such as through collaboratives, with a mix of frontline staff plus leadership) is a core element of bringing a digital health tool into wider use at the system level and is not a process that is done once or at the end of rolling out a new platform or solution. These examples also provide evidence that safety net and public settings face unique barriers to consider during implementation, such as the need for support/technical assistance to stand up digitally enabled services that work within their existing staffing and digital infrastructures. And finally, we must leverage the vast expertise within safety net settings, given that they have long-standing relationships in many marginalized communities and have centered equity within their health programs for many years (55).

Policies/Programs that Addressed Structural Barriers to Digital Health Interventions, such as Broadband Access or Devices

A growing amount of literature has documented the provision of broadband and Internet-enabled devices within health or health care programs; key studies are summarized in **Table 1e**. The most robust studies in this space are from the US Department of Veterans Affairs (VA), which delivers health care to 9 million veterans in the United States, one-third of whom live in rural areas with limited access to in-person care. Throughout various waves of a nationwide VA connected care program, provision of video-enabled tablets increased access to both medical and mental health care (33), but barriers persisted, such as the lack of digital skills, a need for technical support, and a need for improved Internet connectivity (22, 42, 89, 105, 110).

Providing smartphones with data plans is another strategy to help improve access to care. One pilot program demonstrated modest success with this strategy to facilitate the use of a mental health app-based intervention among youth, though data limits were a key obstacle for participants (84). Among adult populations, one recent study described the prescription of smartphones in the emergency department during the COVID-19 pandemic with no health outcomes reported (44); another pilot program distributing smartphones to adults experiencing homelessness found limited impact of smartphones on care coordination but increased empowerment for self-management activities in this population (63, 96).

Finally, there are no studies to date that assess the direct impact of broadband or other Internet service provision on health outcomes. In 2017, the Federal Communications Commission (FCC) convened a public-private partnership with the National Cancer Institute to bridge the broadband health connectivity gap in Appalachia through the LAUNCH (Linking and Amplifying User-Centered Networks through Connected Health) initiative in order to improve

cancer-related health care and symptom management, though no health or outcomes data are available yet (18, 27, 85).

RECOMMENDATIONS FOR THE FIELD

In summary, digital health equity necessitates a multilevel understanding of how policy, systems, community, individual, and intervention factors interact. A summary of the multilevel determinants of digital health and associated interventions to reduce inequities is shown in **Figure 1**. While many barriers impede the ability for all individuals to take up and effectively use digital health tools and services, known strategies for advancing and centering equity can be replicated and spread. It is critical for practitioners and researchers to move beyond a single level of influence to implement programs and interventions that target foundational aspects of digital health equity, such as community codesign utilizing inclusive principles, digital skills/literacy training and interpersonal support, and implementation approaches that both reflect real-world practice within safety net and public settings and ensure universal access to devices and data/Internet.

Moving forward, the work to date also indicates recommendations for advancing the field of digital health equity. First, much of the work presented here was often completed within a specific discipline, such as clinical research or public health practice. Future work must break down silos between fields as well as ensure a broader definition or focus on overall health, not specific to a single disease or health behavior. Designing or implementing equitable digital health programs

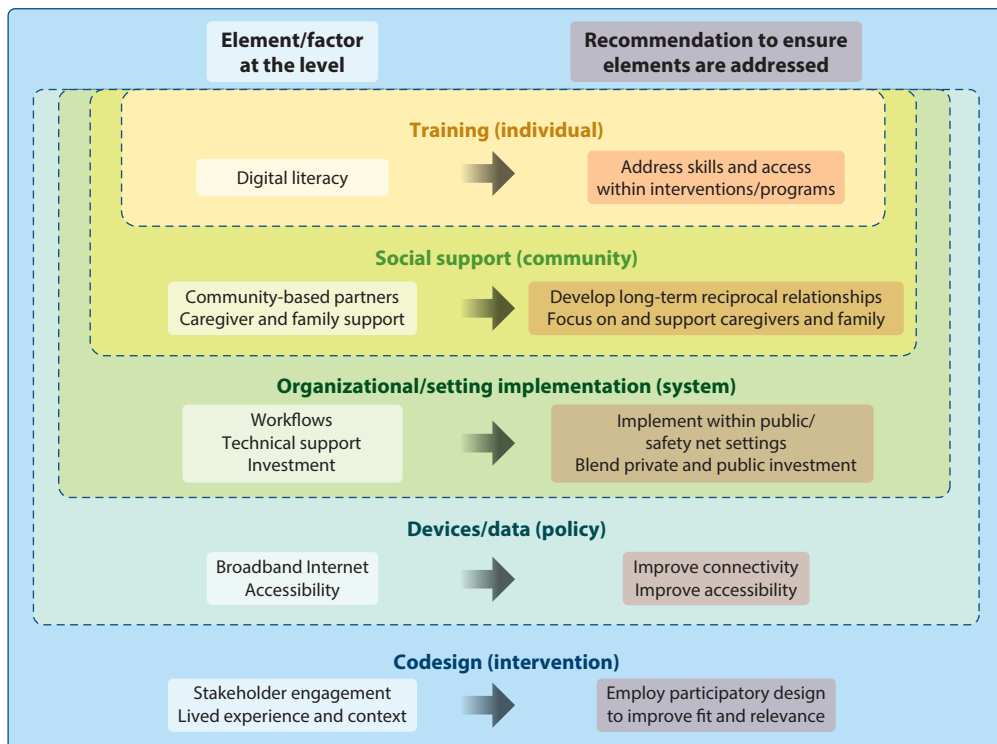


Figure 1

(Left, white boxes) Element/factor at the level. (Right, pink boxes) Recommendation to ensure elements are addressed. Dotted lines represent porous relationship (e.g., training feeds back into social support, social support feeds back into systems, systems feeds back into policy).

also requires both broad and deep stakeholder engagement. For example, stakeholders must be identified in health care, community, public/social service, and other sectors to generate better synergy in our work. In addition, the deep community-based partnerships and input from community members must be invested and supported over the long term, not on a project-by-project or transactional basis.

Second, to generate true impact, we must also utilize implementation approaches and generate real-world evidence from the outset. Because we know that digital health often involves new ways to deliver existing health education or support/services and evolves very quickly as technology changes, we cannot rely on traditional program evaluation or research approaches alone. Instead, we must consider both the process of implementing digital health (particularly in public and safety net settings) alongside the effectiveness of digital health services and programs. This implementation focus will better allow us to understand key steps, such as evaluating (a) who will take up the digital program as it is rolled out; (b) how care providers, coaches, or others are involved in the program, and what their roles are in promoting or using the technology; and (c) what the barriers are to adoption and spread across the entire implementation process.

Finally, centering equity in digital health will require new measurement approaches and standards. We will not succeed in understanding and addressing digital health gaps unless we collectively measure and report on key equity domains. This process will involve research studies and programs defining and reporting on digital access, such as devices and Internet at home; skills and interest, such as comfort in using digital platforms without assistance as well as trust in digital services/tools; and participant demographics, such as language or race/ethnicity, to monitor specific subpopulations that have been historically and are presently excluded from many digital health programs to date.

All of us will use digitally enabled health and health care programs in the future, and this work can advance equity if we explicitly focus on the multifactorial drivers of digital health use and then spread strategies that center engagement among marginalized individuals, communities, and systems.

DISCLOSURE STATEMENT

The authors are not aware of any affiliations, memberships, funding, or financial holdings that might be perceived as affecting the objectivity of this review. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health (NIH).

ACKNOWLEDGMENTS

The authors thank Marika Dy for her support with project management, data collection, and presentation of results. C.R.L. is funded by a University of California–San Francisco/Genentech career development award, and by a Center for Diabetes Translational Research grant from the National Institute of Diabetes and Digestive and Kidney Diseases (P30DK092924). E.C.K. is supported by a career development award from the National Heart, Lung, and Blood Institute (K23HL157750).

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