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GLOBAL HEALTH: SCIENCE AND PRACTICE

2018 | Volume 6 | Supplement

www.ghspjournal.org

Digital Health and Health Systems of the Future

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Global Health: **Science and Practice** (ISSN: 2169-575X) is a no-fee, open-access, peer-reviewed journal published online at www.ghspjournal.org. It is published quarterly by the Johns Hopkins Center for Communication Programs, 111 Market Place, Suite 310, Baltimore, MD 21202. The journal is made possible by the support of the American People through the United States Agency for International Development (USAID). The Knowledge for Health (K4Health) Project is supported by USAID's Office of Population and Reproductive Health, Bureau for Global Health, under Cooperative Agreement #AID-OAA-A-13-00068 with the Johns Hopkins University. GHSP is editorially independent and does not necessarily represent the views or positions of USAID, the United States Government, or the Johns Hopkins University.

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Front cover: Mobile phone users in Kolkata, India. © 2018 Avishek Das, Courtesy of Photoshare

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EDITORIAL

Digital Health and Health Systems of the Future

Alain Labrique,[a] Lavanya Vasudevan,[a,b,c] Garrett Mehl,[d] Ellen Rosskam,[e] Adnan A. Hyder[a]

Digital strategies have been formally recognized as a critical health systems strengthening strategy to help meet the Sustainable Development Goals and universal health coverage targets. This landscaping collection reviews multiple possible approaches across health system pillars, from digital referrals to decision support systems, identifying key knowledge gaps across these domains and recognizing the growth needed in the field to realize its full potential.

FROM MHEALTH TO DIGITAL HEALTH

Over a decade ago, the emergence of mobile phone networks across the globe presented a novel opportunity for rapid improvement in global health. Although health system challenges were not important drivers of this global mobile network proliferation, the public health and clinical community rapidly recognized the potential of mobile phones to tackle many immense challenges experienced by health systems, including early diagnosis, access to care, and equitable provision of services.[1] This technology revolution soon became recognized as a way to connect health workers to the people they serve; capture health information, even in hard-to-reach areas; and compress the time between a crisis and an appropriate response.[2] As is discussed in the opening article of this special issue, the past 10 to 15 years have been characterized by different periods in the evolution of the emergent field of "mHealth"—the common term used to describe mobile phone technologies used in public health or clinical medicine—or digital health, which is our preferred term.

Initially a wide field of discordant experimentation, in the past 5 years digital health has seen an unprecedented convergence on a shared vocabulary,[3] common tools, and, importantly, principles to guide the selection, implementation, and evaluation of digital innovations. Inspired but also frustrated by the 'wild west' character of mHealth innovation, atypical alliances of donors, innovators, governments, and the private sector have emerged in support of common objectives. These alliances and innovations were principally driven by the need to and importance of investing limited human and financial resources into solutions that have value and are robust, scalable, and able to be evaluated. Two key resources were developed to guide digital development and investment: the Principles for Digital Development[4] and the Digital Investment Principles.[5] While innovations have been piloted in low- and middle-income countries, concerns about high-income country dominance of digital innovations, inequitable use of and access to digital health technology, and ethical issues related to digital health data remain and continue to be discussed and worked on nationally and globally. The number of digital health programs scaled to the national and subnational levels is growing quickly,[6] with many countries integrating mobile tools into routine programs to strengthen reporting or boost community health worker performance.

DIGITAL HEALTH RESOLUTIONS AND GUIDANCE

As we noted previously,[7] in the early days of mHealth, there was limited enthusiasm and financial support to measure the impact of these interventions through rigorous assessment. The digital exceptionalism that may have colored this early period has since been greatly reduced while, at the same time, a healthy evidence base covering many facets of digital health has grown. To support the development and dissemination of high-quality digital health research, in 2016 the World Health Organization (WHO) mHealth Technical Evidence Review Group published new guidelines[8] and a toolkit[9] to help improve and standardize research and reporting of mHealth in the literature.

In May 2018, at the 71st World Health Assembly, WHO member states unanimously endorsed a

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In May 2018, WHO member states unanimously endorsed a resolution for governments to recognize the importance of digital systems for facilitating health systems strengthening and achieving universal health coverage.

resolution on digital health[10] that states governments must recognize the importance of digital systems for facilitating health systems strengthening and achieving universal health coverage. The resolution underscores the need to "ensure that digital health solutions complement and enhance existing health service delivery models," strengthen already integrated patient-centered health services, contribute to improving population health and gender and health equity, and address the lack of research and evidence on the impact of digital health on public and clinical health.[10] The resolution identifies coordinated, systematic, and evidence-based approaches that WHO, with member states and the broader ecosystem of partners, will need to prioritize to ensure that the full potential of digital health can be realized.

The landmark June 2018 WHO digital health guidelines development meeting and soon-to-be-published guidelines on digital interventions for health systems strengthening[11] mark a turning point in the digital health ecosystem by addressing another important convergence in the discourse in health systems strengthening and digital health innovation: the consolidation of the evidence-base in the form of global recommendations.

EXAMINING THE LITERATURE

In this special issue of *Global Health: Science and Practice*, we present 6 articles that explore the ever-growing overlap between health systems and digital health, with each paper led by experts in these 2 domains. Supported by the Aetna Foundation, teams of researchers and practitioners in these often-intersecting domains were asked to use their respective lenses and knowledge of the literature to explore and present an overview of state-of-the-art evidence that illustrates how digital health is being leveraged to address health system constraints across each of the WHO health system building blocks.[12] Beyond describing key successes, the authors were also asked to identify important roadblocks, such as nascent policy and stewardship architecture, to help guide digital health investments in most low- and middle-income countries. In short, the authors were asked to reflect on key research, policies, and funding priorities within that particular building block.

Labrique et al.[13] begin the series by summarizing the key milestones marking the journey from the early mHealth pilot studies to the emergence of the digital health ecosystem in 2018. The latter focuses on investments being made in shared resources and the creation and support of a necessary enabling environment for scaling up digital health innovations. The authors assert that greater, concerted investments must be made in the extrinsic ingredients required for digital health scale-up, from establishing national technical standards to bolstering electrical and communications infrastructures at the proverbial last mile, rather than lamenting the fact that so many demonstration projects have failed to thrive. Despite the failures of many pilots, they have, to their credit, generated and continue to develop confidence in novel strategies and solutions. Once tested, however, these innovations need extrinsic enabling systems to allow them to grow and flourish. Frost et al.[14] build on this theme, exploring the centrality of ministries of health in digital stewardship. Drawing from the literature on successes in policy and leadership, they provide guidance on stewardship responsibilities and the institutional structures and goals needed to meet them.

Meessen[15] shifts the conversation to the health system's second building block—health care financing—to explore resource generation, resource pooling, and health services purchasing. Using an exciting 'flash consultation' approach to poll a global community of implementers, the authors illustrate how digital tools are being leveraged to accomplish these goals using current, real-world examples while also cautioning the reader about the dearth of robust evidence in this space. From innovations in provider selection to smart contract execution and enforcement, Meesen covers the latest innovations and next steps for this domain.

A scoping review of digital technologies that focus on the health workforce, led by Long, Pariyo, and Källander,[16] assesses current applications in low- and middle-income countries, covering not only the state of the evidence but also the best practices and a research agenda for this space. This team of authors brings many decades of work with community health workers to the table to discuss one of the most researched areas of digital health in health systems strengthening. Through this review, they identify important gaps in best practices and standardized guidelines, which will help lead implementers and governments to develop appropriate digital workforce solutions.

Finally, 2 articles take on the dual aspects of health service delivery—separately tackling digital innovations that target the providers of care (supply-side focus) and the receipt of care (demand-side, client focus). Together with digital health colleagues at WHO, Gibson et al.[17] review

the state of digital demand-generation interventions, highlighting emerging trends in this space. They identify subtleties in the literature that suggest that the contextual tailoring of behavioral interventions by addressing message 'dose,' prevalence, and timing may be crucial to program success. Orton et al.[18] update Agarwal et al.'s[19] foundational review of mHealth and health worker interventions to include key service delivery research. They identify substantial continuing gaps in current research related to the effectiveness of interventions on health outcomes, improvement in health system efficiencies for service delivery, and the human capacity required to implement and support digital health strategies at scale.

CONCLUSION

As described earlier, digital strategies have been formally recognized as a critical strategy to help meet the Sustainable Development Goals and universal health coverage targets. As such, this landscaping collection reviews multiple possible approaches, from digital referrals to decision support systems, identifying key knowledge gaps across these domains and recognizing the growth needed in the field to realize its full potential. Strengthening the digital strategy evidence base is crucial, as it provides the necessary support to convince investors and risk-averse governments to invest in this solution space. Across all 6 articles in this supplement, key areas for research, investment, and evidence generation are highlighted, providing a road map for resource allocation in digital health moving forward. An important objective of this series was to identify the 'big unanswered questions' that may further the interdisciplinary meeting of health systems strengthening and digital health. The entropy and chaos of the early days of digital health is rapidly decreasing, guided by strong leadership, clear visions, and key investments in 'global goods.'[20] With measured optimism, we see the coming decade continuing the trend of thoughtful experimentation, planning for scale and sustainability, and cooperation.

Funding: This work was made possible by a grant from the Aetna Foundation, with support from the World Health Organization and The Johns Hopkins University Global mHealth Initiative.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of The Johns Hopkins University, Duke University, or the World Health Organization.

Competing Interests: None declared.

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Strengthening the digital strategy evidence base is crucial, as it provides the necessary support to convince investors and risk-averse governments to invest in this solution space.

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Cite this article as: Labrique A, Vasudevan L, Mehl G, Rosskam E, Hyder AA. Digital health and health systems of the future. Glob Health Sci Pract. 2018;6(suppl 1):S1-S4. https://doi.org/10.9745/GHSP-D-18-00342

GLOBAL HEALTH: SCIENCE AND PRACTICE
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COMMENTARY

Establishing Standards to Evaluate the Impact of Integrating Digital Health into Health Systems

Alain Labrique,[a] Lavanya Vasudevan,[a,b,c] William Weiss,[a] Kate Wilson[d]

The key milestones in the rise of digital health illustrate efforts to bridge gaps in the evidence base, a shifting focus to scale-up and sustainability, growing attention to the precise costing of these strategies, and an emergent implementation science agenda that better characterizes the ecosystem—the social, political, economic, legal, and ethical context that supports digital health implementation—necessary to take digital health approaches to scale.

INTRODUCTION

The rapid and global growth of mobile phone use in the last decade has enabled health system and development innovators to leverage digital health strategies in low-resource settings to alleviate persistent health system challenges. From supply chain management to frontline health-worker training, digital strategies have demonstrated varying degrees of promise. Despite the pervasiveness of these digital innovations, there has been rampant criticism of limited evidence to support their effectiveness.[1] Numerous systematic reviews have been conducted with the same conclusion—the available evidence is of low-to-moderate quality and rigorous methodologies are needed to evaluate digital health strategies in low-resource settings.[2] Despite this evidence deficit, global stakeholders' interest in implementing and scaling digital health strategies in these settings remains strong.[3,4] In this commentary, we summarize the key milestones in the rise of digital health, illustrating efforts to bridge gaps in the evidence base, a shifting focus to scale-up and sustainability, growing attention to the precise costing of these strategies, and an emergent implementation science agenda to better characterize the necessary ecosystem of scale—the social, political, economic, legal, and ethical context that supports digital health implementation.[5] We also identify key remaining gaps in the evaluation of digital health interventions to support their integration into health systems at scale.

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DISCORDANT PROLIFERATION: "PILOTITIS" AND FRUSTRATION

In the early years of the mobile phone revolution, between about 2005 and 2010, the digital-health landscape was populated by numerous small-scale demonstration and pilot projects across low-, middle-, and high-income countries.[6] The focus of these limited-scale 'proof-of-concept' initiatives was often simply to demonstrate concept feasibility, with little consideration of what might be required to scale-up the intervention. Moving from hundreds of users or data points to millions requires technical capacity that is large enough to withstand the load of national-scale use, attain and maintain economic sustainability, and achieve interoperability with other systems. While the pilot approach successfully accelerated the introduction of technology and pace of innovation, and resulted in unprecedented global awareness and interest in the implementation of digital health strategies, it also led to the development of predominantly stand-alone systems that provided limited evidence on their impact on health systems. The now infamous diagram (Figure 1) of mobile health (mHealth) pilot projects in 2010 in Uganda shows the number and spread of potentially redundant digital health investments. At the time, there was little coordination or planning or means of sharing information between projects; the figure, thus, illustrates the state of disarray that was likely across most countries involved in digital health experimentation in the early 2010s. In Uganda, this situation led to a moratorium on digital health projects, as the Ministry of Health worked to strengthen the coordination of information and communications technology (ICT) investments being made by international nongovernmental organizations and to sharply reduce potentially duplicative efforts in this space. Other important factors that may have contributed to these failures include the lack of local technical

resources and capacity within the government to absorb these programs. Around this same time, global efforts to align and standardize information systems were led by the now-closed Health Metrics Network—a global partnership focused on widening the traditional scope of disease-centric information systems to broader national health systems monitoring and building country capacity for data-driven decision making.[7]

SCRUTINY AND RECOGNITION OF THE NEED FOR RIGOROUS EVIDENCE

Between 2008 and 2013, Free, Cole-Lewis, Tamrat, Whittaker, and several others performed pragmatic reviews of the scant literature in mHealth, which highlighted (1) substantial variability in the quality and completeness of published findings and (2) inadequate descriptions of interventions' technologies, modes of delivery, and doses.[8–14] While these authors lamented the lack of robust research designs being used to measure impact, some questioned whether alternative evaluation strategies based in qualitative science might be more appropriate at earlier stages of mHealth development. Questions also arose as to whether the randomized controlled trial (RCT) itself is the appropriate gold standard to measure efficacy of rapidly evolving digital health technologies.[15]

As the lack of evidence to support digital health strategies became evident through these reviews, United Nations organizations, international nongovernmental organizations, unilateral and multilateral donors, and research institutions began advocating for use of rigorous evaluation methodologies for this new field. One of the first major responses was the development of the Bellagio Statement on eHealth Evidence following a high-level meeting of experts in 2011.[16] The statement cautioned that "to improve health and reduce health inequalities, rigorous evaluation of eHealth is necessary to generate evidence and promote the appropriate integration and use of technologies."[16] A similar caveat was noted by participants at a landmark workshop the same year on mHealth evidence hosted by the U.S. National Institutes of Health: "In a healthcare system already burdened with suboptimal outcomes and excessive costs, premature adoption of untested mHealth technologies may detract from, rather than contribute to, what is needed for true overall health improvement."[15]

Early review of mHealth literature revealed considerable differences in the quality and completeness of published studies and the technology described within them.

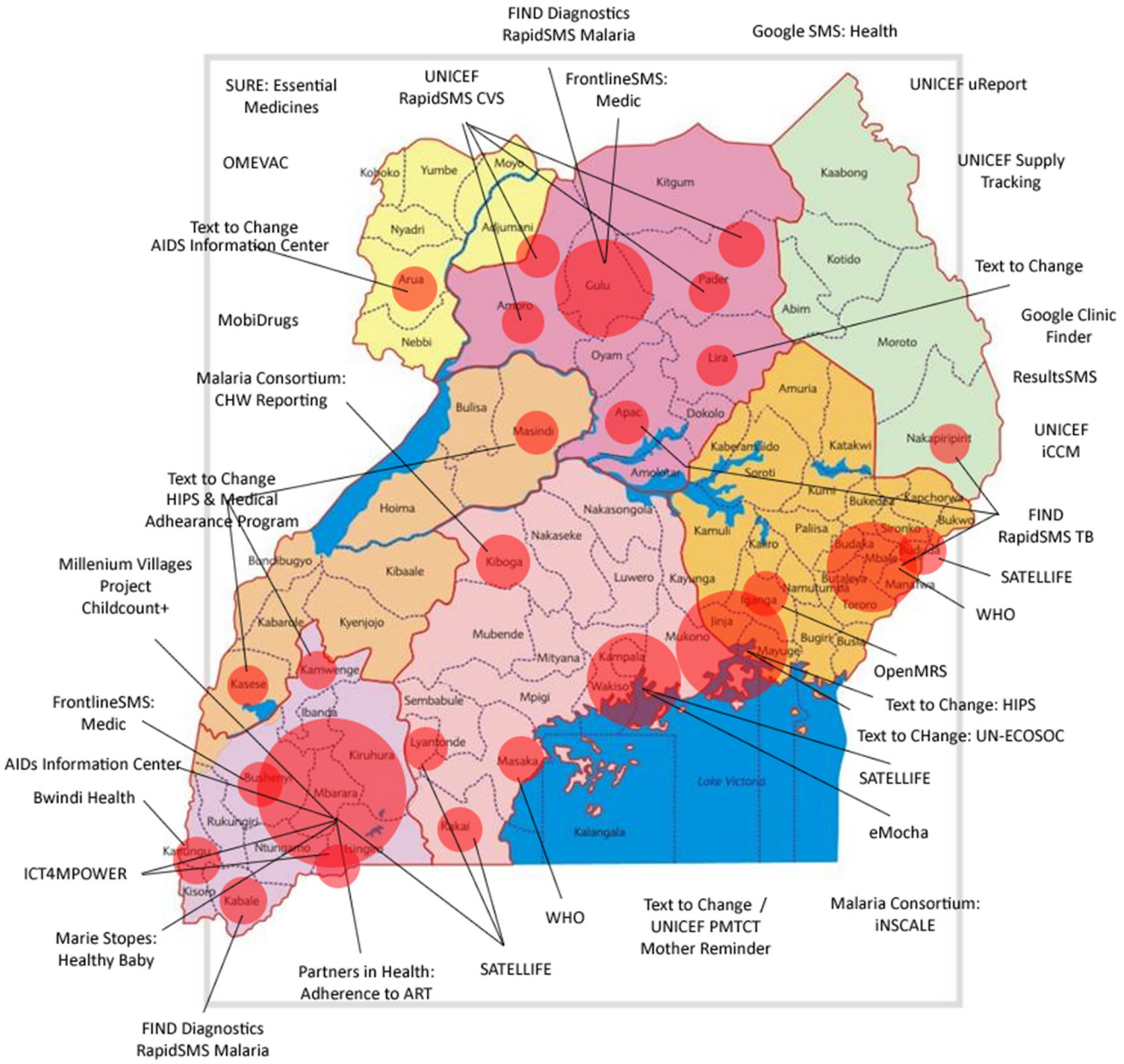
Among the earliest strategies to undergo stringent evaluation were RCTs of mobile phone short message service/text messages to improve adherence to antiretroviral drugs. These first rigorous studies by Lester et al. and Pop-Eleches et al. remain among the most cited in this field (>800 and >600 times, respectively), illustrating the value of methodologic rigor to influence policy.[17,18] A 2013 systematic review recognized that RCTs in this complex, emergent space had to be augmented by mixed-methods research to adequately understand contextual factors that influence the digital strategy's implementation efficacy across populations.[19] About 20% of the sources considered in the review were drawn from the non-peer-reviewed literature, highlighting the risk of publication bias that could limit the availability of research in a rapidly growing, novel field. Even in this early stage of understanding, the importance of context on the efficacy and impact of intervention was clear, highlighting themes that would re-emerge 5 years later to dominate the digital health conversation.

In 2013, Tomlinson et al. published a sharp critique of the field, noting the identification of hundreds of mHealth studies demonstrating little known efficacy or effectiveness.[1] They underscored the generally poor quality of research and the lack of a unifying language or framework to guide this space. That same year, Johns Hopkins University researchers published a review of the state of evidence in this space, noting that numerous examples of high-quality research exploring the efficacy of digital interventions were being developed, including those using accepted, rigorous methods of evaluation, such as RCTs.[20] Several systematic reviews of digital interventions have been published since, corroborating the increasing volume of high-quality evidence.[10,21,22]

DEVELOPMENT OF COMMON FRAMEWORKS

As efforts to generate and synthesize evidence in digital health grew, a unifying language to classify digital health investments became necessary. In late 2010, WHO convened the mHealth and Technical Evidence Review Group (mTERG; 2011–2014), whose first task was to develop a detailed taxonomy for adoption by the digital health community.[23] The absence of a standardized language with clear definitions of technologies, channels, services, and, most importantly, the combination of technologies to accomplish a health system process, or digital health strategy, made it very difficult to analyze and synthesize emergent literature. Further complicating matters, donors and

FIGURE 1. Map of Digital Health Pilot Projects in Uganda in 2010



Source: Sean Blaschke, UNICEF, written communication, May 2016.

governments could not differentiate projects using different terms to describe their work, which led to duplicative investments. Because innovators did not work together or share experiences or resources, projects often "reinvented the wheel."

The "12 common applications" (or building blocks) framework,[24] from WHO, the United Nations Children's Fund (UNICEF), the Johns Hopkins Bloomberg School of Public Health, and frog Design, is among the most widely used to describe projects in the emerging field of mHealth; it focuses on innovations that leverage mobile devices as a core component of its strategy. Since August 2013, the publication

The "12 common applications" framework focuses on the health system challenges digital technologies aim to address.

describing this visual framework has been downloaded over 56,000 times and cited 172 times. Building on a structure initially proposed by Mechael in 2010, this framework draws focus away from the technologies and toward the health system challenges they address.[25] This framework was an effort to help digital health programs communicate the value of their innovations; to reduce duplicative efforts, as had happened in Uganda; and also to recognize that digital strategies should be considered health system process catalysts focused on overcoming constraints. This reframing, away from using technology for technology's sake, was useful for shifting attention to how digital tools could improve the quality or coverage of interventions of known efficacy. The goal of evaluations, therefore, the authors argued, should be less focused on health outcomes—such as vaccine-preventable morbidity or mortality—and more focused on the processes optimized by the digital catalyst, such as vaccine coverage or timeliness. As illustrated in Figure 2, WHO promoted a standard taxonomy of constraints to center discourse on the problems being solved by digital strategies—across layers of clients, providers, and the system—rather than the technologies themselves.[26]

In December 2017, WHO released a revised classification scheme for digital health interventions aligned to health systems challenges.

In December 2017, after undertaking a 2-year process to update and standardize the taxonomy, WHO released a revised classification scheme for digital health interventions.[27] Although more sophisticated technical frameworks have been adopted from architecture developed by Health Level Seven (HL7) or Control Objectives for Information and Related Technologies (COBIT),[28,29] these frameworks are somewhat challenging for non-informaticians to access and integrate into public health discussions. Feedback from WHO mTERG, the Health Data Collaborative, and the wide community of practice led to the revised and extended standardized taxonomy to describe digital health interventions aligned to health systems challenges[27] (Figure 3) in December 2017, which will be periodically updated by WHO to reflect the dynamic nature of the ecosystem.

The mTERG commissioned the development of mERA reporting guidelines to improve the completeness and comparability of mHealth reporting in peer-reviewed literature.

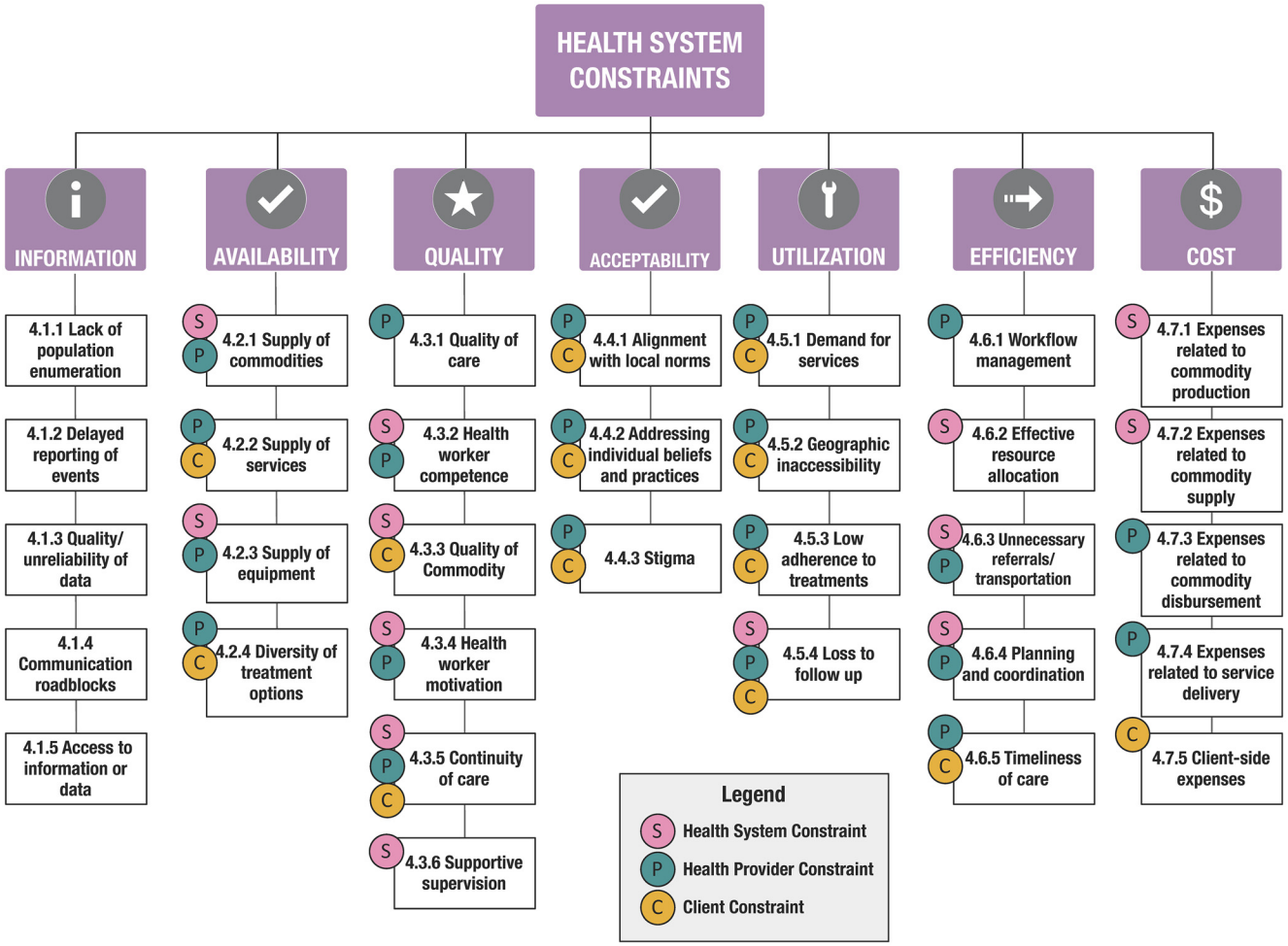
Among the frustrations also expressed by policy makers was the continued absence of demonstrated health impacts attributable to digital health investments. For most projects implemented in the early 2010s, digital health budgets were not commensurate with the effort required to set up efficacy and effectiveness studies or power them to detect health outcomes. Researchers demonstrated that through the intermediaries of coverage improvements modeling project outcomes could be used to prioritize digital health investments in cases where outcome measurement, such as infant or maternal mortality, might not be possible.[30] To demonstrate this, they used the Lives Saved Tool (LiST),[30] an evidence-based modeling software, to identify priority areas for maternal and neonatal health services in Bangladesh and Uganda. Their findings suggested that digital inputs targeting health system constraints—that reduced or limited skilled birth attendance and facility delivery—were able to increase coverage of both, potentially providing the highest impact to reducing mortality in the 2 countries. Together, the modeling approach and consequent digital health investment road map provided some guidance to seemingly uncoordinated investments in this space.

IMPROVING THE QUALITY OF REPORTING DIGITAL HEALTH RESEARCH

As the use of shared language began to improve, several efforts to synthesize knowledge about archetypal digital strategies were undertaken. These efforts were soon frustrated by the wide variability in reporting quality across the work that had been published. In response, mTERG commissioned the development of mHealth evidence reporting and assessment (mERA) reporting guidelines in an effort to improve the completeness and comparability of mHealth reporting in peer-reviewed literature.[31] The aim of these guidelines, now integrated within the EQUATOR (Enhancing the Quality and Transparency of Health Research) network[32] of methodology-specific guidance, which includes PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and CONSORT (Consolidated Standards of Reporting Trials), was to encourage authors to better describe the technologies and digital strategies they use as well as the implementation context. The mERA guidelines are recommended by WHO as a strategy to improve the synthesis of digital health research findings and improve replicability of interventions.

In recent years, numerous parallel efforts toward strengthening the linkage between evidence generation and digital health scale-up have been implemented. In 2016, WHO published a practical guide to the monitoring and evaluation of digital health interventions.[33] This guide, targeting implementers and researchers of digital

FIGURE 2. WHO Model Illustrating Health System Constraints



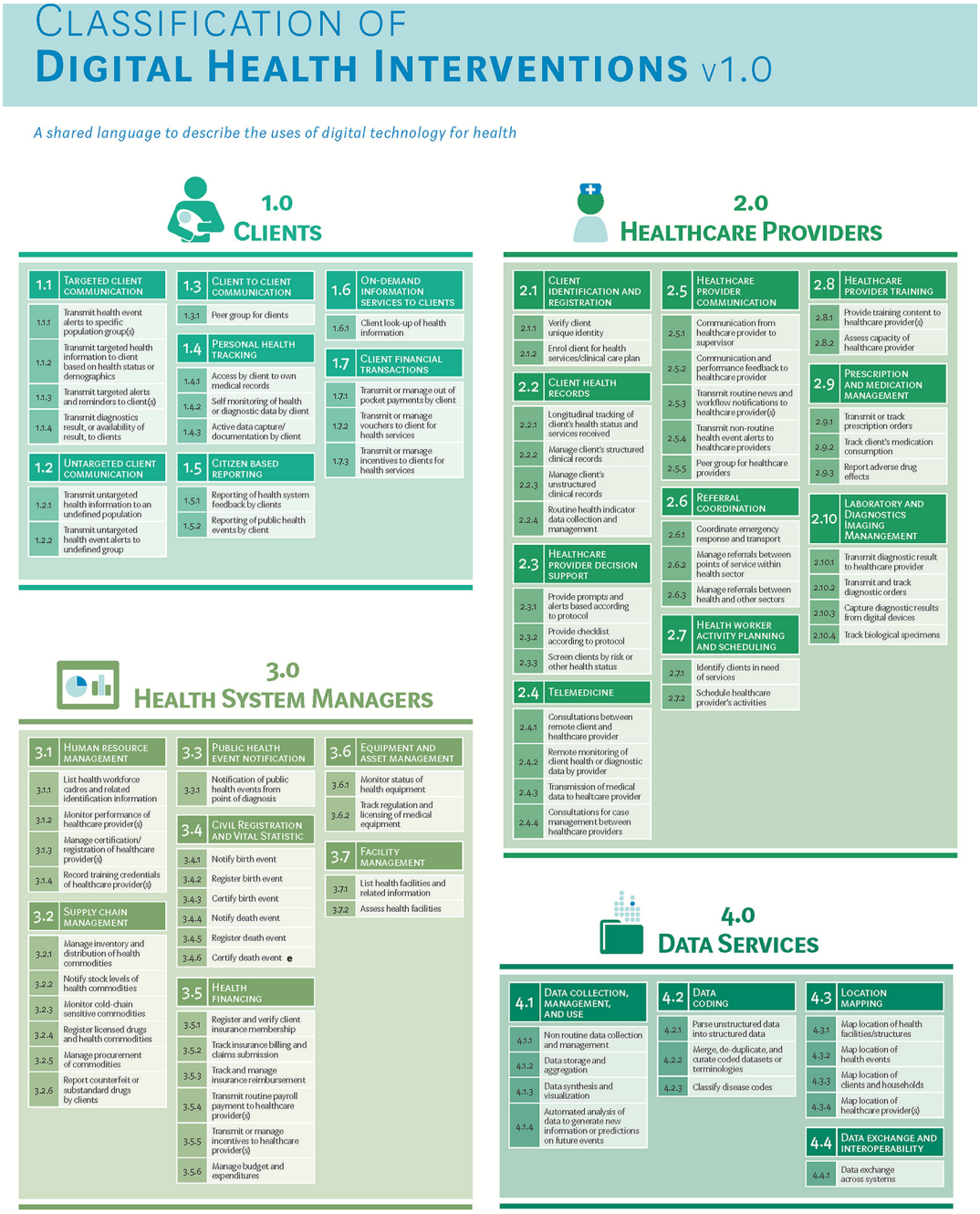
Source: Mehl (2014).[26]

health, prescribes a stage-based approach for testing digital health interventions—from feasibility and fidelity to impact evaluations (Figure 3). Several chapters of the guide are devoted to helping implementers and researchers tailor their evaluation programs with the objective of scale-up: from understanding stakeholder evidence needs for scale-up, formulating relevant objectives of the monitoring and evaluation plan, selecting thoughtful indicators that provide evidence to support program expansion, and ensuring the availability of reliable data sources for measurement of those indicators. The guide provides a diagram showing the methods and objectives of monitoring and evaluation activities used across the lifespan of a digital health program as it matures from prototype to national implementation (Figure 4).

Another important tool, *The MAPS* (mHealth Assessment and Planning for Scale) *Toolkit*[34] was released in 2015 by WHO and partners to help strengthen the discourse about scaling-up digital health innovation. The toolkit integrates lessons from both failures and emerging successes from the digital health ecosystem, providing a semi-quantitative approach to assessing program maturity and readiness for scale.[34] The goal of this toolkit is to help project managers and other stakeholders periodically assess the maturity of their mHealth program and to provide stage-based strategies to bolster the potential for scale-up. This guide adapted and updated practical guidance

The aim of *The MAPS Toolkit* is to help project managers and other stakeholders assess their mHealth programs and to provide stage-based strategies to increase potential for scale-up.

FIGURE 3. WHO Classification of Digital Health Interventions Released December 2017



Source: WHO (2018).[27]

from several field-tested WHO resources, including ExpandNet,[35] thereby ensuring knowledge transfer of lessons and successful practices from other global health domains to digital health.

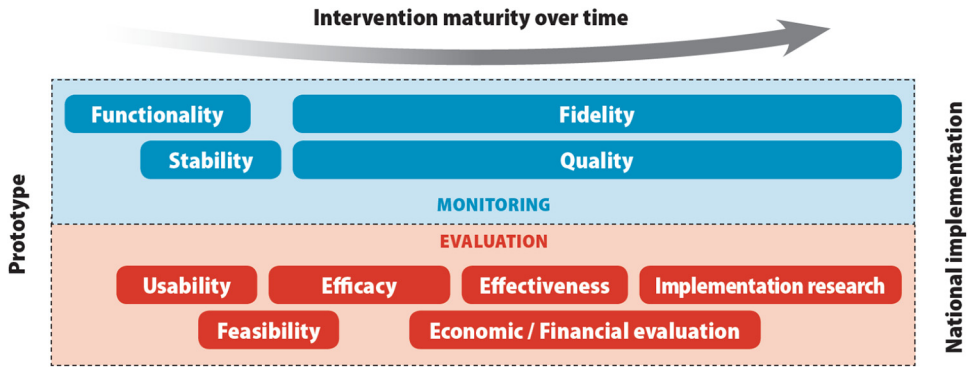
THE IMPORTANCE OF THE ENABLING ECOSYSTEM

While most of the resources discussed have focused on project-level introspection, *The MAPS Toolkit* focused some attention on the importance of the local environment in which digital health innovations are being tested. Despite substantial financial investments, several large projects had not succeeded in reaching or maintaining national scale, which led to the recognition that extrinsic factors play a crucial role in a program's survival.[36,37] In 2011, WHO and the International Telecommunication Union released the *National eHealth Strategy Toolkit* in which they stated that "harnessing ICT for health requires strategic and integrated action at the national level, to make the best use of existing capacity while providing a solid foundation for investment and innovation."[38] The strategy toolkit has 3 core components: (1) development of the national eHealth vision, (2) development of an implementation road map, and (3) development of a plan to monitor and evaluate the implementation. This document was one of the earliest to place emphasis on stakeholder involvement—including the government—from the early stages of the planning and implementation process for digital health while focusing heavily on preparing the landscape to allow digital innovations to flourish. As a result, investments in large national and global programs like BBC Media Action's work with the government of India, the multi-partner Mobile Alliance for Maternal Action initiative, and the Better Immunization Data (BID) initiative were launched.[39–42] Several scale-related guides were also developed during this time; for example, GSMA's interactive Service Maturity Tool[43] was designed to help define the innovations, services, or features that appeal to different stakeholders, notably from the perspective of telecommunications partners, upon whose infrastructure most of these digital health strategies depend. The Program for Appropriate Technologies for Health (now PATH) identified the conditions of success required to establish and support digital health solutions and provided a framework for areas of investment in digital health solutions that are required to reach that level.[44,45] Working with the ministries of health of Bangladesh, Ghana, and Tanzania, these tools were applied with a particular focus on improving the collection and management of health systems data to inform program planning, policy development, and resource allocation. The Tanzania framework and road map[45] now serves as a useful illustration of how a systematic needs assessment process can (and should) be used to drive strategic investments in digital health.

MOVING TOWARD HEALTH SYSTEM INTEGRATION: GAPS AND RECOMMENDATIONS

Despite a substantial increase in the level of organization and high-quality research in digital health, several key areas require more research.

FIGURE 4. Methods and Objectives of Monitoring and Evaluation Activities Across the Lifespan of a Digital Health Program



Source: World Health Organization (2016).[33]

The transition to large-scale implementation has proven frustrating for implementing agencies, donors, and governments. While initial efforts to study digital health scale-up have yielded road maps and toolkits, such as *The MAPS Toolkit* and the monitoring and evaluation guide described earlier, there is an unmet need for high-quality economic evaluation and implementation science studies to better understand the complexities in scaling up digital innovation.[5] We identified 4 key gaps in our quest to achieve health system integration of digital health strategies.

Gap 1: Economic Evaluation of Digital Health Strategies

Governments need economic data to inform decisions on the adoption and scaling of digital health strategies. In the absence of economic data, governments lack the information to choose between competing digital health strategies, recognize the full value of individual strategies, or effectively plan and budget for the implementation of these strategies within their countries, when budgeting against other competing investments. In a recent systematic review of the economic evaluations of digital health strategies, two-thirds of the 39 studies conducted in middle- and high-income countries showed cost savings and increased cost-effectiveness resulting from the implementation of digital strategies.[22] The study identified gaps in the evidence base for economic evaluations in low- and middle-income countries, the use of established reporting guidelines to improve quality of publications, and the selection of appropriate methods and indicators for evaluation to allow for meta-analysis. In 2017, Lefevre et al. published a 6-stage process for selecting and integrating economic and financial evaluation methods into the monitoring and evaluation of digital health strategies, with the goal of helping implementers understand the value of economic evaluations as a means to promote future efforts in this space.[46] Funders of digital health need to require the systematic capture of economic data and the assessment of cost and benefits as part of the business case for scale-up.

Research and guidance on fidelity and quality must be part of implementation planning in order to ensure long-term stability.

Enabling ecosystems include the supporting technologies, policies, infrastructure, and human resources needed to support and expand key systems.

Gap 2: Enabling Ecosystem for Digital Health Strategies and Interventions

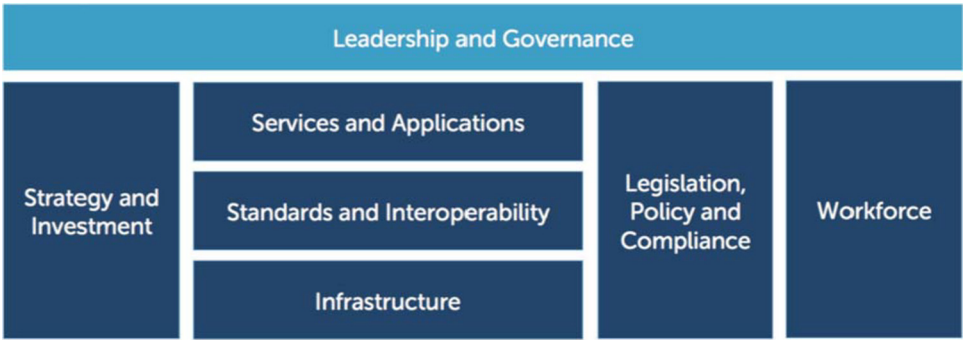
Although many stakeholders have stressed the difficulty in expanding and sustaining digital programs at scale, we are only beginning to understand the necessary external factors required for success. In other words, the most effective 'seed' of innovation may not flourish if the 'soil' in which that seed is planted lacks the requisite nutrients to grow. This enabling ecosystem, as first described in the 2012 *National eHealth Strategy Toolkit*[38] (Figure 5), includes the supporting technologies—such as electricity, network stability, and network capacity—necessary for systems to expand as well as the policies, governance structures, and human resources necessary to guide and manage the program as it grows. For example, the policy environment may need to include guidance for technical developers on data and interoperability standards, including what methods and practices should be used to store, transmit, and share data across platforms and maintain a high-level of security and confidentiality. A recent example of this type of standards is the South African *National Health Normative Standards Framework for Interoperability in eHealth*.[47] Without such an enabling ecosystem, digital health solutions may not be sustainable and/or may continue to be siloed from other digital health investments. An implementation science approach is needed to better study and characterize these factors and learn from successful programs that currently exist at scale, such as MomConnect in South Africa[40,41] or the Mwana Program in Zambia.[48]

The 2017 Broadband Commission report on digital health[49] focused on the importance of strengthening cooperation between ICT and health domains, largely through the actions of government leadership. Stressing the importance of a strong nation vision and strategy, the report provides multiple examples of road maps that have helped countries invest strategically, over time, in building health information system capacity and an enabling environment required for the success of these systems.[49] Health information systems require careful, layered planning and implementation, including equal attention to and investment in the technical systems being put into place and the human and institutional change management required to adapt to the emerging status quo.

Gap 3: Financial and Sustainability Evaluation

Inadequate focus on monitoring the quality of programs, once deployed, has led a number of large digital investments to have limited impact.[50] Just as with non-digital projects, research and

FIGURE 5. WHO-ITU National eHealth Strategy Toolkit eHealth Building Blocks



Abbreviations: ITU, International Telecommunication Union; WHO, World Health Organization.

Source: WHO and ITU (2012).[38]

guidance on fidelity and quality must be part of implementation planning for long-term stability. Resources and improved tools must be developed to facilitate program monitoring—from system functionality to staff performance quality. Few projects, globally, have reached a level of scale or longevity needed to provide insight into the actual anticipated and unanticipated costs of large digital health operations. In contrast to many decades of well-documented operational costs for paper-based systems, program planners lack reliable information on the durability of digital assets, necessary overages, and contingency procurements to allow for digital device failures or losses. Models estimating the total cost of ownership or operational costs are often based on short-term programs or extrapolated from pilot and research environments, which may not accurately represent real-world data. Economies of scale and cost-savings possible through the use of shared digital assets remain underexplored. Finally, understanding the collateral gains to be made from digital investments can also strengthen the case for these investments; that is, the time and effort previously spent on manual data summarization or aggregation—often repeated at multiple health-system levels—can be liberated for repurposing to other primary-care tasks.

Gap 4: Effective Pathways for Change Management and Data Use

Lastly, one of the more difficult challenges for digital health lies not in the development or distribution of technology, but in maximizing the use of data generated to improve system performance and, consequently, health outcomes. The data capture and population health tracking systems in use in many low- and middle-income countries have been entrenched for decades—they are deeply reliant on paper, with complex data aggregation and reporting systems in place. Understanding and addressing the threats to established processes, especially potential changes to transparency and accountability, are essential to future success. Strategies to develop cultures of data use are needed to shift the way systems are managed on quarterly or annual cycles to more frequent access of real-time data "on demand." Recognizing and mitigating the perceived risks of better data—increased visibility of dysfunction, exposure of incompetence or graft, and poor program performance—is vital to the long-term success of these interventions. In several settings, the monitoring of real-time or near real-time program performance using national-level dashboards has become a crucial part of providing data for government operational planning and reporting. In Ghana, Kenya, Tanzania, Bangladesh, and at least 50 other countries, data entered into the District Health Information System 2 is being used to support data-driven decision making with active programs to verify and improve their quality of data reporting.[48]

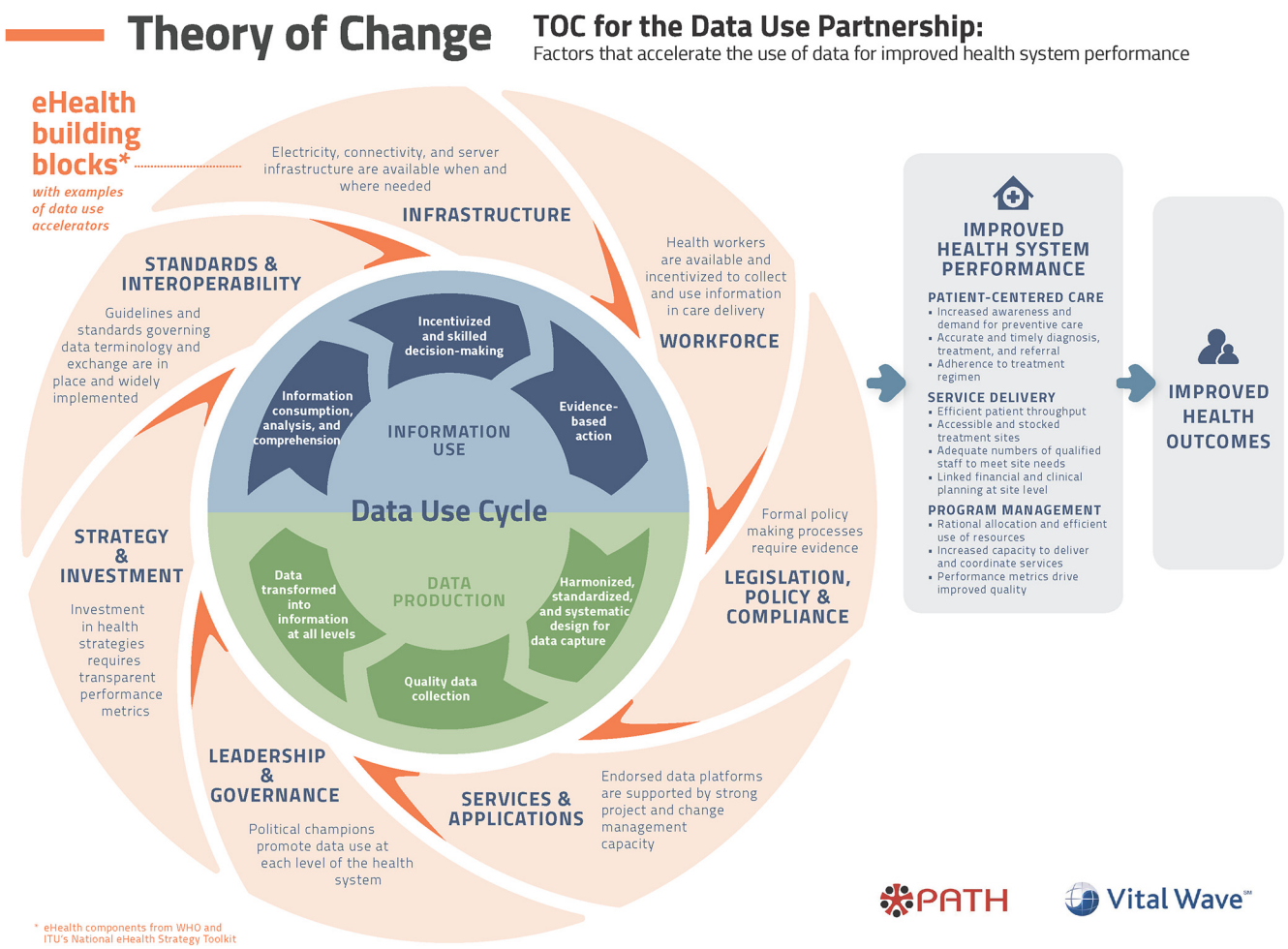
The use of improved denominators, for example, rather than target population estimates may reveal a lower rate of coverage, which may mean perceived needs or gains are lower than expected. Supported by more accurate data, these issues can

be overcome by strong leadership and development partners as they move toward results-based financing. In 2016, PATH and VitalWave released an elegant framework[51] (Figure 6) illustrating how the digital health building blocks introduced in Figure 5 are interwoven into a data-use cycle where data production feeds into information use through a continuous feedback loop. Already overtaxed health systems may have difficulty finding resources, particularly skilled staff, to actively monitor data quality and take actions to improve it. Innovations that harness machine learning/artificial intelligence to identify errors or aberrations in data quality may help to alleviate this burden. More research is also needed to elucidate program components that promote data-driven decision making and evidence-based action.

CONCLUSIONS

We suggest that intensification of efforts to bridge these gaps will likely alleviate some of the frustrations associated with scaling and sustaining digital health strategies. Throughout this paper, we have described how an increased push for evidence by donor agencies and global stakeholders has driven the growth of peer-reviewed literature describing the benefits of digital health for mitigating health system constraints. Looking ahead, a similar call to evidence for economic evaluation and adoption of an implementation science lens is crucial to

FIGURE 6. The PATH-Vital Wave Data Use Cycle



Source: PATH (2016).[51]

driving health system integration. In 2016, WHO established a guidelines development group to assess current evidence and recommendations for digital strategies. The guidelines development process not only recommends appropriate strategies that are adequately supported by sufficient evidence but also highlights promising strategies that currently have a low threshold of evidence that require future research, with a particular eye toward health system integration of these strategies. For the evaluation of digital health strategies, the standards established during the guidelines development process should help countries facilitate streamlining the application of and investments in digital strategies, moving us closer to the vision of a health system of the future.

The process of systems change is difficult, especially when current practices are the result of decades of professional practices layered upon each other. Health systems are often massive bureaucracies with limited resources, struggling to provide essential population services to large numbers of clients. The introduction of digital health innovations is still seen by many as a wasteful distraction from core health system functions, potentially diverting resources from primary ser-vices. The failures of imperfect pilot systems and gaps between promised results and actual performance seem to vindicate these claims. However, the needs of a rapidly growing human population and the challenges of measuring progress toward and meeting global health goals requires taking important steps to improve health-system reporting. After an initial period of unchecked enthusiasm and technologic experimentation, the field of digital health is now structured and increasingly organized. The evidence base of digital health approaches that have been successfully scaled up is growing, and new technology and shared standards provide a framework that can decrease the risk and amplify the promises of digital health investments. Digital health innovations are increasing accessibility, promoting transparency, and have the capacity to increase accountability—all necessary facets of lasting health systems strengthening.

Funding: This work was made possible by a grant from the Aetna Foundation, with support from the World Health Organization and The Johns Hopkins University Global mHealth Initiative. In addition, Vasudevan's effort on this publication was supported in part by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number 1KL2TR002554.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of Duke University or The Johns Hopkins University.

Competing Interests: None declared.

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Peer Reviewed

Received: June 30, 2018; **Accepted:** August 16, 2018

Cite this article as: Labrique A, Vasudevan L, Weiss W, Wilson K. Establishing standards to evaluate the impact of integrating digital health into health systems. Glob Health Sci Pract. 2018;6(suppl 1):S5-S17. https://doi.org/10.9745/GHSP-D-18-00230

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ORIGINAL ARTICLE

What Does It Take to Be an Effective National Steward of Digital Health Integration for Health Systems Strengthening in Low- and Middle-Income Countries?

Michael J. Frost,[a,b] Jacqueline B. Tran,[c] Fatema Khatun,[a,d] Ingrid K. Friberg,[a] Daniela C. Rodríguez[c]

A purposeful literature review of peer-reviewed and gray literature identified 4 broad thematic areas of digital health stewardship—strategic direction, policies and procedures, roles and responsibilities, and health service delivery—that need further research and development in order for digital health to be better positioned to positively impact low- and middle-income country health systems.

ABSTRACT

Background: Digital innovations have evolved over the last 15 years to support health activities, and their introduction in low- and middle-income countries has shown the potential to catalyze gains in health systems and service delivery. Despite widespread efforts to roll out these technologies, standardized approaches for formalizing national stewardship responsibilities and ensuring that digital health is a routine, mature, sustainable, and country-owned component of the health system are lacking. In this paper, we define digital health stewardship, with a focus on the ministry of health's role; describe practices undertaken to date; and identify gaps where increased attention could improve sustainability, impact, and local ownership.

Methods: We conducted a purposeful review of peer-reviewed and gray literature. Of the 404 identified resources from the peer-reviewed literature, 12 met all of the inclusion criteria. After searching various online gray literature repositories, we identified 6 sources based on their quality, source, and relevance. Selected resources were abstracted for relevance to our stewardship themes and synthesized.

Results: Findings are presented in 4 broad thematic areas: strategic direction, policies and procedures, roles and responsibilities, and health service delivery implications. Evidence related to strategic direction offers guidance on the main responsibilities under digital health stewardship, including regulations and incentives to promote compliance with standards, mechanisms for oversight, and structures to support evidence-based decisions, and the potential institutional structures and goals that could be used to achieve them. A number of examples of high-level policies and implementation-oriented procedures, such as from the European Commission and the World Health Organization, demonstrate how to operationalize the strategic direction. Available evidence for the remaining themes was sparse, drawing attention to key areas for future work.

Conclusions: Despite the importance of country-owned stewardship of digital health, the guidance available is limited and aspirational. Concrete recommendations, including how to adapt existing innovations to the local context, are needed. In particular, the role of external partners needs to be oriented toward building and supporting country capacity to achieve digital health stewardship's potential to support health systems into the future.

INTRODUCTION

In recent years, the use of digital technologies to support global public health efforts has become common, with donors, nongovernmental organizations (NGOs), technology providers, and ministries of health (MOHs) all providing varying levels of attention and support to a range of digital approaches. Public health leaders such as the World Health Organization (WHO), the U.S. Centers for Disease Control and Prevention the United States Agency for International Development, and the Global Fund to Fight AIDS, Tuberculosis and Malaria have written about, funded/invested in and implemented a wide variety of digital health approaches and interventions, signaling a general consensus about digital health's importance for public health now and in the future.

The term 'digital health' encompasses eHealth, information and communication technology (ICT) for public health[1]; mHealth, mobile wireless technologies for

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public health[2]; as well as novel areas of technology with roots in computing but applied to health. The most common interventions within this increasingly broad area of activity can be categorized into 3 overlapping domains: (1) support for health services and outcomes, such as point-of-care diagnostics and behavior change communication messaging to patients; (2) provider-targeted tools for clinical decision support, work planning, training, and management; and (3) digitization of routine health systems functions such as electronic health records, vital event registries, supply chain management, and financial transactions.[3]

In May 2018, the World Health Assembly adopted a digital health resolution urging member states to assess and consider how to appropriately include digital technologies in their health systems.[4] Documentation highlighted such issues as multiplicity of pilot projects, lack of interconnectedness, absence of standards and tools, and lack of multisectoral approaches within government and agencies.[2] This resolution clearly demonstrates that proper stewardship of this complex digital health landscape by MOHs is crucial to ensure impact and sustained success beyond the life of externally funded and/or driven initiatives. A shift from the current environment of mostly project-led, externally funded, siloed interventions to sustainable, integrated, locally owned and managed digital health programs is needed. Without changing the landscape to systematically support and guide country leadership, the field of digital health will likely continue to be characterized by small one-off projects and short-lived activities.[5] Unfortunately, guidance to accomplish these goals has been sorely lacking.[6] Improper stewardship can result in not only wasted resources on low-impact digital health activities and the diversion of resources from other more proven health interventions but also missed opportunities for promising technological breakthroughs and evidence-based strategies to improve efficiencies within routine systems. Digital health interventions can only fully realize their promise if they become routine, locally managed, properly stewarded approaches, but what would this entail?

In this paper, we focus on defining stewardship for digital health—and identifying current trends and gaps to address in the future—as a foundational topic in support of the other papers in this issue. For more complete discussions related to digital health's contribution to health workforce, service receipt, demand generation, service provision/delivery, and financing, see the rest of the papers in this series.

Stewardship of Digital Health

The goal of a locally managed digital health environment implies proper stewardship and governance of the entire system. For the purposes of this paper, we are using 'stewardship' as a broader term than 'governance.' Our definitions build upon a comparison of the International Organization of Standardization (ISO) standards 38500:2015[7] and 14639-2:2014[8] on governance of information technology (IT) and health informatics, respectively; the Broadband Commission for Sustainable Development's report on digital health;[5] and the WHO definition for health systems stewardship.[11] We further clarify that stewardship for digital health includes considerations beyond those relevant for health systems and offer a complete definition.

Under ISO, governance of IT "provide[s] principles, definitions, and a model for governing bodies to use when evaluating, directing, and monitoring the use of information technology [...] in their organizations."[7] This standard provides guidance with regard to 6 specific principles: (1) responsibility, (2) strategy, (3) acquisition, (4) performance, (5) conformance, and (6) human behavior.[7] While many other standards-related IT applications for health care exist, they lack a usable overview that combines the health, privacy, security, human resource, evidence, sustainability, and investment considerations that together lead to a comprehensive stewardship approach.

Digital health interventions can only fully realize their promise if they become routine, locally managed, properly stewarded approaches.

The Broadband Commission for Sustainable Development defines 'governance' in terms of mechanisms: "the means by which intragovernmental and cross-sectoral collaboration is organized by entities that advise, coordinate, support, regulate, monitor, and implement digital health services and applications, and ensure the security of the health information exchange."[5] They also highlight the function of a governance mechanism to engage stakeholders across the public and private sector.

The WHO definition of health system stewardship contains some of this context, but does not emphasize the specific considerations relevant to the use of digital health technology. The definition states that 'stewardship' [emphasis ours][11]:

> *refers to the wide range of functions carried out by governments as they* ***seek to achieve national health policy objectives****. In addition to improving overall levels of population health,* ***objectives are likely to be framed in terms of equity, coverage, access, quality, and patients' rights****. National policy may also* ***define the relative roles and responsibilities of the public,***

private and voluntary sectors – as well as civil society *– in the provision and financing of health care.*

Stewardship is a political process that involves balancing competing influences and demands. It will include: ***maintaining the strategic direction of policy development and implementation; detecting and correcting undesirable trends and distortions; articulating the case for health in national development; regulating the behavior of a wide range of actors – from health care financiers to health care providers; and establishing effective accountability mechanisms.*** [. . .]

A key concern in many countries is to build the capacity needed to carry out stewardship functions effectively. This, in turn, requires a better understanding of what constitutes best practice when it comes to stewardship and ***how national leadership can be developed.*** *It is increasingly recognized that the provision of development assistance needs to be geared to fulfilling these objectives.*[9]

Digital health stewardship refers to the comprehensive national actions and policies required to ensure the appropriate, sustainable, routine, and safe use of digital health technologies within the broader national health and IT domains.

This definition highlights not only the overarching function of supporting the attainment of high-level policy objectives but also the more specific components of that function. More succinctly, health system stewardship entails setting a strategic direction, guiding the policy and procedures to achieve that vision, defining and regulating the roles and responsibilities of actors in the system, and ensuring that critical health service delivery implications, like equity and access, are regularly and systematically addressed.

While digital health stewardship shares many aspects with health systems stewardship practices, such as informed policymaking or cost-benefit or effectiveness analyses, there are number of unique tasks that differ as well, such as integrating routine technology-related trainings and education programs for health staff, regular landscape scanning for both potential interventions and activities that would benefit from a digital update, approaches for combining and integrating digital health technologies into an overarching and sustainable ecosystem, and innovative thinking about how to adapt digital health strategies to local facilities and practitioners with limited resources. MOHs operate within the constraints of significant resource challenges, especially in low- and middle-income countries (LMICs)—not only in terms of funding but also in terms of technical and human resource capacity. Decades of investment in education, training, infrastructure, policies, and health commodities has helped make many public health interventions routine in LMICs; however, the investments needed to fully prepare countries to adopt a new set of digital strategies that, in many ways fall outside of the norm of public health activities, are still missing.

We, thus, offer the following definition for digital health stewardship:

> **Digital health stewardship** refers to the comprehensive national actions and policies required to ensure the appropriate, sustainable, routine, and safe use of digital health technologies within the broader national health and IT domains. Located at the intersection of health and technology, digital health stewardship necessarily includes considerations from both fields, including clearly established approaches for evaluation and selection of technologies; integration of technologies and health practices into a combined ecosystem; governance of sensitive health information; routinized training, education, and support for health staff; dedicated financial streams for ongoing support; standardized IT-support mechanisms; and policies/legislation governing each of these domains.

In order to gain and maintain an effective stewardship role, MOHs need to provide leadership and capacity to deliver on the abovementioned functions and ensure more locally owned and driven responses. The challenge of local ownership is not solely a digital health domain issue.[10] Public health, in general, is influenced by a variety of global actors, both public and private, seeking to affect critical health areas irrespective of national borders. To that end, there are many examples of global and national actors interacting over policies—from child health to HIV to tobacco—that highlight the role and power or powerlessness of LMIC MOHs as they attempt to exert their governance role.[11–13] For digital health to enter a stage of maturity, improved models for stewardship at the national level must be developed, adopted, and supported, with actors across the digital health space leveraging their contributions without undermining local capacity, ownership, and sustainability.

The Sustainable Development Goals[14] and the pursuit of universal health coverage,[15] with their explicit and implicit reliance on digital health technologies, suggest opportunities for countries, especially LMICs, to take on the challenge of digital health stewardship as part of broader efforts to improve efficiency and effectiveness of health systems and have a greater impact on health. In this paper, we review the available evidence and current recommendations concerning best practices

for stewardship of digital health innovations and present the current state of knowledge about proper stewardship and explore gaps in that knowledge.

METHODS

Our goal was to identify lessons that can be drawn from existing literature to help ensure an effective stewardship of digital health projects, and to suggest what practices MOHs, donors, NGOs, and other groups can adopt to increase the likelihood of proper stewardship.

To identify these lessons, from July to September 2017, we conducted a purposeful review of both peer-reviewed and gray literature using expansive search terms to reflect the shifting language and changing contexts around stewardship of digital health technologies. For the peer-reviewed literature, we searched Scopus and Web of Science using a combination of digital health terms with 'governance' or 'stewardship' to ensure a complete literature review (Table 1). Terms focused primarily on service delivery, such as 'telemedicine,' or on data analysis techniques, such as 'big data,' were purposively excluded from these searches. For the gray implementation-focused literature, we conducted a search for documents in several repositories and websites, including those belonging to GSMA, an association representing mobile operators worldwide; the U.S. President's Emergency Plan for AIDS Relief; the Vodafone Foundation; the United Nations Found-ation's Mobile Alliance for Maternal Action project; and the World Health Organization as well as the Knowledge for Health project's mHealth Evidence (www.mhealthevidence.org) and mHealth Knowledge (www.mhealthknowledge.org) websites and HingX.com, a website serving as repository for health ICT initiatives. We also searched Google and Google Scholar and used the snowballing method to identify additional sources from references cited in various fact sheets, conference proceedings, and book chapters.

Using these search terms, we scanned the publication titles, abstracts, and executive summaries to determine their relevance to our research objectives. Only those resources that explicitly addressed issues of governance or stewardship were included. Despite requiring these terms in our search, we found that authors did not often directly address these issues. As a result, of the 404 resources we identified from the peer-reviewed literature, only 12 were deemed relevant. From the gray literature, only 6 resources were reviewed and included, based on quality, source, and relevance.

We read and analyzed the full text of the selected resources and abstracted information relevant to our stewardship themes—strategic direction, policies and procedures, roles and

TABLE 1. Literature Search Strategy

Database Searched	Search Terms	Limits	Initial Search Results	Included in Review
Peer-Reviewed Literature				
Scopus and Web of Science	Governance/stewardship/accountability PLUS Digital health/eHealth/electronic health/mHealth/mobile health	• No articles before 1995 • Medicine/health/nursing or social science/decision science or environment • English or Spanish only	304 (Scopus) + 318 (Web of Science) = 404 deduplicated results	12[16–27]
Gray Literature				
HingX.com and the GSMA, PEPFAR, Vodaphone Foundation, MAMA, mHealth Evidence and mHealth Knowledge by K4Health, Google, WHO, and others	Governance/stewardship PLUS eHealth/mHealth/digital health/mobile health/individual data/subject tracker/registry/register/registration tracker/patient tracking/individual data	• English only		6[11–13]

Abbreviations: K4Health, Knowledge for Health project; MAMA, Mobile Alliance for Maternal Action; PEPFAR, U.S. President's Emergency Plan for AIDS Relief; WHO, World Health Organization.

responsibilities, and health service delivery implications—and synthesized our results.

RESULTS

Results of the literature review identified 4 broad areas—strategic direction, policies and procedures, roles and responsibilities, and health service delivery implications—where additional digital health stewardship research is needed.

We focused our review of the literature to identify lessons for digital health stewardship related to 4 broad thematic areas: strategic direction, policies and procedures, roles and responsibilities, and health service delivery implications. Other papers in this series will focus on financing, human resources, service provision, and service receipt.

Strategic Direction

Although the overall available information was sparse, strategic direction was the theme most reflected in the publications reviewed. Importantly, although most of the work in this space has used the term 'eHealth,' the evolution of the conversation now appears to include 'mHealth' and, more broadly, 'digital health,' to which we believe that these findings also apply.

According to our research, strategic direction for digital health should address the following 6 topics[25,28–32]:

1. ***Responsibility for landscape scanning*** health sector needs as well as emerging innovations/solutions to identify priorities to pursue and potential stakeholders to involve
2. ***Establish consistency and comparability*** within the health sector and across sectors both for operations, such as definitions and standards, and benchmarks for privacy
3. ***Regulations and incentives to promote compliance*** with standards across stakeholders, which are reviewed and adapted to address emerging issues
4. ***Mechanisms for oversight and accountability*** of existing systems and introduction of new innovations, including concerns for equity
5. ***Structures to demand and support evidence-driven decisions*** for digital health, including introduction, expansion, and discontinuation of innovations and for how digital health outputs are used to inform others within and outside the public sector
6. ***Analysis of current and future availability of financing***, including approaches on how to address financing gaps

Three potential governance mechanisms may be effective: broadening the mandate of existing MOH units, establishing multi-stakeholder technical working groups, and tasking other government institutions, such as national statistics offices, with providing guidance.

Further, the strategy should provide guidance on other themes, including which aspects of strategy implementation will be the government's responsibility as a public good, such as ICT infrastructure[16] or data availability.

To establish an effective strategy, efforts must engage all stakeholders—including multiple government sectors, civil society, and private-sector actors—and target their needs and incentives in order to be successful.[25] Private-sector actors for digital health present a unique case that is unlike most other health systems and service delivery areas. Although all actors have competing agendas and incentives, private-sector actors in the digital space, such as mobile network operators and technology developers, bring different objectives, expectations, and dynamics into the process, including profit orientation and shorter timeframes. MOHs in LMICs unfamiliar with these differences may consequently have less experience tailoring engagement and negotiation approaches that still ensure that all actors are held accountable.[33] Data from the Global Observatory for eHealth suggests that public–private partnerships for eHealth are better leveraged by governments, which have more capacity and experience and, relatedly, are less affected by private-sector pushback on legislation that constrains their activities.[23] Lang suggests that governments that develop eHealth legislation were able to do so by building on earlier experience, capacity, and resources for general governance and legislating.[23]

In terms of approaches, evidence from Europe indicates that certain settings are more successful in achieving effective strategies, such as in top-down health systems that are more directive and in countries that engage in policy dialogues.[20] In the last decade, multiple LMICs, including the Philippines, Mozambique, Nigeria, Rwanda, and Tanzania,[34] have started to create national approaches to eHealth. Despite these steps forward, the actual implementation of these strategies has been more complicated and time consuming than the countries expected.

The Broadband Commission for Sustainable Development has categorized 3 potential governance mechanisms that are likely to be effective: through the MOH, through a government-wide digital agency mechanism where the MOH is responsible for health issues, or through a dedicated third-party digital health agency with its own resources.[5] Examples of institutions established in high-income countries can provide useful illustrations (Table 2). Institutional arrangements for eHealth are common in LMICs; they include (1) broadening the mandate of existing MOH units to include eHealth; (2) establishing technical working groups that include the public sector,

TABLE 2. Examples of Digital Health Institutions

Example	Institutional Features	Mandate and Focus Areas
Canada Health Infoway (founded 2000)[16]	Independent, not-for-profit organization governed by 14 deputy ministers of health representing provincial authorities	Establishing strategic direction for electronic health records in Canada in collaboration with local authorities. Areas of focus include interoperability; information systems for registries, drugs, and labs; and innovation/adoption.
MedCom (established in 1994)[16]	Danish coordinating agency for health care IT. Danish central government contributes to health care IT through its National Board of Health.	Establishes standards for electronic data exchange.
eHealth Governance Initiative (established formally in 2011)[17,18]	Created with agreement of member states, and reports to high-level councils of the European Union	Created to promote eHealth services, establish strategies around eHealth, and help foster cooperation at the political, strategic, and operational levels. Four key areas of focus are identification and authentication of eHealth users, trust and acceptance of eHealth systems, legal issues (such as differing security and privacy requirements), and technical challenges.

Abbreviation: IT, information technology.

external development partners, civil society, and the private sector; and (3) tasking parastatal institutions like national statistics offices with providing guidance.

These examples, both implemented and theoretical, reflect a range of potential institutional arrangements (e.g., parastatal, coordinating agency), with different characteristics (e.g., include multiple levels of government or several countries), and varying institutional objectives (e.g., contribute to national policy or regional cooperation). One aspect that several examples[17,19,21] have in common is that strong political will from government actors was present at the outset, suggesting that this type of support, preferably broad-based, may be necessary for success. This level of government support is typified by the presence of digital health working groups, steering committees, or departments with clear mandates and defined linkages to health programs. Examples for these structures and positions can be found in national eHealth policies of Rwanda[35] and Tanzania,[36] which establish eHealth steering committees, propose the development of an eHealth department, and formalize the relationship between these groups and the MOH IT departments.

It is worth noting that whatever institutional structure is developed, significant flexibility in its outputs is crucial. Guidance generated can be practical (e.g., review process guidelines,[22] ICT infrastructures for cloud computing[27]) as well as vision-oriented (e.g., member state cooperation[21]) as long as it serves the overall objective of providing direction to the sector.

Policies and Procedures

Unlike strategic direction, the guidance on policies and procedures is more limited, and can be broken down into 2 mechanisms intended to carry out a strategic vision: high-level policies and implementation-oriented procedures. High-level policies are those that provide overarching guidance to the introduction, institutionalization, and eventual cessation of digital health innovations. Examples include:

- The 2004 eHealth Action Plan directs the European Commission to monitor the eHealth innovations landscape and promote best practices in sharing[20]
- The 2011 *mHealth: New Horizons for Health Through Mobile Technologies* document, as part of the WHO's Global Observatory for eHealth Series, identifies evaluation as a widespread barrier to adopting mHealth policies[31]
- The 2012 WHO and the International Telecommunication Union (ITU) *National eHealth Strategy Toolkit* provides guidance for developing national strategies on eHealth[32]
- The 2015 *Roadmap for Health Measurement and Accountability* provides standards for privacy and security[28]
- Additional publications from 2014 and 2015 examine country[27] and regional[19] efforts related to interoperability

Implementation-oriented procedures are routine processes necessary for assessing new technologies and innovations and for regularly assessing the health system for potential innovation opportunities.

Ideally, these processes become institutionalized in the MOH so that they become standard practice by, for example:

- Harmonizing eHealth with existing laws, including privacy laws (e.g., patient data protection), liability for goods and services (e.g., cross-border telehealth), and trade and competition (e.g., online purchase of medicines)[19]
- Regular assessments of policy implications (e.g., cost-benefit analyses or regulatory impact assessments)[20]
- Design and implementation of governance that addresses consistency, testing, and introduction of new innovations[22]

A key aspect of stewardship policies and procedures is that it requires implementation to occur according to national and local norms and requirements.

A key aspect of stewardship policies and procedures is that it requires implementation to occur according to national and local norms and requirements. Sacks et al. describe the results of unclear stewardship of data management and access to sensitive health information related to the implementation of a digital contact-tracing program during the Ebola outbreak in Guinea.[37] The implementers of the digital tool offered cloud-based data storage based on HIPAA (Health Insurance Portability and Accountability Act) privacy and ethical requirements from the United States, with the hope that these standards would be adequate. Although this approach was used at the beginning of the project, the National Ebola Coordinating Unit insisted on using local storage facilities for the data. This resulted in data being stored in 2 locations and a time lag that, for a period, made the final decisions of data ownership unclear, which also led to potential access and security complications. Had the local requirements been codified and understood at the national level from the beginning, the situation may have been avoided.[37]

While context-specific models are important, many critical stewardship roles can be standardized across settings.

Roles and Responsibilities

The literature search revealed a lack of detailed information regarding the specific and operational staff roles and responsibilities required for a national ecosystem for digital health: some research focused specifically on the staff needed to use or manage end-stage digital tools,[22] while others actively included developers, supervisors, trainers, and other implementation staff.[32] Most recommendations are either broadly available as generic recommendations from global organizations[7,28,38] or as specific project design recommendations from NGOs or implementers.[39] The categories mentioned in the WHO and ITU *National eHealth Strategy Toolkit*[32] are as comprehensive as any we identified, and include these 9 areas of responsibility:

- Program management
- Stakeholder engagement
- Strategic architecture
- Clinical safety
- Management and operation
- Monitoring and evaluation
- Policy oversight
- Health workforce
- Health ICT workforce

The combined recommendations for these 9 areas of responsibility total 1.5 pages of text, and concludes by stating that responsibilities exist at multiple levels of the health system and roles should be defined during implementation as a way of identifying "the preferred leadership and governance model, including defining the relationship to existing bodies at national, state, and local levels."[32]

Country experience in Liberia suggested that clearly defining the role of existing project field staff to include routine data collection successfully reduced costs, enhanced supervision and ownership, and helped streamline the digital intervention to a manageable level of extra responsibilities.[40] While context-specific models are important, a number of critical stewardship roles can be standardized across settings, as suggested by the Liberia example, such as responsibility for oversight of compliance with standards and laws or fundraising for system-wide improvements, which are often out of the purview of those actively using a device.[40]

Health Service Delivery Implications

Digital health approaches offer the promise to address longstanding challenges with regard to equity, coverage, quality of care, and patient/consumer rights; however, very few publications addressed health service delivery implications.

Canada's Health Infoway was established in 2001 with the overarching goal of improving service delivery by reducing waiting time, improving patient safety in the community and institutions, improving quality of care, and improving efficiency and value for money.[17] Hovenga indicates that health information governance, not just information, is needed in order to achieve improved health, responsiveness, social and financial risk

protection, and efficiency.[25] However, neither of these resources specifies what specific steps must be taken to achieve their objectives. This includes the key issue that the financial arrangements needed to sustain health IT implementation must address the rewards and incentives for digital health services improvement, which requires common ground across organizations and care providers to increase the quality of overall service delivery value system.[16]

Marshall, Lewis, and Whitaker describe a decision-making tool for allocating resources that could serve as a model for selecting digital health innovations for scale-up.[29] The framework's criteria represent aspects of health service delivery that MOHs should be concerned with, including (1) physical access to technology; (2) appropriateness of technology; (3) affordability and use of technology; (4) human capacity and training; (5) locally relevant content, applications, and services; (6) integration into daily routines; (7) sociocultural factors; (8) trust in technology; (9) local economic environment; (10) macroeconomic environment; and (11) legal and regulatory frameworks. Another issue to resolve is related to citizens' rights to access health data and what entities (e.g., governments, external partners) are responsible for promoting the health data, especially when data are collected unidirectionally through mHealth activities without obvious benefit to individuals or communities.[30]

DISCUSSION

In May of 2018, the World Health Assembly adopted a digital health resolution that calls on countries to assess and optimize their digital health offerings and "to identify areas where [. . .] guidance and technical assistance and advice on digital health would be beneficial."[2] Although some of the topics mentioned included partial aspects of stewardship, stewardship and governance were never explicitly or formally described. The exclusion of stewardship in this key document corresponds with the results of our literature review, which shows that evidence-informed recommendations to facilitate national stewardship of digital health ecosystems are lacking. Guidance to facilitate strategic direction is often derived from generic stewardship recommendations or is limited to a discussion of eHealth that does not consider mHealth or the future direction of digital health, which will bundle a variety of technologies into a comprehensive ecosystem. Although recommendations related to stewardship have been around globally for years, practical ideas on institutionalizing robust digital health stewardship in LMICs have not made sufficient gains, as evidenced by similarly framed eHealth strategies developed years apart in Rwanda[35] and Tanzania.[36]

The formation of potential digital health ecosystems has been primarily driven by a variety of actors outside of national health systems. Without formalized strategic direction, these organic fledgling ecosystems are unlikely to develop into efficient environments that will fully capitalize on the promise of digital innovations. As a result, governments will continue to face challenges of inefficiencies, competing systems, uncoordinated efforts, and unnecessary diversion of resources. A potential approach for addressing these challenges is to evaluate the successes and failures of LMICs that have attempted to develop national eHealth strategies and use those findings to support the funding and coordination of national (or regional) level multi-stakeholder workshops or policy dialogues to develop and/or update digital health strategies. At the same time, the best mechanisms through which to engage civil society and citizens at large remains elusive.

Without an adequately structured digital health ecosystem, governments will continue to face inefficiencies, competing systems, uncoordinated efforts, and unnecessary diversion of resources.

Private-sector engagement in digital health has the potential for both great opportunity and great risk. For instance, private-sector involvement from banking institutions or mobile network operators can suggest creative financing approaches that are less familiar or seem more risky to governments, such as mobile-based health savings schemes. Regardless of what options are considered, sustainability must remain at the forefront of any discussion. Another consideration is that countries with weaker governance or limited governing experience will likely not fare as well under public–private partnership arrangements; in those cases, external actors should be cautious of promoting these indiscriminately in LMICs.

With regards to policies and procedures, WHO observed in 2011 that policymaking was not keeping up with technological advances or the public's interest, especially around mHealth,[31] and not much has changed since then. Cross-sectoral policy coordination, particularly with regards to the complex realities of technology, means that national policies often lag far behind digital health implementation. This not only results in challenges for digital health adoption but also opens up very real possibilities for misuse of health data, unverified health recommendations, and reduced adherence to clinical guidelines. Leaving this area of stewardship in the hands of outsiders has not resulted in many successes. This could be

When national policies lag behind digital health implementation, these gaps enable misuse of health data, unverified health recommendations, and reduced adherence to clinical guidelines.

attributed in part to LMIC legislative and legal communities that have been largely uninvolved in the development of digital health policies to date. The development of a standard set of recommendations on a variety of policy topics, learning from but not copying the health regulations of wealthy countries, would ease the path for national discussions.

The roles and responsibilities for digital health stewardship is an area that could still be significantly improved. Many overarching models for eHealth strategies have been proposed, yet useful details of specific positions and responsibilities needed for a sustainable national ecosystem are largely absent. The organic process of adopting digital health into routine work procedures is not only slow but inadequate—many of the people in decision-making roles lack the training necessary to identify and hire for the skill sets needed to ensure proper long-term stewardship of a national digital health environment. A well-functioning digital health ecosystem in most countries will likely require such changes as the creation of new crosscutting units, new educational and training opportunities, a transformation of decision-making authority, revised reporting structures, and the delineation of legal authorities for data management and governance. Most donor-led health projects do not have the mandate or funding to focus on system-wide transformations, and most countries lack the incentives or resources to do so themselves. Funding for the development of a set of generic digital health staffing and responsibility recommendations would be a useful starting point. These recommendations could then be adapted for specific countries during or following the strategic and policy activities recommended above.

One outstanding issue has been how to manage the roles of external partners, including donors and NGO implementers, under new stewardship structures. The 2012 WHO and ITU *National eHealth Strategy Toolkit*[32] includes extensive guidance relevant to digital health stewardship. The focus of the guidance is on developing an eHealth vision, or strategic direction, and an overarching action plan. The toolkit does highlight, however, that the successful application of a vision, strategy, or action plan requires experienced individuals to guide the core processes and engage with broader stakeholder groups, which echoes this finding of our review: local capacity and experience must be built and supported to ensure a long-lasting stewardship role.

Governments must lead digital health stewardship initiatives in order to reinforce country ownership, but to do so most countries require focused capacity building efforts.

Government actors must take the lead in any digital health stewardship initiative in order to reinforce country ownership, but to do this most LMICs will need capacity building. External partners have significant contributions to make not only in capacity building but also in supporting alternative approaches to stewardship. However, they must think beyond specific digital health applications and technologies and consider larger structural governance issues that reflect broader health systems issues that may need to be addressed. A regional stewardship initiative could be useful both from a country and donor perspective, as it would provide an opportunity for knowledge and practice sharing, increase the potential of scaling certain innovations, become the platform for cross-national interoperability, and address power imbalances between national governments and external actors. The Digital Regional East African Community Health Initiative recently launched a road map that includes a framework for unifying digital health approaches intended to support the cross-national environment necessary for digital health technologies to achieve sustainability and scalability.[41] Although it is in its early stages, this type of effort underscores the potential of regional approaches in catalyzing gains in digital health.

Limitations

While we gathered what we believe is a comprehensive picture of the literature, our review is not without limitations. Our review was a rapid purposive review and could have benefitted from a more systematic review, particularly of the gray literature. Additionally, we only included papers available in English or Spanish; there may be valuable publications available in other languages. Although we kept our country scope generally broad in order to better capture the state of the field, we recognize that not all high-income country approaches are easily transferable to LMICs. Further theoretical and practical work is needed to translate and adapt appropriate approaches to different contexts.

CONCLUSIONS

While a lot has been written about the potential of digital health to address longstanding challenges with health service delivery, better guidance is needed to help countries use digital health in transformative, rather than replicative, ways. Despite the importance of national stewardship for achieving the global health community's goals for digital health—outlined in *The Roadmap for Health Measurement and Accountability*,[28] the

Principles for Digital Development's principles,[38] and implied in the goal of universal health coverage within the third Sustainable Development Goal[42]—significant work remains to standardize and operationalize recommendations. Formal focus and attention on the areas of stewardship and governance still needs considerable attention, even by the most current and high-profile actors in this space. While a fair amount of relevant literature in this space has been published, most of it has not been peer reviewed, does not reflect LMIC experiences, and—more importantly—has not been replicated. Most of the guidance available is aspirational in tone, informed by standalone projects, or highlighting the difficulty of the task at hand. Yet the promise of digital health is undeniable. To help make aspirations a reality, specific efforts should be undertaken to improve national stewardship that reflects a country-owned vision of how digital health can catalyze health system achievements.

Funding: This work was made possible by a grant from the Aetna Foundation, with support from the World Health Organization and The Johns Hopkins University Global mHealth Initiative.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of the Norwegian Institute of Public Health, the University of Oslo, or The Johns Hopkins University.

Competing Interests: None declared.

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Peer Reviewed

Received: July 20, 2018; **Accepted:** August 29, 2018

Cite this article as: Frost MJ, Tran JB, Khatun F, Friberg IK, Rodríguez DC. What does it take to be an effective national steward of digital health integration for health systems strengthening in low- and middle-income countries?. Glob Health Sci Pract. 2018;6(suppl 1):S18-S28. https://doi.org/10.9745/GHSP-D-18-00270

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ORIGINAL ARTICLE

The Role of Digital Strategies in Financing Health Care for Universal Health Coverage in Low- and Middle-Income Countries

Bruno Meessen[a]

The development and adoption of effective digital health financing solutions that fit well in both coherent digital health information architectures and the universal health coverage agenda will require strong partnerships between entrepreneurs, developers, implementers, policy makers, and funders.

ABSTRACT

Countries finance health care using a combination of 3 main functions: raising resources for health, pooling resources, and purchasing health services. In this paper, we examine how digital health technologies can be used to enhance these health financing functions in low- and middle-income countries and can thus contribute to progress toward universal health coverage. We illustrate our points by presenting some recent innovations in digital technologies for financing health care, identifying their contributions and their limits. Some examples include a mobile-health wallet application used in Kenya that encourages households to put money aside for future health expenses; an online software platform developed by a startup in Tanzania in partnership with a private insurance provider to give individuals and families the opportunity to choose among different health coverage options; and digital maps by a number of start-ups that bring together data on health facility locations and capacity, including equipment, staff, and types of services offered. We also sketch an agenda for future research and action for digital strategies for health financing. The development and adoption of effective solutions that align well with the universal health coverage agenda will require strong partnerships between stakeholders and enough proactive stewardship by authorities.

INTRODUCTION

There is a strong movement promoting digital technologies as a means of strengthening health systems, in low- and middle-income countries (LMICs), including innovations for demand generation, better management of information, and improved efficiency of health workers.[1] However, the role and potential of digital technologies in financing health care in the context of health systems strengthening is poorly understood.

To understand the possible role of digital technologies for health financing in LMICs, one must first describe their health systems and identify the health financing challenges they face. In many LMICs, traditionally, the government was responsible for all key health system functions, including priority setting, financing, allocation of inputs, and provision of health services. This is exemplified by the original 1948 tax-funded British National Health Service model in which health services were provided free of cost at the point of care by public civil servants in government-owned facilities. Since the late 1990s, the health sector in LMICs has seen transformative changes consistent with broader societal changes in favor of liberalism, privatization, and citizen emancipation. For instance, in many countries, public-sector facilities have been granted more autonomy and user fees have been introduced. At the same time, the health care market has also seen a growing role of the private sector in service delivery.[2] Despite these changes, in most LMICs, the public sector still remains the backbone of health service delivery, especially for preventive health services and services that address global health priorities, such as childhood illnesses, HIV/AIDS, and tuberculosis. The private sector, which primarily focuses on curative care, varies in size across countries. For many people, particularly those who are poor and live in rural areas, health care may be provided by a myriad of informal providers delivering services of varied quality.[3–5] In nearly all LMICs, ministries of health have been slow to build stewardship capacity to manage this new mixed landscape.[6] Combined with low levels of government health spending, this can result in a general pattern of health financing where households have to cover a substantial share of the costs. Indeed, in most low-income countries

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(LICs), only a minority of households benefit from an extra formal financial protection program, such as complementary health insurance. In most middle-income countries (MICs), the proportion of households enrolled in such a financial protection program—usually through employment-based insurance arrangements—is higher but large segments of the population, especially in the informal sector, often remain inadequately covered.

A considerable amount of literature has shown that financial accessibility to health services is a major problem in many LMICs.[7] While financial accessibility to health services often applies to entire populations, it is particularly relevant for the poorest and the most vulnerable living in these countries. Many poor households decide to curb their use of health facilities or even forego treatment, while others face the risk of impoverishment through so-called catastrophic health care expenditures—out-of-pocket payments for health services that exceed a given fraction of total household expenditure.[8] Over the last 2 decades, many LMICs, often in partnership with external partners, have tried to address these challenges. A key axis of intervention has been the introduction of innovative health financing schemes, such as community-based health insurance,[9] social health insurance,[10] health equity funds,[11] voucher schemes,[12] performance-based contracting,[13] and performance-based financing (PBF).[14] Many LICs have also opted to remove user fees in public facilities,[15] often with some targeting for specific vulnerable groups, such as children under the age of 5 or pregnant women,[16] or high-priority disease areas such as HIV/AIDS or tuberculosis.

Health financing is traditionally conceived of as having 3 key functions: collecting funds, pooling funds, and purchasing health services.

With the global spotlight on achieving universal health coverage (UHC) under the Sustainable Development Goals (SDGs), it is critical to identify and scale up effective strategies for promoting equitable access to health services by reducing financial hardships for individuals.[17] The main purpose of this paper is to explore how digital solutions can contribute to the ambitious agenda of progress toward UHC in LMICs. We have organized the paper around the health financing framework describing the key functions of mobilizing and pooling resources and purchasing services.[18]

METHODS

To our knowledge, this is the first paper that attempts to discuss digital innovations for health financing in LMICs. As there is not much literature to review, the development of this paper relied largely on our own professional engagement in health financing in LMICs and, to a lesser extent, our own exposure to the digitalization of this health area (see also conflict of interest).

To illustrate possible directions of focus, we provide references to not only existing digital health solutions and tools but also financing schemes that heavily rely on the latest technological developments. They were identified through our own practice, as well as a flash consultation organized on the platform Collectivity (https://www.thecollectivity.org/en/flash_consultations/7).

Clearly, this review is not meant to be exhaustive; rather, the goal of this paper is to map emerging digital health strategies for health financing, identify issues deserving the attention of both the digital and health financing communities, and present recommendations for future action for researchers, digital innovators, governments, and their partners.

HOW DIGITALIZATION ENHANCES THE 3 FUNCTIONS OF HEALTH FINANCING

Health financing is traditionally conceived of as having 3 key functions: collecting funds, pooling funds, and purchasing health services.[18] The collection of funds refers to the mobilization of resources to finance health services, with contributions coming from tax payers, employees, employers, public and private donors, and users. The World Health Organization (WHO) recommends that health systems have mandatory funding sources, such as taxes or social security contributions. An important indicator of progress toward UHC is the level of direct, or out-of-pocket, payments for health care.[17] Payment at the point of care has several drawbacks: it requires cash; it includes a level of uncertainty about the amount to be paid, which deters households from seeking care, especially under fee-for-service systems; and, more fundamentally, it leaves households to cope with the costs without any financial protection.

The pooling of funds refers to the "accumulation of prepaid health care revenues on behalf of a population."[18] To achieve UHC, pooling arrangements need to be established so there are large sustainable pools that allow for the adequate redistribution of financial risk between the healthy and sick and the rich and poor. An important step to address this issue includes reducing pooling fragmentation—the multiplicity

of financial pools covering fragmented groups—and duplication, where some people are covered for the same needs by multiple schemes.

Purchasing is the transfer of pooled resources to service providers on behalf of the population for whom the funds were pooled. In many LMICs, health services, particularly those in the public sector, continue to be purchased using line-item budgets. While this method of purchasing is good for containing costs, it represents a passive approach to purchasing health services because it is not related to health or performance outcomes. WHO recommends purchasing to be strategic and to aim for an efficient and equitable allocation of resources to producers of good health.[19] Next, we describe the current state of evidence for the use of digital strategies for each of these 3 health financing functions.

Collection of Funds

As explained in our introduction, in many LMICs, a large part of health financing comes directly from the pockets of the users. This is managed through cash payments and paper administration at the facility level. The key digital technology that could transform the collection of funds function is the electronic payment. However, from a UHC perspective, electronic payments will only lead to significant progress if they allow movement from payment at the point of care to prepayment—contribution by the household before the occurrence of the episode of illness—and pooling.

Collecting funds from people who are active in the formal sector does not require major technological developments, as the financial transfer can be organized directly from the employer. Collecting funds from people active in the informal economy is more challenging, as their locations may be unknown, and their administrative existence limited. For this group, the pervasiveness of mobile phones in LMICs and the success of mobile-money initiatives could open up new avenues, especially in settings where the bank system is underdeveloped, costly, or absent.

Kenya is one of the countries currently using mobile money. A study has shown how the mere introduction of the M-Pesa mobile phone-based money transfer, financing, and microfinancing service has already helped households to tap remittances and respond better to health shocks.[20] M-TIBA (http://m-tiba.co.ke/) is a mobile-health wallet application that builds on this potential by encouraging households to put money aside for future health expenses or to collect contributions from other relatives, such as contributions from adult children to finance elderly parents' health care. It also allows organizations—for instance, a program or a charity—to sponsor targeted households. As providers are enrolled after selection by M-TIBA, it also integrates a purchasing function. By June 2017, nearly 900,000 users were reported registered, giving them access to 450 health facilities, and the system had processed payments totaling $1.4 million for 100,000 visits.[21]

From a UHC perspective, this example highlights at least 2 benefits of using digital technologies for the collection of funds: (1) the possibility to raise funds, outside of formal banking systems and without cash handling, through mobile money (see also experiences in Mali and Kenya)[22] and (2) the possibility of raising funds from various sources, even across borders—relatives in the diaspora, for instance—for individual or collective use.

It is currently unclear, however, how this potential can be converted into sustainable financing schemes that support UHC. One concern is that if the initiative comes from private investors the focus will be on profitability, which will likely mean that the poorest segments of the population will be overlooked.

Collecting funds from people active in the informal economy is challenging, as their location may be unknown and their administrative existence limited.

The collection of funds has 2 sides: households contribute to a scheme and, in exchange, they receive an entitlement. Some implementation challenges related to the collection of funds and entitlement are: avoidance of fraud (claim for support or reimbursement from people who are actually not covered by the arrangement, with or without collusion between the subscribers and providers); timely updates of the composition of households (birth and death); portability of the entitlement across geographical areas (particularly important for migrant workers); and renewal of insurance policies. Digital strategies may be valuable for overcoming some of these implementation challenges. For example, government-sponsored health insurance programs, like the Aarogyasri Scheme (http://www.aarogyasri.telangana.gov.in/aarogyasri-scheme) in India, use digital technology to maintain electronic health records and prevent fraud by health care providers and patients. The management of entitlements is an area where the gains from digitalization are obvious, as evidenced by systems already in place in high-income countries.

Pooling of Funds

From a UHC perspective, a digital health solution like M-TIBA has some limitations, as M-TIBA was

As most health shocks are idiosyncratic, the law of large numbers suggests that setting up a sufficiently large common pool will allow for the removal of uncertainty.

developed as a medical savings account, not as insurance. The application reminds households to be well-prepared. While it can help family members to handle, and ration, pressing demands from relatives, it does not organize the pooling of funds among subscribers and, therefore, the expenses paid cannot be more than the money uploaded on the account.

A key principle of health financing is that pooling risks between individuals is efficient. As most health shocks are idiosyncratic, meaning they are uncorrelated between individuals, the law of large numbers suggests that setting up a sufficiently large common pool will allow for the removal of uncertainty. A proposition can be made to individuals to pay a certain price, the premium, in exchange for an insurance—the assurance of being protected from the financial risk. Since people are generally risk-adverse, they usually agree to pay the premium.

There are various ways of setting up such pools. Subscription can be compulsory or voluntary. Governance can be under the responsibility of the government, a multi-stakeholder body, private investors, or representatives of the subscribers. About 15 years ago, several non-governmental organizations (NGOs), bilateral aid agencies, and multilateral agencies explored the feasibility of community-based health insurance (or *mutuelle* in French) and micro-health insurance.[23] Under such arrangements, households or individuals were invited by an NGO, a social entrepreneurship, or a community group to pay a subscription fee to an insurance scheme, which would then cofinance their health care costs for a given period. Rwanda made huge progress toward UHC with this model,[24] partly thanks to strong presidential leadership, but replicating this success elsewhere has proven difficult.

Many countries have set up health financing schemes tailored to overcome specific informational, geographical, financial, and cultural barriers encountered by the poor and vulnerable.

The primary problem with community-based health insurance and microinsurance schemes is the high transaction cost to enroll households and collect their premiums, especially in low population density areas, and the selection and monitoring of health providers. Today, some actors take advantage of the pervasiveness of mobile technology and test variations of the voluntary insurance model. Digital tools can contribute in several ways to setting up and managing pools: the Internet can significantly increase access to new subscribers by reducing search costs on both sides of the transaction; as seen in the previous section, smartphone applications can reduce transaction costs for premium collection; and database systems are crucial for managing and processing subscriber data and expense claims from patients and health facilities.

Several private actors are currently developing online solutions that offer insurance packages to households. An example is the software platform developed by Jamii, a startup in Tanzania that partnered with a private insurance provider (http://www.jamiiafrica.com/) to give individuals or families the opportunity to choose among different health coverage options. Interestingly, M-TIBA is aware of the limits of the savings account model, and seems to be heading in this direction as well by setting up a partnership with the National Hospital Insurance Fund of Kenya. Another interesting experience is "My Tonic.com" developed by Telenor Health in partnership with Grameenphone. Through a phone application, the population of Bangladesh can access a wide range of services, including health information, advice, preselection of providers, and health insurance. The most remarkable feature is how the different services are provided in packages designed to empower households to manage their own health, including nudging them toward healthy choices. About 4.5 million people are currently insured through this partnership.

While voluntary health insurance certainly offers a valuable service to their subscribers, from the UHC perspective, it also has a drawback, as it ignores those who cannot afford the premium. Recently, WHO de-emphasized voluntary insurance as a sustainable approach to achieving UHC.[25] In order to guarantee that everyone is covered, WHO instead recommended countries move toward a predominant reliance on compulsory insurance. However, progress in rolling out compulsory schemes has been variable in LMICs, as it is easier to organize pools within the formal sector than in the informal one. If the market opportunities are real, more initiatives like Jamii or My Tonic will emerge; the trend seems to be particularly strong in the telecom industry. This dynamism should be appreciated not only for the value it brings to households, but also because it invites public authorities and their international partners to move faster on issues, such as stewardship of the sector, and to consider greater use of public–private partnerships.

A particular responsibility for governments is to provide coverage to the poor and vulnerable who cannot contribute. Many countries have set up health financing schemes tailored to overcome specific informational, geographical, financial, and cultural barriers encountered by these groups.[26] Similar to contributory schemes, a

key issue is ensuring the identification of beneficiaries. This is particularly challenging, given that 2.4 billion people in the world have no official identity.[27] This is an area where the use of digital technologies has been evolving fast. Operators have moved from paper-based registers to digital databases that include pictures and geographic information system (GIS) coordinates of households, and, more recently, to datasets incorporating unfalsifiable identifiers, such as iris scans or fingerprints, for age groups for whom these identifiers work. In this respect, some technological developments look promising.[28] We anticipate that this will generate new societal questions for the many LMICs that have no advanced experience managing personal data and no established legislation. Interestingly, blockchain technology might open new territories, as it could provide individuals with an immutable identity[29] independent from state authorities (see the solution created by idbox, http://www.idbox.io/). Yet we anticipate that many governments would want to keep control of the digital identification of entitled households. To that end, a country case to follow is that of India, for at least 3 reasons: it is a democracy concerned with civic and privacy rights, it is embarking on a massive free health care program for 500 million people, and authorities have decided to build this new entitlement program on Aadhaar, a 12-digit unique identity number already used by 1.22 billion residents.[30]

At the household level, the entitlement document may be digitalized from paper to an electronic identity card with chips or scan codes, or even fully dematerialized e-vouchers that are sent directly to the mobile phones of beneficiaries[26] (see the various solutions developed by RedRose, https://www.redrosecps.com[31]).

The creation of too many siloed health financing schemes can create fragmentation, which is a source of both inefficiency and inequity.[32] To address that, WHO recommends reducing the number of concurrent schemes in order to reduce fragmentation of offerings for pooling financial resources. Merging pools by itself is difficult and raises several political and technical issues. For instance, merging voluntary health insurance, mainly subscribed to by those with more wealth, with a health equity fund, funded by the government and its aid partners for the health care of the poor, may be challenging because the public resources allocated for the poor might actually finance the use of health services by the wealthy, as the latter have less barriers to overcome.[33]

In many LICs, insufficient pooling even prevails at the level of public funds; this is particularly true with off-budget external aid. Many health authorities are not aware which geographic areas, health needs, or population groups are covered by several projects and which are underserved. In Uganda, the United Nations Pulse Lab is developing a digital solution for visualizing off-budget contributions from aid actors and identifying funding gaps and overlaps. This highlights the need for the development of computational tools to prepare, implement, and monitor instances of pooling where disparities may be heightened.

In each country, greater convergence and interoperability between data systems used by different schemes will be key. In the absence of prudent stewardship, incompatible proprietary software solutions may become an additional obstacle to the consolidation of pooling. Governments and aid agencies, including WHO, have begun to move toward more unified pools by working on common architectures; agreeing on terminologies and classifications; adopting common identification numbers for users, providers, and health facilities; and requesting interoperability of data systems.

Purchasing of Services

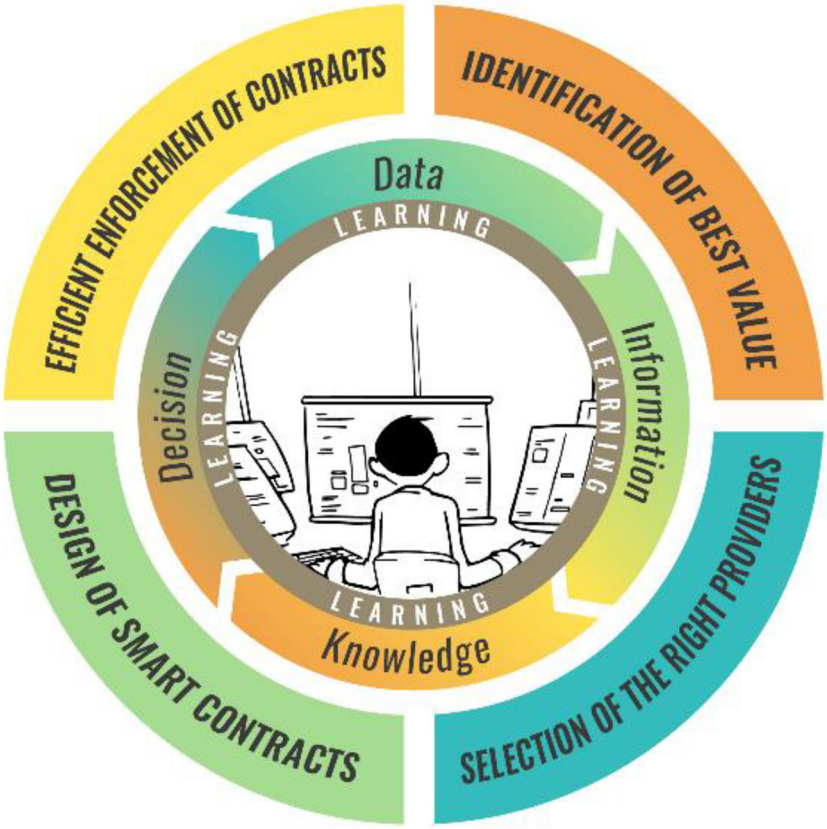
From a technical perspective, purchasing is probably the most complex and sophisticated of the 3 functions of health financing. Several exciting digital developments can be linked to the move away from line-item budgeting and toward strategic purchasing. The latter is described as a progression on 4 + 1 functions: identification of best value, selection of the right providers, design of smart contracts, efficient enforcement of contracts, and finally, learning, which is the overlying function supporting the 4 others (Figure).[34]

The creation of too many siloed health financing schemes can create fragmentation, which is a source of both inefficiency and inequity.

Identification of the Best Value

A purchaser has to develop a good and up-to-date knowledge of (1) the population it covers (the number of people) and their health needs (the 'burden of diseases'), health expenditures, and values and preferences; as well as (2) the interventions and solutions to respond to these needs and demands. This information is vital for determining the content of the benefits package—the set of health goods and services and the conditions to access them—to be provided to the beneficiary group. The main technique to determine the benefit package is cost-effectiveness analysis, a data-hungry evaluation method that uses modeling

FIGURE. 4+1 Functions of Strategic Purchasing



and results from clinical trials. Whereas this field of global health is dynamic in terms of methodological developments,[35] digital innovations seem to have been occurring at a slower pace.

Today, as far as LMICs are concerned, the most visible digital players in these areas are global actors. However, health financing is not their primary objective; their main aim is to establish burden of diseases (see http://www.healthdata.org/) or gather aggregate data on health services (on primary health care, see https://phcperformanceinitiative.org/). Their use of digital technologies is focused on compiling and processing data, producing forecasts, visualizing analyses, and sharing these products with stakeholders, often with a limited view of the actual needs of national strategic purchasers. A pioneering step toward linking data with the actual allocation of resources by ministries of health in LMICs was the Microsoft Excel-based marginal budgeting for bottlenecks tool jointly developed 15 years ago by UNICEF and the World Bank.[36] The more recent alternative, developed by WHO, is the OneHealth tool (http://www.who.int/choice/onehealthtool/en/), which not only links strategic objectives and targets of disease control and prevention programs to the required financial investments but also includes scenario analysis.

WHO's OneHealth tool links strategic objectives and targets of disease control and prevention programs to the required financial investments.

We expect further developments in this area in LMICs. One driver will be the growing number of LMICs developing their own health technology assessment capacity. Another driver will be the progressive use of so-called real-world data—data obtained not from randomized trials but from more heterogeneous groups of patients already under treatment or observation.[37] In the future, strategic purchasers will make greater use of granular data on population and health services. The main challenge will probably remain the same as described earlier: solutions will have to combine data of very different natures from very different sources. This will require the development of governance models that secure participation from the

different public and private stakeholders needed to create real value for purchasing bodies and the whole health system.

Selection of the Right Providers

With the growing pluralism of the health sector in LMICs, the choice of possible providers is also growing. As mentioned in the introduction, in many LMICs, private for-profit facilities are loosely regulated and often not included in the national health information system. In this context, it will be up to the purchasers to identify, screen, select, and enlist the facilities that will deliver the benefit packages covered by the financing scheme. Many elements of information can help purchasers to make informed choices. Yet collecting and analyzing such data entails huge search costs; this is typically an area where digital solutions can bring major gains. First, purchasers need to locate private health facilities and determine what services they provide. Startups such as Healthsites (https://healthsites.io/), Blue Square (https://bluesquarehub.com/), and World Pop (http://www.worldpop.org.uk/) are developing digital maps that will bring together data on locations, health facility capacity (equipment, staff, package of services), and, soon, households (number, needs, socioeconomic status, and so on) in the catchment areas. They tap different opportunities, such as crowdsourcing, GIS, high-resolution satellite imagery, and, perhaps soon, big data from mobile network operators.

Second, purchasers also have to think systemwise and be ready to consider 'provision' beyond health facilities only. For some needs, this requires opting for a whole chain of service providers, including sometimes the users themselves. For instance, Vodaphone developed an Uber-like mobile phone application to organize payment of taxis for transporting women to health facilities for delivery in Tanzania.[38] Another example of such an approach is Tiko, a social marketing solution that tries to incentivize the uptake of healthy behaviors (http://triggerise.org/). Third, for any service provider, whether a hospital, taxi driver, or community health promotor (see, for instance, https://livinggoods.org/), the capacity to guarantee quality standards in the benefit package is a central component of the purchaser's value proposition to users. There are various ways of collecting information, assessing performance, and recognizing and rewarding technical capacities, such as certification, franchising, and accreditation. One could, for instance, imagine combining information collected from users through a crowdsourcing application—such as the Mera Aspataal application introduced by the Ministry of Health of India, which has already generated more than 2 million user feedback comments about 1,084 hospitals (http://meraaspataal.nhp.gov.in/)—with an evaluation produced by mandated professional evaluators. Collecting continuous information about the performance of providers, analyzing it, and taking action will be major areas of development in the years to come.

Design of Smart Contracts

The health sector is primarily a service sector. In economic terms, this means that most of the transactions are of the principal–agent relationship type: one party pays another party for a job to be done under uncertainty.[39] In this type of relationship, the principal defines and measures as accurately as possible, and at the lowest cost, the service it expects to get. Uncertainty can blur the attribution of the results and an asymmetry of information may allow the agent to shirk, underproduce, or save on costly attributes of the service under purchase. Over the last decades, technology—such as tablets, digital cameras, and cloud computing—has enabled a substantial reduction in the cost of collecting and reporting information on human behaviors and resources, including services delivered by health providers. This has encouraged the emergence of new provider payment methods and their expansion worldwide. For instance, today, more than 30 LMICs are piloting or scaling up PBF schemes. PBF compensates health facilities according to the quantity and quality of services they have provided to the population.[40] Digital technologies allow the implementation of contracts with sophisticated definitions of performance and tailor them to the behaviors of targeted providers and the users themselves. New data collection techniques—such as tablets, Internet of Things (physical devices, such as refrigerators for vaccines, that are embedded with electronics, software, and sensors, allowing them to connect and exchange data), and wearable health technology—are expected to increase the granularity of collected data and improve contractual terms in the future.

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Efficient Enforcement of Contracts

The execution and payment of contracts requires checking whether the providers deliver;

monitoring how they adapt to incentives, which includes detecting fraud; and processing payments. The cloud-based solutions developed for PBF illustrate well how technology is a key enabler of contract enforcement. For example, Open Results-Based Financing (OpenRBF) software (http://www.openrbf.org/) allows PBF purchasing agencies to enroll facilities, define performance indicators, collect performance data from facilities, verify the data, organize payments to facilities, produce invoices for the scheme sponsors, produce an analytical dashboard, and report publicly on health facility performance. Efficient enforcement of contracts also requires leveraging synergies with existing data systems. A new version of OpenRBF has been developed on the District Health Information System 2 platform (https://www.dhis2.org/), which is used in many LMICs as a routine health information management system. Another way to be efficient is to reduce redundancies in paperwork. Under output-based payments, verification of data and activities is necessary, as performance-based contracts can result in providers overreporting activities or inventing fake users. A growing number of PBF programs use tablets for data verification: field verifiers enter data during their visits of health facilities and households and then transfer the data to the purchasing agency. Verification in PBF programs can be costly; one proposal is to move from exhaustive verification to risk-based verification.[41] Benchmarking and algorithms are expected to help to identify facilities presenting a risk, such as outlying performance. More fundamentally, digital progress elsewhere in the health system—unique identifiers for each user, better electronic patient records, and direct access to patients through phones—will significantly reduce the need for physical verification.

Digital strategies can help automate the learning process, especially when iterative data analyses are involved.

Traditionally, principal–agent models assume that principals are loyal contractors who respect contractual terms. In LMICs, this is a strong hypothesis: the purchaser—governments, in particular—can encounter budgetary or cash-flow problems leading to delayed payments; for example, its own health or treasury administration can also be unreliable and inefficient. Digital tools can limit opportunism by the principal by enhancing the integration of the payment system with the banking system, moving to mobile payment[22,42] and maybe, in the future, using blockchain solutions to log transactions, such as the one developed by the startup Disberse (http://disberse.com). At the same time, open digital dashboards, such as Data Viz (https://bluesquarehub.com/services/data-viz/), can enhance transparency and—in limited circumstances, such as the presence of trained data journalists or activists—accountability.

Learning

Learning is a crosscutting function at the heart of purchasing and of UHC piloting, more broadly.[43] In many LMICs, paper-based systems introduced by different schemes or vertical programs have led to the fragmentation of data and underutilization of information for governance and resource allocation. In reality, data-driven learning requires openness, proactivity, curiosity, analytical skills, time, and readiness to change our own and others' preset notions at the risk of engaging in disagreements and conflicts. Digital strategies can help automate the learning process, especially when iterative data analyses are involved. Several examples exist in the digital health world where program managers and various stakeholders can view real-time data via smart dashboards and data visualization software. Algorithms to aid decision making—such as a recommendation to change the price for some services to boost their production or identifying and handling outlier facilities—and artificial intelligence will feature more as technology evolves. We highlight the importance of developing collective intelligence within the international community of health financing experts. Digital tools have facilitated the setup of communities of practice and expert networks, such as the Harmonization for Health in Africa Communities of Practice (http://www.healthfinancingafrica.org/) and the Joint Learning Network (http://www.jointlearningnetwork.org/).[44] The PBF Community of Practice, which currently has more than 2,000 users, is, for example, the leading user of the collaborative platform Collectivity (http://www.thecollectivity.org/).

DISCUSSION AND CONCLUSION

Institutional arrangements are key to not only structuring transactions but also to achieving the overall collective action required for progress toward UHC. The main objective of this paper was to explore how digital solutions could contribute to the effectiveness of health financing institutional arrangements in the context of LMICs and to recommend future directions for research and innovation in this space. We illustrated health financing issues and solutions using digital health strategies that are already in place or are currently

being piloted, in order to highlight some key principles for the development of a fair and efficient health financing system. In the process, we presented our critical appraisals of some recent digital health financing strategies and highlighted gaps that need to be addressed, especially with respect to equity concerns, in order to consolidate the UHC agenda. Obviously, achieving UHC is a long-term endeavor, requiring action at both the global and country level. The main challenges to reaching UHC are not technological, they are political, financial, and organizational.[43] While the contribution of digital solutions is partial and dependent on progress made by the other building blocks of the health system, digital solutions can still play an important role as enablers and levers for change.

The Box provides a list of possible gains generated by digital solutions for health financing. This list should be interpreted with caution. In this review, we have not provided scientific evidence to support the effectiveness of the digital solutions under consideration; to our knowledge, such evidence does not exist. This is obviously a major limitation of our work, and it inspires 3 main reflections.

First, we posit that this lack of scientific evidence does not equate to a lack of knowledge, learning, and evidence. Those who work in the digital industry do focus on learning and validating their innovations in digital strategies for health financing. Investors back innovators to the extent that their solutions gain enough 'traction' from customers, including revenue generation. In search of market validation, entrepreneurs implement fast learning cycles[45]: they are not afraid to fail, as long as they fail fast and can learn, adapt, and 'pivot.' As much as possible in our review, we provided figures about customers adopting applications and countries using innovations for their digital strategies; for digital entrepreneurs, these are the key metrics to focus on. Willingness to pay is a strong indication of value creation.

Second, more scientific research on digital strategies for health financing is needed. Enthusiasm and 'disruptive' vision are important drivers for social change, but there are at least 2 reasons to advocate for more critical assessment by scientists: (1) some digital solutions are promoted by their developers as generating benefits for vulnerable groups with limited collective agency and (2) most solutions aim at public budgets for their long-term funding. It is crucial that long-term health impacts are proven; however, an appropriate research agenda has yet to be developed. Some of the gains digital solutions bring are obvious—for example, digital platforms improve the quality and timeliness of data—and do not seem to require research. For other aspects, it is sometimes difficult to isolate the actual contribution of the digital solution from the health financing scheme in which it is embedded. For instance, countries will rarely consider implementing a PBF scheme without a data system to process the claims by the health facilities. In such situations, the cost-effectiveness of the digital tool is closely linked to the PBF scheme itself. But some

While the contribution of digital solutions is partial and dependent on progress made by the other building blocks of the health system, digital solutions can still play an important role as enablers and levers for change.

BOX. Untapped Benefits of Digital Solutions for Health Financing

At several levels, digital solutions can contribute to health financing arrangements that support moving toward universal health coverage. They can:

- help users and their relatives overcome cash constraints and the underdevelopment of the bank system (with mobile-money)
- reduce many transaction costs, such as identification of beneficiaries and fast processing of payments, when parties have to contract, such as households with insurers and purchasers with providers
- save time and reduce administrative costs by more efficiently capturing and transferring data by removing, for example, hard copies
- enhance computation of economic data, allowing for more accurate estimates and advanced analysis
- allow a larger pool of providers by structuring the screening of their capacities and creating economic incentives for them to join the pool, such as giving them access to more patients
- allow new contractual terms by capturing and transferring more granular information about users and providers and thus reducing asymmetry of information at different levels
- consolidate trust between parties by allowing greater transparency and accountability
- allow new kinds of analysis, such as benchmarking
- enhance decision making with models and algorithms making use of big data
- allow new kinds of collective learning processes through online communities of practice
- allow the emergence of new actors—such as entrepreneurs and startups—and service providers, bringing more competition and innovation to the overall health financing sector

other gains deserve special scrutiny in the context of UHC. For instance, does the digitalization of a voucher scheme affect the equity of the program; meaning, does it help the most vulnerable populations gain access to the scheme? Does the adoption of tablets for data collection at facility level or biometric-based recognition for user authentication reduce the cost of verification in PBF programs?[46]

Third, we recommend establishing a more proactive stewardship of the overall learning and action agenda on digital solutions for health financing. Several questions will not be resolved by empirical research, but rather through systemic analysis, coherent vision, and coordinated action. We believe that key international organizations like WHO can take a stronger stance on issues such as governance models, interoperability and integration (also, with solutions serving other building blocks of the health system), open source solutions, and open data. Aid agencies have an important role to play beyond funding new technology developments and pilot studies at the country level. They can promote principles and good practices (see, for example, the 10 principles of donor alignment for digital health at http://digitalinvestmentprinciples.org/) as they have the resources and the prescriptive authority to encourage the development of open source solutions, versus the purchase of proprietary systems. A good example of that is the open source health insurance management information system (openHIMIS) developed by the Swiss Tropical and Public Health Institute for the management of district-based community health funds in Tanzania, and is now an open source solution that is available to other countries.[47,48] Aid agencies could also support the emergence of a stronger and more cohesive digital health ecosystem.

The development and adoption of effective solutions that fit well in coherent digital health information architectures will require strong partnerships between entrepreneurs, developers, implementers, policy makers, and funders. One issue will be to find the right balance between creating opportunities for entrepreneurs from the digital industry and protecting LMICs from being trapped in expensive and out-of-control digital developments.

LMICs have to develop their own vision for digitalizing the financing of their health sector; however, they will need to pay particular attention to technological path dependencies, as data systems might be a constraint when it is time to merge risk pools.

For all these actors, there are interesting momentums to seize: several SDG targets, including those outside the health SDG, such as SDG target 16.9 on providing legal identity for all, could structure our global efforts. We hope that this paper will convince some actors to join forces for better solutions for health financing.

Acknowledgments: I am grateful to the experts who responded to our flash consultation on Collectivity (https://www.thecollectivity.org/fr/flash_consultations/7): Abiodun Awosusi, David Collins, Filippo Curtale, Fahdi Dkhimi, Anna Gorter, Pamela Riley, Siddharth Srivastava, Jane Thomason, Nazzareno Todini, and Charlotte Wagenaar. Their input allowed us to considerably enrich this paper with examples of digital solutions. I am grateful to Krishna D. Rao for his guidance on the first version of the text and all the reviewers who commented the subsequent versions of the paper.

Funding: This work was made possible by a grant from the Aetna Foundation, with support from the World Health Organization and The Johns Hopkins University Global mHealth Initiative.

Disclaimer: The content is solely the responsibility of the author and does not necessarily represent the official views of the Institute of Tropical Medicine.

Competing Interests: Bruno Meessen contributed to the emergence of PBF as a global health policy, through technical assistance, research, and knowledge management. He is the lead facilitator of the PBF Community of Practice. He holds minority shares in Blue Square, a firm developing global health software solutions, and coordinates the development of the collaborative platform Collectivity.

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Peer Reviewed

Received: July 20, 2018; **Accepted:** September 12, 2018

Cite this article as: Meessen B. The role of digital strategies in financing health care for universal health coverage in low- and middle-income countries. Glob Health Sci Pract. 2018;6(suppl 1):S29-S40. https://doi.org/10.9745/GHSP-D-18-00271

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ORIGINAL ARTICLE

Digital Technologies for Health Workforce Development in Low- and Middle-Income Countries: A Scoping Review

Lesley-Anne Long,[a] George Pariyo,[b] Karin Kallander[c]

Digital health interventions have the potential to improve the health workforce by supporting training, supervision, and communication. More evidence is needed on the effectiveness of interventions implemented at scale, including the return on investment, the effect of government and donor policies on scale up, and the role of the private sector.

ABSTRACT

The collection of journal articles, systematic reviews, and reports published over the last decade that attest to the potential of digital technologies to achieve health workforce improvements across all aspects of the health system is vast. As a capacity-building mechanism, digital technology has potential for low- and middle-income countries (LMICs) to support development of the health workforce, including those health workers based in remote or rural areas, to train, motivate, support, monitor, and pay them. The purpose of this scoping review to present, at a high level, the state of the evidence and best practices in digital strategies for human resources for health and to propose a roadmap for a research agenda to fill identified gaps in the evidence. A variety of peer-reviewed and gray literature sources were searched using selected key terms related to digital health and health workforce, limited to materials published from 2010 to 2018. More than 70 articles, reports, and blog posts were reviewed, with in-depth analysis of 29 articles. Findings show that a range of digital health solutions for health workforce development have been tested and used, such as for health worker training, provider-to-provider communication and professional networking, and supervision of and performance feedback to health workers. There is some evidence of improved efficiency and effectiveness, at least at the level of pilots or small-scale projects. There is, however, a growing urgency in global health to move beyond small-scale demonstration projects and to define the capital and recurring costs of implementation and scale up of digital health interventions, including the return on investment. The next frontier is to select, adapt, and implement at scale those digital health interventions for health worker development and management found to be most promising.

INTRODUCTION

It is estimated that 2 billion more people will be born around the world over the next 35 years.[1] The challenges facing fast-growing developing countries are serious and real, and the threat of global pandemics as well as increasing morbidity linked to non-communicable diseases (NCDs), such as cardiovascular conditions, cancers, and diabetes, will have dramatic and negative impacts on the health of populations globally.[2,3]

Evidence indicates that where frontline health workers are effectively trained and deployed, there is a reduction in maternal and child mortality, a reduction in the spread of HIV, TB, and malaria, and better management of chronic diseases.[4] Coupled with effective support and supervision, relevant and regular training has the potential to build a health workforce that can extend the reach of quality health care, in particular to poor and marginalized populations.[5] The Sustainable Development Goals (SDGs), especially SDG 3 ("ensure healthy lives and promote wellbeing for all at all ages"), recognize this and emphasize the need for a substantial increase in the recruitment, development, training, and retention of the health workforce, especially in least-developed countries.[6,7] Yet gains in survival are being lost because of weak and fragmented health systems with overburdened and overstressed health workers—too few in number and without the necessary support, training, and supervision that they need.[8]

There is an emerging consensus among researchers, as well as among global leaders and donors, that digital health represents an opportunity for developing stronger health systems to ensure adequate service delivery by frontline health workers.[9] Mobile connections globally now stand at 7.6 billion (with 4.7 billion unique users) and mobile broadband penetration has risen sharply in the last 10 years.[10] Smartphone penetration

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Digital health represents an opportunity for developing stronger health systems.

is already 48%, and predictions are that there will be 5.6 billion smartphones by 2020 with 90% of users in low- and middle-income countries (LMICs).[10]

The collection of journal articles, systematic reviews, and reports published over the last decade that attest to the potential of digital technologies to achieve health workforce improvements across all aspects of the health system is impressive.[11,12] As a capacity-building mechanism, digital technology—comprising the use of computers, tablets, and mobile phones—represents an opportunity for LMICs to train, motivate, support, monitor, and pay health workers. For example, digital health (a term used synonymously with e-health, mHealth, and mobile health in this article) offers a good opportunity to reach cadres such as community health workers (CHWs)[13,14] or health workers in remote and hard-to-reach areas that are routinely underrepresented in human resources for health (HRH) information systems. A comprehensive World Health Organization (WHO) classification of digital health interventions[15] highlights how technology potentially offers opportunities for intelligent devices to automate data collection, disease surveillance, and rapid testing as well as to improve accountability and strengthen the interconnections between frontline health workers, health facilities, and ministries of heath.[14] However, despite this general understanding of its potential benefits, digital health at a national scale is still slow to becoming a reality in many LMICs and there remains limited use of technology for training, communication, and data sharing between health professionals.[10]

The purpose of this article is to provide an overview of the state of the evidence at a high level and best practices in digital strategies for HRH/health workforce development and to propose a research agenda where gaps in the evidence are identified. We used a scoping review approach, a form of knowledge synthesis, which aims to summarize and synthesize evidence to inform practice, programs, and policy and to provide direction to future research priorities.[16,17]

METHODS

A scoping review was conducted using the framework recommended by Arksey and O'Malley[16] and further developed by Colquhoun et al.[17] The framework includes agreeing on clearly articulated questions, listing detailed inclusion criteria, designing a structured search process to locate and select relevant documentation, and agreeing on methods for critically appraising, extracting, and presenting the data.

This review was guided by the following 2 questions: "How are digital technologies potentially usable to improve health workforce capacity, confidence, and motivation?" "How can digital solutions improve monitoring of health staff performance across health system levels?" Documents included in the review were systematic reviews, thematic reviews, and other scoping reviews, as well as articles, reports, and blogs including published and unpublished (gray) literature. We excluded articles or reports that did not focus on LMICs, that considered digital health broadly (across several sectors), or that focused on digital financing or areas covered by the other articles included in this special supplement. We conducted searches on Google, Google Scholar, PubMed, the World Health Organization website, the Broadband Commission Working Group on Digital Health website, and the United States Agency for International Development website, limiting our search to materials published from 2010 to 2018. Search terms included "mobile health", mHealth, "digital health", eHealth, "ICT for health", "frontline health worker", "human resources for health", "health workforce", and "community health worker".

Study selection involved applying the post-hoc inclusion and exclusion criteria based on the specifics of the research questions and on new familiarity with the subject matter after reading the studies. The most promising articles and reports were subjected to an in-depth analysis by the first author, who extracted relevant information using a descriptive analytical method for the contextual or process-oriented information.[17] Examples of literature that were scrutinized included literature that featured successful implementation of digital health programs that provided effective health worker training using mobile devices, improved staff performance, and supported enhanced health service delivery. The descriptive data extracted were organized in conceptual categories to specifically shed light on the strength of current evidence for scaling programs using digital health technologies, as well as the documented weaknesses of that research.

RESULTS

More than 70 reviews, articles, reports, and blog posts were analyzed. A more in-depth review of 29 articles (of which 8 were systematic, thematic, or scoping reviews) and reports informed the views and conclusions presented in this article.

Why Digital Health?

The evidence suggests digital health has the potential to improve the efficiency of the health workforce, advance quality health services coverage, and enable better health outcomes.[18] Digital health solutions that fit into existing health systems functions can support health systems strengthening objectives such as a well-performing health workforce; a functioning health information system; cost-effective use of medical products, vaccines, and technologies; and accountability and governance.[5] Digital technologies can be used to train health workers, facilitate communication between them, provide job aids, and assist with supervision. In a review of the existing literature on use of digital health strategies by frontline health workers, DeRenzi et al.[19] outlined 6 health systems functions that are typically addressed using digital technologies, including access to training and information for health workers, facilitation of communication between health workers, provision of job aids and decision support tools, and assistance with health worker supervision. The evidence to support these strategies is rapidly growing, though yet remains in early stages.[9,19]

In relation to health workforce development specifically, there is a range of digital health interventions with some evidence of effectiveness, at least at the level of pilots or small-scale projects. Huang and colleagues state[20]:

> *There is a voluminous literature on a multiplicity of digital health innovations in middle and low income countries and in recent years a growing number of evaluation studies that have demonstrated beneficial impacts from these interventions.*

Some of the benefits of introducing digital tools into existing systems for health workforce development include access to digital health training content, better support with professional networks, and an expanded role for health workers in active case detection using disease surveillance systems. For example, Cesario et al.[21] find that:

> *Cellular phone use may contribute to the diagnosis and epidemiological surveillance of diseases in areas where physical access is difficult and/or which have limited human resources, medical, and technical equipment.*

Furthermore, Nicole Ippoliti et al.[22] indicate that:

> *Better data for decision making with virtually real-time reporting of services and commodities through a health management information system (HMIS) and logistics management information system (LMIS) improved provider capacity through continuous learning, digital provider tools, and mobile supervision [and] [i]ncreased transparency, efficiency, and accountability through digital financial services.*

Digital tools can also promote continuing professional development to increase knowledge and skills as well as improve health workers' confidence in their day-to-day practice.[23]

Some of the recent research on digital health indicates promising impact and potential to scale, including:

- **Health worker training:** In a correspondence to the *Lancet Global Health*, O'Donovan and Bersin report on how mHealth strategies can be a low-cost, high-impact solution to mapping outbreaks and providing education for both health workers and the public.[24] For example, mobile phones were used by the local community to send free text messages about Ebola to the Government in Sierra Leone, who then created heat maps that health workers could use to track the epidemic. In addition, digital strategies were successfully deployed for health care workers in Liberia where they downloaded onto their phones reference and training materials demonstrating the correct and proper use of personal protective equipment and safe injection and burial practices.
- **Provider-to-provider communication:** A number of digital health applications have been designed as tools to increase communication and professional networking to support health workers, with many concluding that basic mobile phone use along with SMS capabilities can improve CHW efficiency while potentially reducing overall program costs.[25] In Malawi, CHWs were provided with SMS capabilities to report medical supply shortages and communicate both general information and specific information about patients with emergencies.[26] The average cost per communication was about 5 times less expensive using SMS than in areas without SMS service, and reporting was significantly faster. Similarly, in another study using SMS for CHWs providing tuberculosis (TB) and HIV care in Malawi,[27] communication between CHWs and the hospital staff freed up over 2,000 hours of hospital staff time, which resulted in expanded health care delivery capacity and a greater number of TB patients starting treatment.
- **Human resource management:** Supervision of and performance feedback to health workers

Digital technologies can be used to train health workers, facilitate communication between them, provide job aids, and assist with supervision.

is critical to maintaining their motivation, improving their performance, and retaining them in their posts.[28] Digital tools can provide a mechanism for delivering supervision to remote health workers who often work in isolation with little and infrequent support.[29] In sub-Saharan Africa and in rural areas more generally, where health worker coverage is the lowest, digital health offers the promise of maximizing health care worker impact and efficiency.[25,30] In India, for example, CHWs working to reduce malnutrition in their communities who received performance feedback and supportive supervision via mobile phone calls were shown to have improved motivation and performance compared with their motivation and performance before the program.[31] The study suggests that regardless of the performance information disclosed, calls can improve performance due to elements of supportive supervision encouraging CHW motivation. There is also evidence that establishing a high-quality human resources information system can support health workforce management and efficient targeting of limited domestic resources.[12]

Other literature pointed to gaps where additional research is needed, including:

- **Total cost of ownership and implementation**: Although digital health interventions offer the prospect of long-term cost savings, they usually require significant investments upfront as well as regular expenditure on training and maintenance. There has been some research on total cost of ownership[32,33] but mostly with the purpose to develop an advocacy tool to highlight how a certain device or particular software provides the most cost-effective way to deliver digital health programs. There is less evidence on the capital and recurring costs needed to implement and maintain, let alone scale up, a digital health program.
- Linked to this is the need to demonstrate the **return on investment** (ROI) in digital health. Government (largely via donor funding) is likely to be the largest funder of digital health initiatives in developing countries. Digital health stakeholders need to stimulate government investment by demonstrating how digital health solutions help address national health care issues. This is a critical knowledge gap; without longitudinal evidence and in the face of limited examples of digital enterprise architectures delivering better health outcomes, governments and global health donors remain unlikely to prioritize investments into large-scale HRH digital health programs.

Strength of the Evidence

As of 2015, there were more than 6,000 peer-reviewed or gray literature articles or documents on digital health.[10] Evidence on the actual impact of digital health on population health outcomes is still largely lacking in the peer-reviewed literature.[34,35] Bergmo explains[35]:

> *Despite promising results, more evidence is needed on the cost implications of digital health and the degree to which it can improve health outcomes over the short and long term. While there is anecdotal evidence that digital health can bring health benefits, the lack of sufficient rigorous clinical evidence and large-scale studies to confirm this claim is a barrier to investment.*

It is this lack of evidence that presents one of the key challenges to moving digital health approaches from pilot projects to national programs while properly engaging health workers and communities in the process. A common feature emerging from literature published in the last 5 years (i.e., once the initial excitement of digital health innovation began to settle into a valley of 'reality-on-the-ground') is that a major weakness of digital health interventions is that the claimed benefits are unclear and long-term results remain uncertain.[36] David Novillo-Ortiz, coordinator of the Regional eHealth Program of the Pan American Health Organization/WHO, is quoted in the Broadband Commission for Sustainable Development[10] as saying:

> *The big challenge is to ensure the sustainability and continuity of digital health initiatives, whose benefits can sometimes only become apparent after ten to fifteen years. And to accomplish this, it is fundamental to promote the production of scientific evidence to raise awareness among decision-makers about the importance of investing in eHealth.*

While studies may be successful at a small or moderate scale, large-scale or nationwide coverage of digital health interventions to support health workforce development is still rarely reported in the literature. Though rife with a descriptive analysis of the potential of such interventions on health care outcomes, few have empirically assessed the incremental effectiveness of such interventions on health care coverage,

utilization, efficiency, quality, or outcomes.[37] The speed of innovation, including the constant evolution of platforms, the broad range of initiatives and tools, and the heterogeneity of reporting have also made it difficult to uncover and synthesize how digital health tools might be effective.[38] Until the WHO published the classification of digital health interventions in 2018, an absence of shared language and approach to describe digital health interventions made it challenging to compare results across programs.[5] Furthermore, economic evidence for investing in digital health is limited. While often reputed to be cost-effective or cost-saving, the strength of the evidence supporting this assertion is typically considered insufficient to attract significant investment. In a systematic review of the economic evaluations of digital health, unknown cost-effectiveness was listed as one of the top 6 barriers to digital health implementation and a key factor in limited digital health policy investment.[39]

DISCUSSION

Digital technologies, when focused on delivery of care, training, staff performance, and monitoring, have the potential to improve health workforce capacity, confidence, and motivation. With partnerships forming between governments, technologists, NGOs, academia, and industry, the literature suggests there is increasing potential to improve health services delivery and support health workforce development by using digital health in LMICs. By harnessing the increasing presence of mobile phones among health workers, digital health can be used to deliver increased and enhanced health care services to individuals and communities while helping to strengthen health systems.[14]

Digital health use at national scale is slow to becoming a reality in many LMICs despite the general understanding of its potential benefits,[6] and there remains limited use of technology for communication and data sharing between health professionals.[40] Although digital technology can be a highly effective delivery system for national health systems, it, so far, has not been deployed as widely as technologists have anticipated. The research community has struggled to create an evidence base for decision makers to confidently expand digital health pilots to a provincial or national level.[34,35]

There are several well-catalogued reasons for this general failure of pilots being taken to scale. The research points to the lack of coordinated approaches to digital health investments, leading to a fragmented digital health landscape, with multiple pilot interventions or short-term projects that do not include planning for scale or sustainability. Furthermore, traditional development funding flows are often disease- or country-specific, limiting adaptation, inhibiting data sharing, and resulting in inefficiencies.

In addition, until recently, there have been few agreed digital health commons, hubs of best practice, or standardized guidelines to guide implementers and governments in how to develop scalable, interoperable, and sustainable digital health systems for health workforce development. There is some progress in this respect, however: broad consensus around the shared values of digital development are enshrined in the Principles for Digital Development,[41] and guidance has been developed by WHO, the International Telecommunication Union, and others on how to develop and maintain digital health systems at scale.[42–44] Nonetheless, it remains challenging for donors to align funding and activities to support governments to create effective digital systems that are sustainable beyond the term of any one project or program.[45] This despite recommendations urging greater collaboration around investment in digital health systems at national level[46] and commitment from over 20 donor organizations to align around investments in digital health.[47] In fact, it is still not unusual for digital health interventions to be developed and operated without any involvement of national governments. In addition, digital health solutions may be introduced by organizations without clear knowledge of the state of affected countries' information technology infrastructure at national and decentralized levels, making implementation of solutions inappropriate and, in the worst cases, resource-draining.[45]

Digital health use at national scale is slow to becoming a reality in many LMICs.

A Roadmap for Research

Key areas of digital health research needed, as highlighted by the literature, include the following:

Value of scaling up digital health approaches to HRH management and support. Given the clear message from the literature that the case for investing in, and scaling up, digital health remains to be made, areas for additional inquiry include how digital technologies could be leveraged to expand the reach of performance management and timeliness of feedback for CHWs and other frontline health workers not currently being reached, timely updates of data for workforce

planning and projections, cost-effectiveness of continuing education using digital health versus traditional approaches, and updating training needs assessments by regularly reaching out to health workers to ensure training content is well tuned to actual needs on the ground, among others.

Better evidence on the ROI of digital health. This could be addressed in the short term by economic modeling and research into the ROI of digital approaches in other sectors (e.g., the financial and agriculture sectors). In the longer term, the need for better ROI evidence could be addressed by working with governments implementing regional or national digital health strategies, such as the East African Community Digital Health Roadmap (Digital REACH) and the Tanzania Roadmap for Digital Health.

Effect of current donor and government procurement policies on scale up of digital health technologies for health workforce development. Although technology used in health worker training, supervision, and data collection programs is often designed to handle a large volume of information, it is often procured on the basis of single health issues and/or limited to specific geographic regions within countries. Procurement on this basis does not take advantage of the inherent scalability of the technology.

Role of the private sector and philanthropists in digital health. Despite calls for greater engagement of and investment by the private sector and philanthropic investors in taking digital health technologies to scale in a sustainable way, there are few examples of this kind of partnership happening at scale (or at all). This links back to ROI—without a strong business case for investment in national-level digital health infrastructure, the private sector will not move beyond the transactional corporate social responsibility approach to one based on long-term relationship building and investment. More research is needed into the role of the private sector, taking into account the diverse nature of that sector, and philanthropists in developing and implementing digital health strategies and how to engage them more effectively in this space.

The authors propose that an implementation research perspective, involving an iteration of learning by doing, analysis, and selection of the most promising approaches, will help document additional lessons learned and answer some of the remaining critical questions.[48] An approach of 'more of the same' will result in the continued lack of evidence and represent a lost opportunity to leverage the potential capabilities that improved digital technologies can contribute to the health sector.

Strengths and Limitations

The scoping review approach we used has some strengths and limitations. On the one hand, it allows for presentation, in one publication, of the state of evidence on a particular issue that is useful for policy makers wishing to obtain a high-level view of the topic. But in doing so, it misses out on the type of details that some may want to see. As stated earlier, our main purpose was to present a high-level view of the state of evidence for using digital health technologies for health workforce development and to propose areas for further inquiry in the form of a research agenda that donors and researchers may wish to consider.

CONCLUSION

There is an urgent need to provide the evidence that will support a move beyond small-scale, demonstration projects to selecting, adapting, and implementing at scale those digital health interventions found to be most promising. More research is needed to respond to questions about how governments can develop their digital health leadership and harness the dramatic penetration of mobile and web technology to help improve the lives of their citizens. There needs to be a better understanding of how governments can motivate private- and public-sector staff to deliver tangible growth and security through digital health solutions that harness the advances in technology domains such as network speed and efficiency, cloud computing, data connectivity, and data analytics to improve health workforce capacity and improve access to and quality of health care services. An implementation research perspective will help uncover answers to these questions and document additional lessons learned. An ongoing reluctance to examine these bigger issues will lead to lost opportunities to leverage the remarkable capabilities that improved digital technologies have brought to the health sector.

Funding: This work was made possible by a grant from the Aetna Foundation, with support from the World Health Organization and The Johns Hopkins University Global mHealth Initiative.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of The Johns Hopkins University or the Karolinska Institutet.

Competing Interests: None declared.

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Peer Reviewed

Received: April 29, 2018; **Accepted:** September 10, 2018

Cite this article as: Long L-A, Pariyo G, Kallander K. Digital technologies for health workforce development in low- and middle-income countries: a scoping review. Glob Health Sci Pract. 2018;6(suppl1):S41-S48. https://doi.org/10.9745/GHSP-D-18-00167

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The State of Digital Interventions for Demand Generation in Low- and Middle-Income Countries: Considerations, Emerging Approaches, and Research Gaps

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Despite advances in digital technology to generate demand for health services, considerable gaps remain in our understanding of which interventions are effective, which characteristics mediate their benefit for different target populations and health domains, and what is necessary to ensure effective deployment. Future research should examine the long-term effects of, equity in access to, and cost-effectiveness and efficiency of digital demand generation interventions.

ABSTRACT

The recent introduction of digital health into generating demand for health commodities and services has provided practitioners with an expanded universe of potential tools to strengthen demand and ensure service delivery receipt. However, considerable gaps remain in our understanding of which interventions are effective, which characteristics mediate their benefit for different target populations and health domains, and what is necessary to ensure effective deployment. This paper first provides an overview of the types of digital health interventions for demand generation, including untargeted client communication, client-to-client communication, on-demand information services, personal health tracking, client financial transactions, and targeted client communication. It then provides a general overview of 118 studies published between January 1, 2010, and October 3, 2017, that used digital interventions to generate demand for health interventions. The majority (61%) of these studies used targeted client communication to provide health education or reminders to improve treatment adherence, and the most frequently (27%) studied health condition was HIV/AIDS. Intervention characteristics that have been found to have some effect on gains in demand generation include modality, directionality, tailoring, phrasing, and schedule. The paper also explores new emergent digital approaches that expand the potential effect of traditional demand generation in terms of personalization of content and services, continuity of care, and accountability tracking. Applying existing frameworks for monitoring and evaluation and reporting, research on emerging approaches will need to consider not only their feasibility but also their effectiveness in achieving demand generation outcomes. We propose a research agenda to help guide the field of digital demand generation studies and programs within a broader health systems strengthening agenda, including establishing and documenting the influence of intervention characteristics within different populations and health domains and examining the long-term effects and cost-effectiveness of digital demand generation interventions, as well as equity in access to such interventions.

INTRODUCTION

Global efforts to strengthen health systems have predominantly focused on ensuring adequate supply of, and access to, health commodities and services. Yet inadequate coverage on several key indicators of health use persists. Interventions that generate awareness and demand for health commodities and services in an equitable manner are often overlooked but show much promise for addressing 'last mile' populations and achieving the Sustainable Development Goals. Additionally, by increasing demand for health services, there is the potential to improve the quality of health care and to reduce inequities in health services.

The unprecedented reach and use of ubiquitous mobile technology by the general population[1] has driven interest in leveraging digital health for demand generation. Its widespread use and growing sophistication of technical functionality has spawned an array of novel digital approaches to generate demand. Yet the health effects of these interventions have neither been documented nor reported at the same pace as implementation of the digital innovations. The substantial diversity of deployment and generalizability characteristics and factors associated across intervention study design and research settings may explain some of the observed heterogeneity in the reported effects. This

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The Senegal MOHSA sent >4 million SMS messages during the 2014-2015 Ebola outbreak to warn the population about the dangers of the disease and provide prevention guidance.

diversity in implementation practices within limited settings not only has hindered comparisons across outcomes but has also resulted in a limited understanding of the conditions in which digital demand generation approaches can impact health outcomes.

This paper explores the variety of ways in which digital tools have been use to create demand in low- and middle- income countries (LMICs) as well as the factors that have contributed to variability in the evidence base. Additionally, we offer the reader guidance for documenting specific characteristics of demand generation interventions, an overview of emerging approaches aimed at strengthening the potential value of digital demand generation, and a proposed research agenda to further advance this promising field.

TYPES OF DIGITAL HEALTH INTERVENTIONS FOR DEMAND GENERATION

Interventions that generate awareness and demand for health services are a staple in public health.[2–5] Demand generation activities typically fall under 3 categories: (1) enlisting new users to adopt new health behaviors and services, (2) increasing demand among current users, and (3) taking market share from competing or inappropriate behaviors and products.[6] The recently released World Health Organization (WHO) Classification of Digital Health Interventions[7] categorizes the ways in which digital and mobile technologies can address health sector needs and strengthen both health systems and health outcomes. In the following section, we use this classification system to provide examples of digital demand generation interventions for untargeted client communication, client-to-client communication, on-demand information services, personal health tracking, client financial transactions, and targeted client communication.

Untargeted Client Communication

Untargeted client communication, often referred to as mass communication, is defined here as the transmission of untargeted health promotion content in which relatively undifferentiated audiences receive identical communication material.[7,8] Traditionally, untargeted client communication has been conducted through mass media techniques that can easily reach the general public, such as billboards, television, radio, and newspapers.[9,10] The penetration of mobile technologies has since introduced new communication channels to this repertoire of mass communication strategies, particularly through the use of short message service (SMS)/text messages and social media platforms that are able to accommodate a large volume of users. This type of mass engagement has been used during disease outbreaks by ministries of health to transmit generic messages to notify constituents about a public health threat. For example, during the Ebola virus disease epidemic of 2014, the Ministry of Health and Social Action in Senegal transmitted 4 million SMS messages to the general public warning of the dangers of Ebola and telling them how to prevent contracting the disease.[11] Similarly, health promotion campaigns have used untargeted client communication to notify the general population about available medical services or broadcast general information about health behaviors.[12] Due to limited knowledge about the recipients, untargeted client communication usually contains generic content and, therefore, does not address the needs of specific demographic groups. As a result, few evaluations have explored the effectiveness of untargeted client communication using mobile technologies; much of the evidence on untargeted client communication is tied to traditional mass media methods.[9,10,13,14] However, the pervasiveness of mobile technologies provides an opportunity to customize health promotion messaging, potentially shifting the emphasis away from mass communication channels to more targeted client engagement interventions.[9]

Client-to-Client Communication

Client-to-client communication, also known as peer communication, is the interaction between people who share common attributes, such as having similar health conditions, demographics, or prescribed treatments.[7] By harnessing these empathetic and supportive interactions, client-to-client communication is uniquely positioned to influence behavior change and generate demand. Early forms of digital peer communication took place in online platforms such as social media networks, chat groups, and blog communities. For example, QuitNet—a smoking cessation program connecting current and former smokers—was one of first digital peer-communication mechanisms conducted over a web-based platform.[15]

While this virtual social support group model has been replicated across a variety of health areas, the general effectiveness of online groups on behavior change depends on a variety of factors, including a participant's level of engagement.[15–18] Client-to-client communication conducted via mobile technologies, such as SMS and social media platforms, continues to grow in LMICs.[19–22] For example, Project Khuluma, in South Africa, illustrates the use of mobile phones as the way a closed user-group—in this case, adolescents living with HIV—is able to communicate among themselves.[19]

On-Demand Information Services

On-demand information services—defined here as health information accessible to the general public when triggered by the client[7]—are available via websites, helplines, SMS/text-messaging menus, or client applications, among other channels, and may be used to inform decision making. However, the defining feature of on-demand information services is that it relies on individuals to proactively initiate contact with the health system or information service. In its online form, on-demand information services can be as pervasive as the use of medical information websites such as WebMD. Increasingly, these types of health information services are being optimized for mobile devices and use in areas with low Internet connectivity, thus overcoming barriers related to Internet accessibility. Through these mobile phone-based modalities, clients can access health information by sending a message to an advertised number known as a short code. Documented examples of this intervention include platforms used by the Engage-TB approach and the Mobile for Reproductive Health (M4RH) project, whereby clients navigate through a menu of options by texting codes to specify the type of information they are seeking.[23] The use of on-demand information services enables clients to determine the timing and content of the health information and reduces concerns related to client confidentiality, a common challenge associated with targeted client communication.[24–26] Evidence for this type of client engagement in LMICs, particularly related to sexual and reproductive health,[27] is emerging; studies to date have demonstrated its effectiveness in improving client's knowledge and awareness of health behaviors.

Personal Health Tracking

Personal health tracking uses digital devices, such as mobile applications, wearables, and sensors, to document and monitor a client's health status.[7] Clients may use personal health tracking services in a variety of ways, including accessing their own health records, monitoring their health or diagnostic data through wearable tracking tools, and actively documenting or journaling their health information. This approach to demand generation requires clients to proactively monitor their health data and facilitates increased personalization of their health care. However, more evidence on the effectiveness of this digital approach for improving health behaviors and linkages to health services is needed, and questions remain about the potential harm of unregulated digital applications for personal health tracking.[28,29]

Client Financial Transactions

Client financial transactions are another common mechanism to generate demand for the use of health care services and to improve health outcomes. Traditionally, these type of transactions included the provision of vouchers, monetary incentives, or nonmonetary incentives to assist with out-of-pocket payments incurred by clients when seeking health services. With increasing mobile phone penetration, financial services—including savings, insurance, credit, banking, and payments—have rapidly been integrated into mobile phone applications and mobile network operators in what is known as mobile money.[30] Although several systematic reviews have concluded that conditional and unconditional cash transfers and small incentives can improve health outcomes in LMICs,[31–34] only a few studies have provided transfers via mobile money, airtime, or mobile-redeemable vouchers.[35–37] Existing evidence suggests that the timing, frequency,[37] and modality (i.e., airtime or mobile money)[38] of mobile-money transfers are important factors that affect the efficacy of client financial transactions on health outcomes. Studies using conditional incentives have also found differences in health outcomes and health care use by the incentive amount, although these studies did not use mobile money.[39–42] In one randomized controlled trial that provided conditional mobile-money incentives to Kenyan caregivers, the US$2.50 incentive was found to have significantly increased the proportion of children who were fully vaccinated, while the US$1.00 incentive that was given

The use of on-demand information services enables clients to determine the timing and content of the health information and reduces concerns related to client confidentiality.

BOX. Literature Review Methods

On October 3, 2017, we searched the PubMed database for the following terms:

- ("text message" OR "text messaging" OR "short message service" OR "SMS" OR "text reminder" OR "voice reminder" OR "voice message" OR "interactive voice response" OR "IVR" OR "mHealth") AND
- ("Randomized" OR "randomised" OR "RCT") AND
- Country names for all LMICs

Titles and abstracts were screened for the following inclusion criteria:

- Randomized study design with a comparison group
- SMS or voice messages used to remind or inform clients about a health behavior
- Study conducted in an LMIC, as defined by the World Bank
- Study published from January 1, 2010, to October 3, 2017

Data for included studies were abstracted by one of the authors and were tabulated for each of the following variables:

- Year of publication
- Region: Latin America, Eastern Mediterranean region, sub-Saharan Africa, East Asia Pacific, Southeast Asia, South Asia
- Health outcome: Treatment adherence was defined as studies sending messages (reminders or information) to promote a health behavior that did not require participants to attend a health facility. Health care use was defined as a study that required participants to attend a clinic for a provided service.
- Type of health condition

Limitations: This was not an exhaustive literature review and its findings should be interpreted with caution. We only searched 1 database, did not include information from gray literature, and only included English language articles. The aim of this review was to provide a general overview of intervention studies using SMS or voice messages to generate demand for health interventions. WHO is currently developing guidelines on the comparative value of different digital health interventions based on a series of systematic reviews that are currently underway.

Abbreviations: IVR, interactive voice response; LMIC, low- and middle-income country; RCT, randomized controlled trial; SMS, short message service.

to a randomized group showed no significant effect.[43]

Targeted Client Communication

Targeted client communication is defined here as the transmission of targeted health information "in which separate audience segments (often demographic categories) benefit from a shared message."[7,8] Targeted communication can also be further customized according to an individual's specific needs, resulting in "tailored client communication," whereby message content is matched to the needs and preferences of an individual.[8] While this type of communication can be unidirectional and bidirectional, initial contact is from the health system. This contrasts with on-demand information service to clients, where the client initiates the first contact with the health system. In high-income countries, targeted client communication sent via postal mail, automated telephone calls, email, and, more recently, SMS messages, have been successful at increasing several forms of health care use.[44–49] For example, a systematic review found that reminder and recall interventions increased immunization rates by 5% to 20%.[45]

Targeted client communication originates from the health system and can be tailored to address the needs and preferences of an individual client.

Although postal and email reminders have demonstrated value in high-income countries, limited access to such services in LMICs hinders their implementation and viability. The increasing global availability of mobile phones provides alternative avenues for targeted client communication through the use of SMS and voice messages, mobile phone apps, and social media channels. Moreover, a growing body of literature has documented the efficacy of digital targeted client communication interventions, particularly through SMS, to improve health system performance and health outcomes in LMICs.[50–55] MomConnect, a nationally scaled program supported by the South African Department of Health, provides a series of demand generation services to communicate stage-based pregnancy information to pregnant women and new mothers via SMS messaging and a mobile website. From August 2014 through April 2017, MomConnect

TABLE 1. Summary of SMS and Voice Reminder Studies That Included Comparison Groups and Were Conducted in Low- and Middle-Income Countries (N=118)

	No. (%)
Year of publication	
2010	1 (0.8)
2011–2012	16 (13.6)
2013–2014	23 (19.5)
2015–2016	53 (44.9)
2017 (through October 3)	25 (21.2)
Region	
Latin America	9 (7.6)
Eastern Mediterranean (Iran, n=14)	19 (16.1)
sub-Saharan Africa (Kenya, n=12)	43 (36.4)
East Asia/Pacific (China, n=25)	25 (21.2)
Southeast Asia (Malaysia, n=5)	8 (6.8)
South Asia (India, n=9)	14 (11.9)
Health outcome (n=130)[a]	
Treatment adherence	79 (60.8)
Health care seeking	51 (39.2)
Types of conditions (n=124)[b]	
Reproductive health	11 (8.9)
Child health	14 (11.3)
Acute illness or behavior	15 (12.1)
Lifestyle	15 (12.1)
HIV/AIDS	32 (25.8)
Cardiovascular	13 (10.5)
Diabetes	9 (7.3)
Screening visits	5 (4.0)
Other	10 (8.1)

[a] Some studies examined both health care seeking and adherence.
[b] Some studies examined multiple types of health conditions.

registered 1,159,431 pregnancies, which corresponded to half of women attending their first antenatal care visit.[56]

OVERVIEW OF DIGITAL TARGETED DEMAND GENERATION STUDIES

We conducted a landscape literature review to identify published studies that used digital client communication to improve health outcomes in LMICs (Box). Since the seminal publication in 2010, which found SMS reminders improved antiretroviral drug adherence and lowered HIV viral loads in Kenyan adults,[57] the number of published studies examining digital client communication has increased from 16 in 2011–2012 to over 50 studies in 2015–2016 (Table 1).

Of the 118 studies identified, the majority (61%) used targeted client communication to provide health education or reminders in order to improve treatment adherence and other health behaviors that do not require clinic visits. In terms of geographic scope, 51% (n=60) of studies were conducted in 4 countries: China (n=25), Iran (n=14), Kenya (n=12), and India (n=9). The most frequently studied health condition was HIV/AIDS (n=32, 26%). The majority of identified studies were 2-arm studies, where the intervention's effect on the study outcome was compared to a control or standard of care group. Within this field, trials have evaluated the effect of client communication interventions on, for example, HIV treatment adherence,[57–59] prevention of mother-to-child HIV transmission,[60,61] HIV testing,[62,63] and voluntary medical male circumcision (VMMC).[64,65]

With the likely exception of SMS reminders for HIV-treatment adherence,[66,67] the small number of studies, diversity in study populations, and heterogeneity in study designs and intervention characteristics not only have hindered comparisons across outcomes but have also resulted in a limited understanding of the conditions in which digital demand generation approaches can impact health outcomes. WHO is currently developing guidelines on the comparative value of different digital health interventions; a series of systematic reviews will be conducted on these topics in order to inform recommendations.[68]

KEY INTERVENTION CHARACTERISTICS THAT MAY INFLUENCE CLIENT COMMUNICATION

Key intervention characteristics of digital client communication that have been found to have some effect on gains in demand generation include modality, directionality, tailoring, phrasing, and schedule.

Approaches to digital demand generation are distinguished by characteristics of the intervention. Key intervention characteristics of digital client communication that have been studied and found to have some effect on gains in demand generation include: (1) modality, (2) directionality, (3) tailoring, (4) phrasing, and (5) schedule (Table 2). In this section, we briefly discuss each of these characteristics and provide examples of studies

TABLE 2. Intervention Characteristics of Targeted Client Communication

Deployment Characteristic	Definition
Modality	To which communication channel (voice, SMS/text, social media platform) were messages sent?
Directionality	Were messages one-way or two-way; provider to client and/or client to provider?
Tailoring	Were messages sent with information specific to the client, such as messages that include the client's name, the nearest or most appropriate clinic to receive services, or address a particular set of risk factors.
Phrasing	Were messages sent to inform or to motivate a client?
Schedule	When and how frequently were messages sent? For example, SMS reminders sent at 10am, 3 days and 1 day before child's vaccination date.

that seek to establish the relative gains by varying the intervention characteristic.

Modality

The vast majority of client communication interventions rely on SMS or USSD (unstructured supplementary service data), though interactive voice response and communication via social media platforms are gaining prominence.[69–72] SMS, compared to voice, has been more frequently deployed because of its ability to function in the absence of a stable network signal. Few studies have directly compared the performance between voice- and SMS/text-based messages. One study found that SMS and voice reminders performed similarly with regard to increasing attendance at pediatric HIV appointments in Cameroon.[73] The increasing use of social media platforms, such as Facebook Messenger and WhatsApp, in LMICs provides a growing user base that supports not only SMS/text-based messaging but also more sophisticated communication content and interactivity, which warrants additional research.

Directionality

Interactive, or two-way, messaging may be preferred by implementers, as it allows for an exchange of information between client and provider and also between clients. In South Africa, participants randomized to either one-way SMS or interactive SMS groups had similar reductions in systolic blood pressure, compared to the control group.[74] A study including Ghanaian female students found that the interactive SMS group had higher gains in reproductive knowledge than the one-way group at 3 months and 15 months follow-up; the secondary outcomes of self-reported pregnancy and risky sexual behaviors by study arm had mixed results.[75] The type of health outcome or behavior and its frequency, whether a one-off or repetitive behavior, like treatment adherence, are likely factors in determining if one-way or interactive client targeted messages are needed. It is important that issues such as the modality and client privacy are considered, particularly with the use of SMS messaging for sensitive health conditions.

Tailoring

Tailoring is defined as "any of a number of methods for creating communications individualized for their receivers with the expectation that this individualization will lead to larger intended effects of these communications."[8] Tailoring can be as simple as providing a client's name or as sophisticated as leveraging a stored record detailing client characteristics in order to adapt and personalize demand generation content to a client's evolving needs over time. In a sample of Zambia U-Report SMS platform subscribers, no observed differences were made in both self-reported and clinic-verified VMMC between control, non-tailored, and tailored SMS groups, where the tailored group received messages targeting their intention level for VMMC.[65] In contrast, a randomized controlled trial conducted in South Africa and Uganda found that non-tailored reminders significantly improved VMMC.[64] Similar to the Zambia U-Report, a study in Iran showed no differences in hemoglobin A1c levels between control, non-tailored, and tailored SMS groups in participants with type 2 diabetes.[76] Despite these representative examples, the use of tailoring merits further consideration and research, particularly since it can target key client characteristics. Although numerous studies have assumed the benefits of tailoring targeted client

communication in the design of the intervention, very few studies have sought to assess the added gains in the personalization of client-targeted communication.

Schedule

The scheduling of messages is an important characteristic of targeted client messaging. Scheduling refers to the time of day, frequency, and timing of messages sent in relation to an event or behavior, such as an SMS sent 3 days before an immunization appointment. In rural Kenya, investigators found that participants who received weekly SMS reminders were more likely to adhere to HIV treatment at 48 weeks than those who were not sent reminders or those who were randomized to receive daily SMS reminders.[62] In South Africa, the scheduling and phrasing of messages—motivational vs. informational—resulted in different effects. Participants who received 10 motivational messages had significant gains in HIV testing compared to those who received 3 motivational messages, whereas no differences were identified between informational messages and their frequency.[62] In randomized trials lacking control groups, no significant differences were seen in smoking cessation rates between those who received high-frequency or low-frequency SMS in China[77] and mammogram screening rates between those who received a single SMS and those who received 2 messages in Lebanon.[78] These results highlight that there may be a minimum threshold for the number of messages to produce an effect as well as a saturation threshold if too many messages are sent.

Phrasing

Like scheduling, the phrasing of the messages has been associated with the uptake of health services. In the same Kenyan study described earlier, no significant differences were shown between short and long messages—"This is your reminder." versus "This is your reminder. Be strong and courageous, we care about you."—on HIV treatment adherence measured at 48 weeks.[59] In South Africa, participants who received 10 motivational messages were more likely to seek an HIV test than those who received 10 informational messages.[62] The informational messages simply provided statistics about HIV testing, whereas the motivational messages indicated that HIV was not a death sentence, free drugs were available, and you could live a long life with HIV. Although it is not clear if the phrasing of messages has had an impact on health-seeking behaviors, it is likely that the phrasing is specific to study populations and health outcomes. Qualitative studies should be conducted with potential message recipients to optimize the content of messages, particularly for sensitive conditions such as HIV.[79]

Summary

The observed heterogeneity in digital demand generation efficacy studies may be explained by both the content and the characteristics of the intervention. To that end, it is important that researchers and practitioners document the details of digital interventions so others can replicate the studies and so we can better understand what elements of digital demand generation approaches do and do not work. To that end, the WHO mHealth Technical Evidence Review Group has published an mHealth evidence reporting and assessment checklist to help improve the quality and reporting of digital interventions.[80] Lastly, although intervention characteristics are described through the example of targeted client communication, these characteristics can also be applied to other forms of demand generation, such as untargeted client communication, client-to-client communication, and on-demand information services.

Research results have highlighted that there may be a minimum and maximum threshold for the number of messages to produce an effect.

EMERGING APPROACHES

Although they have not yet been captured in the scientific literature, a number of emerging approaches aim to strengthen the value of digital demand generation interventions and reflect the evolving sophistication of digital solutions globally and the growing familiarity of users with digital tools locally. These approaches include integrating demand generation with systems focused on unique identification and persistent health records, capturing information about receipt and effect, leveraging new messaging platform channels to reach additional users, and using artificial intelligence for enhanced personalization, wearables, and natural language chatbots.[81]

With the advent of social media platforms and the integration of digital demand generation approaches with identification systems and persistent records, including electronic medical record systems, digital demand generation approaches could be better positioned to also account for services received. Such systems could facilitate informing actual demand generation content and support measuring the effectiveness of specific digital demand generation interventions on expected and unintended outcomes, which, in turn, could

Integrating digital demand generation approaches with identification and record systems could help inform demand generation content and support measurement of expected and unintended outcomes.

inform personalization strategies. Furthermore, digital demand generation interventions that support client registration can link clients into national record systems and populate reporting indicators. The challenge of integrating these systems is ensuring that ethical data standards and client privacy concerns are appropriately addressed.

To ensure rigorous evaluations of digital health interventions along each stage of its maturity, WHO recently released guidance for monitoring and assessing digital interventions.

The increasing familiarity with SMS and interactive voice response, access to mobile-money systems, and the availability and use of WhatsApp, Facebook, Weibo, and other social media platforms has facilitated narrowcasting messages to specific target audiences and personalizing autonomous interactive demand generation messaging through natural language processing and use of artificial intelligence in LMICs. Increasingly, digital demand generation approaches will be able to apply algorithms to identify clients in need of information or at risk of not adhering to their treatment protocols, who would, for example, benefit from a customized combination of financial incentives and personalized messaging delivered through specific channels with content designed for the intended beneficiary based on their personal motivations, health profile, and history of care.

A PROPOSED RESEARCH AGENDA

The growing evidence base has begun to show that many digital demand generation approaches offer value; however, to what extent depends on the health program area, message content, and population and intervention characteristics. Future research will need to establish and document the influence of intervention characteristics, as highlighted above, within different populations and health domain areas. Rigorous studies that evaluate novel applications of digital demand generation approaches are still needed, as are studies that assess the additive benefits of each of the described intervention characteristics. This could be done through randomized controlled trials or, for scaled programs, implementation science or adaptive randomized studies. Although the majority of the identified literature has come from efficacy trials, many of which could be described as small pilots, digital interventions are gradually being brought to scale. To ensure rigorous evaluations of digital health interventions along each stage of its maturity, WHO recently released a monitoring and evaluation guide for digital interventions.[82]

Aside from conducting additional efficacy trials, larger questions must be asked about the generalizability and equity of previously conducted studies (Table 3). Much of the research shows short-term improvements associated with messaging and financial transactions; however, additional studies are needed that examine the long-term effects of these interventions. Additionally, many uncertainties remain, questioning whether employing these demand generation approaches exacerbates existing inequities. In many published reports, investigators provided a mobile phone[59] or required mobile phone ownership for enrollment.[61,83,84] The digital intervention may differentially benefit those who have access to mobile phones, technology literacy, or can afford the service. As the tested digital health intervention shifts from solely being a research concept to a routine tool for strengthening health services, the intervention needs to not only generate demand but also be measured against an accurate denominator of all eligible populations and reflect on any disparities in accessing the intervention. Future research should address sensitivities surrounding equity and potential disparities that may be perpetuated by digital demand generation approaches, including how device ownership or sharing may mediate the reach of the intervention. Lastly,

TABLE 3. Generalizability Considerations of Intervention Studies

Characteristic	Considerations
Recruitment site	Were participants recruited from a clinic, the general population, an opt-in from mobile network operator service, or a promotional advertisement?
Enrollment eligibility	Were inclusion/exclusion criteria generalizable to a larger population (e.g., mobile phone ownership was not required to participate in study)?
Equity	Were study findings equal across all subgroups? Did interventions reach marginalized populations? Were there trends in sharing mobile phones across some populations, which could have mediated effects?
Follow-up length	At what time point was the efficacy of an intervention assessed?
Target denominator	Was the denominator for the target population a known entity?

additional studies that examine the cost-effectiveness and efficiency of digital interventions, compared to currently used systems, will provide vested stakeholders with the information needed to bring digital demand generation approaches to scale.

CONCLUSION

The recent introduction of digital health into demand generation has provided practitioners with an expanded set of potential tools to strengthen demand and ensure service delivery receipt. Although this paper primarily discussed the predominant forms of digital demand generation interventions in the published literature, the field of digital health is rife with innovations and continues to evolve with the rapid sophistication of digital tools. As the capabilities of digital tools advance, a new wave of research will need to explore the emerging trends of digital technologies and how they may be harnessed to improve demand generation. Applying existing frameworks for monitoring and evaluation and reporting, research on emerging approaches will not only need to consider their feasibility but also their effectiveness on achieving demand generation outcomes.

Acknowledgments: We thank the reviewers of this manuscript for their insightful feedback.

Funding: This work was made possible by a grant from the Aetna Foundation, with support from the World Health Organization and The Johns Hopkins University Global mHealth Initiative.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of The Johns Hopkins University or the World Health Organization.

Competing Interests: None declared.

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Peer Reviewed

Received: April 29, 2018; **Accepted:** September 8, 2018

Cite this article as: Gibson DG, Tamrat T, Mehl G. The state of digital interventions for demand generation in LMICs: considerations, emerging approaches, and research gaps. Glob Health Sci Pract. 2018;6(suppl 1):S49-S60. https://doi.org/10.9745/GHSP-D-18-00165

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ORIGINAL ARTICLE

Strengthening Delivery of Health Services Using Digital Devices

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Delivery of high-quality efficient health services is a cornerstone of the global agenda to achieve universal health coverage. Digital health interventions for service delivery, such as digital health-enhanced referral coordination and mobile clinical decision support systems, demonstrate considerable potential to improve the quality and comprehensiveness of care received by patients but require greater standardization and engagement of health workers at different levels of the health system for effective scale up.

ABSTRACT

Background: Delivery of high-quality efficient health services is a cornerstone of the global agenda to achieve universal health coverage. According to the World Health Organization, health service delivery is considered good when equitable access to a comprehensive range of high-quality health services is ensured within an integrated and person-centered continuum of care. However, good health service delivery can be challenging in low-resource settings. In this review, we summarize and discuss key advances in health service delivery, particularly in the context of using digital health strategies for mitigating human resource constraints.

Methods: The review updates the foundational systematic review conducted by Agarwal et al. in 2015. We used PubMed, EMBASE, and CINAHL to find relevant English-language peer-reviewed articles published 2018. Our search strategy for MEDLINE was based on MeSH (medical subject headings) terms and text words of key articles that we identified a priori. Our search identified 92 articles. After screening, we selected 24 articles for abstract review, of which only 6 met the eligibility criteria and were ultimately included in this review.

Results: Despite encouraging advances in the evidence base on digital strategies for health service delivery, the current body of evidence is still quite limited in 3 main areas: the effectiveness of interventions on health outcomes, improvement in health system efficiencies for service delivery, and the human capacity required to implement and support digital health strategies at scale. Two particular areas, digital health-enhanced referral coordination and mobile clinical decision support systems, demonstrate considerable potential to improve the quality and comprehensiveness of care received by patients, but they require a greater level of standardization and an expanded scope of health worker engagement across the health system in order to scale them up effectively.

Conclusions: Additional research is urgently needed to inform the effectiveness of interventions on health outcomes, improvement in health system efficiencies, and cost-effectiveness of service delivery. In particular, more documentation and research on ways to standardize and engage health workers in digital referral and clinical decision support systems can provide the foundation needed to scale these promising approaches in low- and middle-income settings.

INTRODUCTION

Delivery of high-quality efficient health services is a cornerstone of the global agenda to achieve universal health coverage. According to the World Health Organization (WHO) framework of health system building blocks, health service delivery is considered to function well when equitable access to a comprehensive range of high-quality health services is ensured within an integrated and person-centered continuum of care.[1] However, good health service delivery can be challenging in settings where human and health system resources are scarce. For instance, health workers in low-resource settings may be faced with inadequate access to training and reference materials, poor-quality communication systems for feedback from experts or supervisors in the diagnosis and management of complex cases, and difficulty maintaining patients within the continuum of care through follow-up visits or referrals, thereby impacting the quality of health services they can deliver.[2]

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Similarly, accessing health services, according to individuals' needs and preferences, at the various levels of the health system may be challenging due to logistical and financial barriers. In recent years, the considerable mobile-cellular infrastructure has been leveraged to mitigate some of these challenges in health service delivery, for instance, by facilitating task shifting of health service delivery from facility-based providers to frontline health workers.[3] In these task-shifting applications, mobile devices have been used to provide training content on-demand, enable communication between different cadres of health workers, implement clinical decision support systems, and provide work-planning and scheduling tools. There is growing evidence that such 'digital health' strategies can help improve access to and quality of health service delivery, which, in turn, can improve health outcomes for otherwise underserved populations.[4] Although rural–urban differences in access to and uptake of mobile technology remain, significant progress toward increasing universal access has been made. For instance, it is estimated that global mobile–broadband subscription growth rates grew more than 20% annually in the last 5 years and are expected to reach 4.3 billion by the end of 2017.[5]

In this review, we summarize and discuss key advances in health service delivery, particularly in the context of using digital health strategies for mitigating human resource constraints. We focus the discussion on clinical decision tools and digital referral systems and how recent innovations within these areas have contributed to improvements in health service delivery. We also analyze and discuss gaps in the current evidence base on the effectiveness of the digital health service delivery interventions on health care use, efficiency, and outcomes. Finally, we provide recommendations for and highlight challenges in scaling up digital health service delivery strategies within health systems.

The scope of the literature review was based on 5 potential areas for strategic focus from the WHO framework of integrated patient-centered services.

METHODS

The purpose of this literature review is not to serve as a comprehensive systematic review of all relevant published articles but rather to identify important new evidence on digital strategies for health service delivery that may advance the current body of knowledge and practice. The scope of the review was based on the framework on integrated patient-centered health services.[6] This framework includes 5 potential areas of strategic focus.[6] Digital health interventions, which support a model of care (strategy 3, mobile clinical decision support systems) and coordination of health services (strategy 4, digital referral systems), are discussed in this review. Other reviews in this supplement describe digital health interventions for demand generation (strategy 1) and governance (strategy 2). For this review, we included peer-reviewed studies from high-, middle-, and low-income countries, which described implementation and evaluation of digital strategies for improving health service delivery (Figure).

Our review is based on the foundational systematic review done by Agarwal et al. in 2015.[7] Our search strategy incorporated the key search terms from the Agarwal et al. review, which included variations and combinations of terms for mHealth (mobile, phone, cell phones, information and communication technology, cellular phone, mobile device, SMS, text message, interactive voice response) and health workers (frontline worker, health worker, community health worker, traditional birth attendants, lay worker, village health worker, midwife, health auxiliary, peer health worker, medical auxiliary, health provider, lay advisor, lay counselor, lady health worker, and lay educator).[7] To this, we added variations and combinations of key search terms for service delivery (health service, service availability, service readiness, health facilities, service quality, service coverage, service coordination). We then updated the review via a literature search using the databases on PubMed, EMBASE, and CINAHL for relevant publications published between 2015 and 2018. We restricted our searches to studies published in English and developed a search strategy for MEDLINE based on MeSH (medical subject headings) terms and text words of key articles that we identified a priori.

The updated search resulted in 92 peer-reviewed articles. One of the authors screened the articles and identified 24 abstracts for final review. Two of the authors worked independently and in duplicate to review titles, abstracts, and full-text versions of the identified articles. The inter-rater agreement was 92%. The discrepancy was with 2 articles. After a face-to-face discussion, the reviewers agreed that the 2 studies should be excluded because the studies reported on feasibility and pilot study protocols that did not add to the body of evidence about health care delivery using digital health. Only 6 articles met the eligibility criteria for the review.

FIGURE. Strategic Focus Areas of the Integrated Patient-Centered Health Services Framework

RESULTS AND DISCUSSION

Landscape of State of Evidence on Digital Strategies for Health Service Delivery

There are a number of published studies with rigorous study designs and reporting (i.e., randomized controlled trials, prospective cohort studies, and detailed study protocols), diversity of intervention strategies tested, and selection of appropriate evaluation indicators. Interventions described in these studies cover the spectrum of health service delivery, and include education (training in use of mobile phones for health delivery),[8–15] diagnosis and management of diseases (mobile clinical decision support systems and referral coordination),[16–29] communication between health care providers,[30–35] and communication between provider and health care consumers (appointment reminders and test-result notification).[36–40] While this is not a comprehensive review, notable landmark articles on the use of digital strategies for health service delivery are described and referenced below:

- Several studies reported effective ways to use mobile phones to collect and report data from frontline health workers to health delivery teams, thus bypassing the need for in-person communication for data transfer. Client data were then used by the health delivery team to engage direct patient care by, for example, sending clients health messages or reminders to their mobile phones with the aim of improving health education and behavior change communication.[41,42]
- Lori et al.[12] conducted a study on the training of trainers to train community midwives on the use of short messaging service (SMS) messages for real-time remote data collection in rural Liberia. The study reported a significant increase in overall knowledge and skill acquisition among the 99 traditional midwives who used mobile technology for SMS-based data collection.[12]
- Zurovac et al.[29] conducted a cluster-randomized trial on the effects of SMS message reminders on health workers in Kenya. The results showed that health workers who received SMS message reminders had significantly improved (23.7%) adherence to malaria treatment guidelines compared to the control group who did not receive SMS message support.[29]
- Kim et al.[43] used SMS and web-based systems to achieve glycemic control with significantly improved glycated hemoglobin (HbA1c) in the

Despite encouraging advances in the evidence base on digital strategies for health service delivery, much of the literature remains focused on the use of descriptive data or intervention potential rather than objective measures.

intervention group compared to the control group in a randomized controlled clinical trial in Korea.[43]

- Similarly, Goodarzi et al.[44] conducted a randomized controlled clinical trial in Iran using SMS messages to educate patients with diabetes about exercise, diet, medication compliance, and self-monitoring of blood glucose. Results showed statistically significant improvement in HbA1c levels, diet, physical activity, knowledge, and self-efficacy among the intervention group compared to the control.[44]
- Mitchell et al.[24] showed digital decision-making tools significantly improved adherence to the Integrated Management of Childhood Illness (IMCI) protocol among health providers who used electronic decision-support tools in Tanzania. A few other studies yielded similar promising results, suggesting that mHealth can improve communication and supervision of health workers and evaluate health workers' performance.[26,42,45]

The results of the updated literature search revealed additional noteworthy high-quality studies with greater use of objective measures and rigorous research methodology:

- Lim et al.[46] conducted a randomized controlled clinical trial in Korea to achieve glycemic control using a clinical decision support system and physical activity monitoring device and dietary feedback among patients with type 2 diabetes. After 6 months, HbA1c levels were substantially improved, with a significantly improved decrease in caloric intake and increase in exercise among the intervention compared to the control group.[46]
- Agboola et al.[47] conducted a randomized controlled clinical trial and used SMS messages to coach and monitor patients with type 2 diabetes with HbA1c levels of >7 to achieve physical activity goals. There was no significant difference in change of HbA1c levels or monthly step counts in the 6-month follow-up between the intervention compared to the control group.[47] Arora et al.[48] and Capozza et al.[49] also used SMS in randomized controlled clinical trials to educate, motivate, and achieve glycemic control, however they showed no statistical improvement in HbA1c. All of these studies were conducted in high-income countries.

mCDSS can guide health care providers through process algorithms, provide a checklist based on extant clinical protocols, or provide step-by-step guidance to screen clients by risk status.

- Daher et al.[50] conducted a systematic review and meta-analysis of 99 studies published from 1996 to 2017, and found that SMS interventions improved antiretroviral therapy adherence with pooled odds ratio (OR) of 2.15 (95% confidence interval [CI], 1.18 to 3.91) and clinic attendance rates with pooled OR of 1.76 (95% CI, 1.28 to 2.42). However, the authors did acknowledge that misclassification bias and recall bias were high (58% bias among randomized controlled trials and 64% among quasi-randomized trials) and raised concern regarding the quality of studies included in the meta-analysis.[50]

Despite these encouraging advances in the evidence base on digital strategies for health service delivery, much of the literature is still focused on descriptive data or intervention potential. A substantial number of current studies used self-reported outcomes related to health behaviors, management, or service delivery or use. Only a few studies used objective measures of health or health service delivery.[7,43,44,46–49,51–53]

Mobile Clinical Decision Support Systems

As described previously, health providers from low-resource settings face multiple barriers to the delivery of high-quality efficient health services. These barriers may include: health care providers' limited access to timely and relevant health information; a shortfall of appropriately trained health care workers, especially in rural and remote areas; and the consequential transfer of responsibility for primary health care service delivery to lay health care workers who have little to no health service-related training.[54] Even in settings where health care workers may have adequate training, it may be difficult for them to learn of new evidence and apply it consistently and correctly across a range of disease groups. Mobile clinical decision support systems (CDSS) have potential to mitigate these barriers. CDSS is an "electronic system" designed to aid directly in clinical decision making, in which the characteristics of individual patients are used to generate patient-specific assessments or recommendations that are then presented to clinicians for consideration.[55] The concept behind CDSS is not novel. Clinical decision support tools have been used in hospital-based settings with varying levels of sophistication in high-income countries for several decades.[56] However, employing CDSS on mobile devices can provide opportunities for such tools to become available in areas with limited infrastructure and outside of hospital- or clinic-based settings. As task shifting from a higher cadre of trained providers to lay health workers is

increasingly supported, mobile CDSS (mCDSS) can provide novel opportunities to continually train and support these lay health workers.

Providing CDSS on mobile phones may serve a range of functions, including guiding health care providers through process algorithms using *if. . .then* rules based on evidence-based protocols, providing a checklist based on extant clinical protocols, or providing step-by-step guidance to screen clients by risk status using predetermined models. An mCDSS application may be standalone—to be used at a single point in time to deliver services—or may be integrated with a longitudinal health record, where any information that is entered into the system at a single point in time can be retrieved and used for making decisions during a follow-up visit. Systems that combine mCDSS with health records can facilitate long-term care and support the appropriate referral of clients at different levels of the health system. For example, an intervention developed in partnership with the Tanzanian Ministry of Health and Social Welfare provided community health workers with a mobile job aid to counsel, screen, and provide health-facility referrals to women at the community level for pregnancy, sexually transmitted infections, and family planning services. The data collected during these routine community-level service-provision visits were stored in electronic forms and sent to a central server that could be accessed by district-level health staff.[57] This type of intervention improves not only the quality and comprehensiveness of services provided by lay health workers at the community level but also facilitates appropriate linkages to care and management at the facility level.

The evidence in support of the use of mCDSS is slowly emerging. A before–after cluster trial in Tanzania provided frontline health workers with a mobile electronic decision-support tool to assess sick children according to IMCI protocols. The study reported a significant improvement in the providers' ability to adhere to 10 critical IMCI items.[24] Most studies conducted in low-income settings focus on the feasibility of such interventions and lack a high level of rigor to assess the impact of mCDSS on the quality of health services and health outcomes.[7,58] However, some conclusions may be drawn from interventions conducted in high-income countries. A review conducted by Free et al.[51] identified 7 trials that provided mobile support in clinical diagnosis and management to providers across 25 outcomes. Of the 25 outcomes, 19 showed benefits, of which 11 were statistically significant. The remaining 6 outcomes showed negative effects related to increased time for clinical processes or errors in data. However, none of the trials were assessed to have a low risk of bias.[51]

While mCDSS tools are promising, the challenge of transitioning from paper-based health records and decision-support tools to digital systems must not be underestimated. Despite efforts to make the mCDSS user-interface accessible and user friendly, the learning curve to adopt digital systems is often steep and requires ongoing training and support. To function well, such systems need to be iteratively developed, take into account user feedback, and align closely with existing clinical protocols.

The learning curve to adopt digital systems can often be steep and requires ongoing training and support.

The broader challenge of long-term adoption and scale up is how to ensure digital records are considered official records by ministries of health. As digital systems are tested, managers of health systems are often reluctant to dispose of existing paper systems. The result is that health care workers are then required to enter the same information in both paper and digital systems, adding to the responsibilities of the already overworked frontline health workers. Appropriate efforts must be undertaken to prove that digital records are as or more accurate than paper records. While mCDSS may be promising, the adoption of digital systems relies on understanding whether these systems can work in their specific context or environment, and if the systems can be effectively rolled out at scale.

Digital Referral Systems

Digital referral systems enable client health needs to be managed in a comprehensive manner using resources beyond those available at the patient's initial access to care. When referral activities are delivered effectively, patients are able to receive the full scope of care that is available from their health system, regardless of their geographic location.[59,60] In practice, referral management and coordination include the following activities:

Digital referral systems enable client health needs to be managed in a comprehensive manner using resources beyond those available at the patient's initial access to care.

1. Identifying the signs during a clinical encounter that a referral is needed
2. Preparing the client for this referral
3. Arranging logistics to transport the client to the location of referral
4. Ensuring receipt of health services according to client need at the referral facility
5. Managing receipt of the client at the returning facility where relevant

It is important to note that referral management and coordination is not an isolated process. It is embedded within the context of proper diagnosis, patient support, and post-treatment follow up.[59,60] When these related processes are inadequate, they can impact the effectiveness of referral systems. In health systems that are still reliant on paper-based data collection systems, there is a limitation to the degree in which patient referrals can truly be coordinated: paper referral forms can get lost, delays in paper-based information arriving at the right level of care may occur, and low levels of literacy can create challenges in comprehension.[61] Furthermore, the failure of patients to complete the full care plan in line with their initial diagnosis can often be attributed to a breakdown of referral processes.[62,63] The reasons behind these breakdowns can be complex and multifactorial: referrals to clinic may not account for distance clients need to travel, clients may not be able to afford the means to travel to the clinic, clients may not be able to afford taking time off from work or have child care arrangements to be able to follow up with the clinic, and the client or caregiver may not understand the referral instructions. Enhancing referral coordination activities with digital health systems can help overcome substantial barriers to strengthening referral services.

Binary referral data fail to provide the information required to understand the impact of digital referral systems on improving service delivery, health outcomes, and health systems strengthening activities.

Within the body of research included in this review is a wide array of digital health referral coordination systems that focus on health domains ranging from maternal and child care to noncommunicable diseases and dental care. The primary users of the digital referral systems in these studies included community health workers, clinical officers, nurses, and medical doctors. Several articles describe the improved effectiveness of digital referral systems over the standard of care. For instance, in Zambia, researchers reported a marked improvement in referrals for patients as a result of using coordinated digital health referral coordination systems.[62] In addition, the digital referral system removed barriers to arranging referrals faced by health care providers by improving the providers' ability to communicate with others, preparing patients for care, and changing plans for referral activities quickly, if needed. Similarly, in Zanzibar, the authors noted that an increased proportion of women completed the recommended 4 antenatal care visits, leading researchers to believe that digital health interventions could contribute toward the overall improvement of maternal health.[64] These findings present a strong case to assess the feasibility of scaling referral system.

Even with the implementation of digital referral systems, several challenges related to data completeness remain that limit our ability to assess the effectiveness of these systems. Standard reporting formats typically provide a limited assessment of referrals as a health performance indicator. For instance, referrals are often recorded based on their status (e.g., as complete or incomplete), without providing the details of the nature of the referral, completion of the counter referral, or outcome for the patient. The lack of detailed information prevents an accurate assessment of the quality of health service delivery to the patient. In other cases, referral data may be binary, only counting referrals made, and, occasionally, referrals completed. These types of data sets fail to provide the information required to understand the impact of digital referral systems on improving service delivery, health outcomes, and, importantly, health systems strengthening activities aimed at achieving universal health coverage.

The limited choice of available software and lack of standardization, in terms of data collection and integration, also poses a significant challenge to scaling digital referral systems.[62] The studies in this review deployed referral systems using different and noncompatible digital health software, and none of the systems collected data in the same format.[62,64–68] In some cases, these divergent approaches were implemented in the same country, resulting in unnecessary duplication and limiting opportunities for integration and scale up. Additionally, the literature review revealed gaps related to how referral systems engage patients along the full continuum of care—from the point of initial contact to treatment and management. Two studies included in this review focused on community health workers as the primary referral points for patients and tracked whether patients arrived for treatment at the next level of the health system.[62,68] However, they provided limited to no information about whether the health workers at the next level of care received the patient successfully or whether the treatment was provided to the patient as intended. For example, in Uganda, researchers conducted a detailed review of the number of children who were referred for treatment for malnutrition. The study's metric for success was the overall number of referrals completed during the duration of the study.[62,68] These metrics, however, failed to capture a clear picture of the patient's engagement with the health system. Hence, future implementers and evaluators of digital referral systems must consider how to generate data that are beneficial for quality

TABLE. Major Findings and Limitations of Published Studies on Digital Referral Systems and Mobile Clinical Decision Support Systems

Author(s), Year of Publication	Major Findings	Limitations
Agarwal et al., 2015[7]	The authors demonstrated that mobile job aids can help CHWs deliver integrated counseling on family planning and HIV/STI screening and collect relevant programmatic data on service delivery.	Study is not able to show whether collected data was of good quality and usable by decision makers.
Agboola et al., 2016[47]	This randomized controlled trial examined the effect of personalized text messages on physical activity, as measured by a pedometer, and clinical outcomes in patients with diabetes. Patients who received the SMS messages had significantly higher monthly step counts in the third (RR=4.89; 95% CI, 1.20 to 19.92) and fourth (RR=6.88; 95% CI, 1.21 to 39.00) months of the study compared to the control group. However, over the 6-month follow-up period, monthly step counts did not differ statistically by group. HbA1c levels decreased by 0.07% (95% CI, 0.47 to 0.34) in the intervention group compared to the control group.	Operational challenges related to pedometer software installation and Internet access to upload activity data contributed to a high attrition rate in the study. Investigators also noted differential rates of activity tracker adherence across comparison groups. Group differences in baseline HbA1c that could potentially bias comparisons of follow-up changes were also observed. Finally, the study did not evaluate the effectiveness of the different types/themes of messages.
Capozza et al., 2015[49]	The authors used a randomized controlled trial design to assess the impact on glycemic control of a 2-way SMS-based intervention that provided daily behavioral coaching, education, and testing reminders to patients with diabetes. The secondary aim of the study was to examine patient interaction and satisfaction with the program. The study was conducted in the context of a 6-month clinic-based quality improvement initiative. A comparison of the intervention group and the controls (who continued their usual care without receiving SMS messages) showed similar decreases in average HbA1c levels after 90 and 180 days of follow up, probably reflecting the success of the broader quality improvement initiative. Almost a third (29%) of program users in the intervention group demonstrated frequent engagement, and survey results indicated very high satisfaction with the program.	The primary outcome, change in HbA1c, is difficult to affect in the short time frame (6 months), and sample size was small (58 and 35 in intervention and control groups, respectively). Study also reported wide variation in the timing of baseline HbA1c measures relative to study onset. Authors also reported difficulties recalling patients to the clinic for regular HbA1c testing.
Daviaud et al., 2017[68]	The authors conducted an economic analysis of the implementation of ICCM, which includes the integrated diagnosis, treatment, and referral services for malaria, suspected pneumonia, and diarrhea among children by CHWs. The analysis was conducted across 6 African countries and assessed country-level scale-up implications. Their analysis indicated that between 10 and 603 treatments were given per CHW per year. Weighted economic costs per treatment ranged from US$2 to US$13. CHWs spent from 1 to 9 hours a week on ICCM.	The paper focused on annual costs to providers (health system and donors) to inform planning and budgeting but did not assess program effectiveness due to the recentness of program implementation. CHW time on the program was based on the same assumptions of length of visit and meetings for all countries rather than on observation. Authors note that even though implementation costs are calculated on an annual basis, recent guidelines recommend using a wider window of time.
den Hollander and Mars, 2017[67]	The authors conducted a retrospective review of a referral database of cell phone-generated images to demonstrate that telemedicine can be a reliable method of triaging patients before admission into a burn unit. In 66% of studied cases, telemedicine consultation avoided inappropriate admission or delayed admission in late referrals until the patient was ready for definitive treatment.	Study highlighted complex issues related to patient data security and confidentiality.
Dobson et al., 2017[52]	The systematic review examined 7 randomized controlled trials that investigated the use of SMS-based self-management interventions for patients with diabetes. No clear relationship between positive outcomes and intervention dose, content, and functionality was observed.	The small number of articles reviewed was due, in part, to inclusion criteria restricting studies to randomized controlled trial designs. Because only published full-text papers in English were included, the study results were potentially influenced by publication and language bias.
Kabakyenga et al.,2016[62]	Findings from this observational study suggest that using mobile phones to support the implementation of ICCM by CHWs could improve supportive care for acutely ill children.	The study's design and limited sample size of only 96 trained CHWs did not allow a full assessment of demonstrable improvement in health outcomes attributable to mobile-phone support.

Continued

TABLE. Continued

Author(s), Year of Publication	Major Findings	Limitations
Lim et al., 2016[46]	This clinical trial randomized patients with diabetes into either a group offering routine diabetes care with self-monitored blood glucose or a group employing an Internet-based monitoring device that provided real-time individualized feedback (u-healthcare) system combined with exercise monitoring and dietary feedback. The investigators examined the effect of the u-healthcare combination intervention on glycemic control. After 6 months of follow up, the HbA1c level was significantly decreased in the u-healthcare group (8.0% ± 0.7%) compared with the SMBG group (8.1% ± 0.8 %; $P<.01$).	The study was limited to individuals with access to mobile phones and Internet. Additionally, the 6-month follow-up period may not be long enough to evaluate the long-term effect of this system.

Abbreviations: CHWs, community health workers; CI, confidence interval; HbA1c, hemoglobin A1c; ICCM, integrated community case management; RR, risk ratio; SMBG, self-monitored blood glucose; SMS, short message service; STI, sexually transmitted infection; u, ubiquitous.

improvement and not limit themselves to proximal indicators in the pathway to care.

Despite the increased proliferation of mobile phones and affordability of mobile broadband technology in low- and middle-income countries, only about 30% of the global rural population currently has mobile phone access, compared to approximately 90% of the urban population,[69] and this level of unique mobile-cellular subscriptions is insufficient to support universal access. These trends are particularly important to note when considering the delivery of health services through digital health programs. Ultimately, for digital health strategies to be instrumental in the achievement of universal health coverage goals, a better understanding and stronger emphasis on how they can be used to deliver large-scale, timely, and comprehensive health services to both rural and urban populations will be required.[70] The Table summarizes key published articles that discuss digital referral systems and mobile clinical decision support systems.

For digital health strategies to be instrumental in the achievement of universal health coverage goals, we need to better understand how they can be used to deliver large-scale, timely, and comprehensive health services to both rural and urban populations.

CONCLUSIONS

The current body of evidence on digital strategies for health service delivery is still quite limited in 3 main areas: the effectiveness of interventions on health outcomes, the improvement of health system efficiencies for service delivery, and the level and type of human capacity required to implement and support digital health strategies at scale.[7,51] Additional research is urgently needed to inform these gaps and to show the cost-effectiveness of digital health interventions to provide and support service delivery. Digital health interventions for service delivery, such as digital health-enhanced referral coordination and mCDSS, demonstrate major potential to improve the quality and comprehensiveness of care received by patients. However, these digital health interventions require a greater level of standardization to prepare for scale and an expanded scope of health worker engagement to include more levels of health service delivery. These specific enhancements, if researched and documented, can provide the foundation needed to scale effective digital referral coordination and decision support systems within low- and middle-income settings.

Funding: This work was made possible by a grant from the Aetna Foundation, with support from the World Health Organization and The Johns Hopkins University Global mHealth Initiative. In addition, Vasudevan's effort on this publication was supported in part by the National Center for Advancing Translational Sciences of the National Institutes of Health under Award Number 1KL2TR002554.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of the World Health Organization, Duke University, The Johns Hopkins University, or The American University of Beirut.

Competing Interests: None declared.

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Peer Reviewed

Received: June 23, 2018; **Accepted:** August 29, 2018

Cite this article as: Orton M, Agarwal S, Muhoza P, Vasudevan L, Vu A. Strengthening delivery of health services using digital devices. Glob Health Sci Pract. 2018;6(suppl 1):S61-S71. https://doi.org/10.9745/GHSP-D-18-00229

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