Digital Health Innovations in Low- and Middle-Income Healthcare Systems: Perspectives from South and Southeast Asia

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Abstract

Digital health innovations have emerged as a transformative force globally, pivotal in addressing the intricate challenges of health systems, particularly in resource-constrained settings. The COVID-19 pandemic has unequivocally underscored the critical importance of these innovations in enhancing public health responses. In South and Southeast Asia, a region known for its cultural diversity and complex healthcare landscape, digital health innovations present a dynamic interplay of challenges and opportunities. We advocate for ongoing research built into system development and an evidence-based strategy focusing on designing and scaling national digital health infrastructures, combined with a vibrant ecosystem or “marketplace” of local experiments generating shared experience. As the global digital health revolution unfolds, the perspectives drawn from the region may provide valuable insights for shaping future strategies and informing similar initiatives in low- and middle-income countries, poised to contribute substantially to developing effective and contextually relevant digital health strategies across diverse global health contexts.

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Abstract

Digital health innovations have emerged as a transformative force globally, pivotal in addressing the intricate challenges of health systems, particularly in resource-constrained settings. The COVID-19 pandemic has unequivocally underscored the critical importance of these innovations in enhancing public health responses. In South and Southeast Asia, a region known for its cultural diversity and complex healthcare landscape, digital health innovations present a dynamic interplay of challenges and opportunities. We advocate for ongoing research built into system development and an evidence-based strategy focusing on designing and scaling national digital health infrastructures, combined with a vibrant ecosystem or “marketplace” of local experiments generating shared experience. As the global digital health revolution unfolds, the perspectives drawn from the region may provide valuable insights for shaping future strategies and informing similar initiatives in low- and middle-income countries, poised to contribute substantially to developing effective and contextually relevant digital health strategies across diverse global health contexts.

Keywords

Digital health innovations; public health responses; South and Southeast Asia; healthcare challenges; low- and middle-income countries; global health contexts

Introduction

The rapid development of digital health—encompassing technologies like mobile health (mHealth), telemedicine, digital health information systems, Internet of Things (IoT), machine learning and artificial intelligence (AI), personalised digital nudges, and large language models like the Generative Pretrained Transformer (GPT)—has ushered in a new era of healthcare possibilities [1]. Digital health technology has been proposed as an effective solution to address healthcare access, cost, and quality issues. While the promise of digital health is universal, the context in which it is applied varies across regions. This viewpoint paper critically examines the diverse challenges and opportunities encountered in digital health innovations in low- and middle-income countries (LMICs), drawing on perspectives from the experiences of health systems in South and Southeast Asia, a vibrant and multifarious region.

We advocate for ongoing research built into system development and a two-pronged top-down and bottom-up innovation approach: an evidence-based strategy focusing on designing and scaling national digital health infrastructures, combined with a vibrant ecosystem or "marketplace" of local experiments generating shared experience. This dual approach of top-down design and bottom-up experimentation, enabled through careful evaluation of effectiveness and impact, allows economies with different starting conditions to seize opportunities to "leapfrog" towards more robust, resilient health systems. Integrating research and regional or global partners can help leverage existing technology platforms and standards to generate economies of scale. Cutting-edge applications can be tailored and re-deployed in multiple low-resource settings, allowing LMICs to decrease deployment costs, foster the development of reusable tools and methodologies, and nurture culturally relevant communities of practice. The latter is significant considering technological disparities— "the digital divide."

Despite the rapidly advancing technological landscape in LMICs, significant disparities in digital access and digital literacy persist. Across South and Southeast Asia, less than half of the population in Myanmar uses the internet, and only 2% of people in Cambodia and the Lao People's Democratic Republic (Lao PDR) have a fixed broadband subscription, compared to an average of 4% in LMICs [2]. Cambodia has low digital literacy [3], whereas in countries like Singapore, digital literacy and technology use is relatively high, even among older adults, albeit focused more on leisure than health and functions.[4] Digital literacy and usage can impact one's ability and attitude toward using digital technology [4,5]. The scarcity of technological resources also hampers the introduction, adoption, and integration of digital health interventions into the broader health systems and compounds existing inequities in access to healthcare, potentially exacerbating disparities in

health outcomes [6,7].

The incremental benefits of digital technologies could be significant—even transformational—in LMICs. By providing access to quality care in remote settings, the incremental benefits could be considerably higher than in high-income health systems if sufficient oversight and stewardship uphold the tenet “First, do no harm.” The ethical complications of denying access to the social value of digital health innovations cannot be ignored.

Therefore, just as many have discussed the advantages of a “human-in-the-loop” approach to AI, we underscore the potential benefits of a “researcher-in-the-loop” approach to digital health innovations in LMICs to strive for objective evaluation, improvement, and dissemination of both the failures and the “home runs” that improve patient outcomes while reducing disparities, costs, and health professional burden and burnout. A trilateral team, including policymakers, researchers, and trusted partners, can quickly identify and disseminate best practices in other LMIC settings. Linking to trusted global partners or catalytic funders (e.g., Bill & Melinda Gates Foundation [BMGF], NIH Fogarty International Center, Abdul Latif Jameel Poverty Action Lab, International Initiative for Impact Evaluation, and others) can bring resources to low-resource settings, de-risk the initial phase of adoption, and document when and how scale-up is appropriate to the local context, while simultaneously building a regional or global “toolkit” of use cases and experiences that can benefit other LMICs [8].

The following sections will first examine data and the foundational elements of digital health innovations, focusing on its architecture, standards, privacy and security. Next, we will explore the marketplace of digital health solutions in South and Southeast Asia before addressing the importance of a continuous cycle of learning and improvement through impact evaluation, research, and development with equity and cultural sensitivity underpinning the process.

Data – Architecture, Standards, Privacy, and Security

For digital health technology to have a long-lasting impact on health systems, technology must be developed around an extensible architecture that can be efficiently scaled for new use cases and applications. While we are at the very early stages of technology adoption, it is essential to understand how critical these foundational concepts are to a proper digital solution for healthcare. An essential aspect of this adaptable architecture is incorporating data, a critical consideration during the development of use cases and technology deployment.

Most legacy health information technology solutions centre on providers, hospitals, or clinics. This provider-centric hierarchical architecture can help achieve business goals for these organisations

but presents challenges for data sharing and data exchange for patients as they move across providers. Electronic medical records have been employed to streamline patient data management and improve healthcare service delivery, exemplifying digital health's potential to improve healthcare efficiency [9]. The Indonesian and Singaporean governments are making electronic medical records accessible to the population [10,11], while an electronic information registry for routine immunisation is being introduced in Cambodia and Lao PDR. However, without specific data standards for data organisation and sharing, data elements may not be digitally exchanged between clinical systems.

The process of exchanging digital information is known as interoperability. Although most high-income countries have either implemented or are in the process of introducing legislation mandating interoperability, approximately 90% of the Organisation for Economic Co-operation and Development (OECD) countries, particularly LMICs [12], encounter difficulties in attaining comparable interoperability. Nevertheless, prospects for "leapfrogging" from older standards to patient-centered data architecture are most auspicious for LMICs.

Rather than developing a data architecture that mirrors the health ministry organisational chart, policymakers should consider technology solutions centered on patients, such as personal health records. In Singapore, the government has launched the Next Generation Electronic Medical Record (NGEMR) system to consolidate data and harmonise processes across health establishments, including private care providers, providing a longitudinal view of patient’s health data [13]. Such efforts to integrate digital health solutions into existing healthcare frameworks hold promise in optimising resource allocation and healthcare delivery. Mobile phones have greatly facilitated personal health records but could include cloud-based models or an innovative blockchain model such as those used in Estonia [14]. Personal health records could have distinct advantages for patients, such as having patient records available when making clinical decisions.

Launched in 2021, India’s national Ayushman Bharat Digital Mission (ABDM) was built based on a decade of digitalisation experiences in the national identity system, personal digital records, and payment systems. ABDM uses the Ayushman Bharat Health Account (ABHA) as a digital health identity number that can be shared freely while keeping the underlying information secure. Over 268,000 health professionals have been included in the national registry, irrespective of the medical systems they practice. More than 229,000 health facilities have been registered with the facility registry [15].

These architectural elements are designed for three primary functions: interoperability of health records, interoperability of services through the unified health interface for all providers, and

interoperability of health claims so that hospitals or other providers are not overburdened dealing with multiple payers to submit claims. Together, these layers create a citizen-centric view of public health by building the infrastructure underpinning a vibrant ecosystem, with more than 1280 different public and private applications actively integrating and 166 already integrated with the system. India continues to explore strategies to drive further adoption and innovation.

A key lesson from India's experiences with ABDM is building an integrated data ecosystem instead of disparate information systems. The integration will be crucial to support personalised healthcare and evidence-based policymaking. The overall data architecture at a country or market level should also anticipate the interest in developing these tools and their challenges. Individual tools should anticipate updates to the overall data architecture and regulation at the country and market level.

Apart from data architecture for storage and exchange, data standards vary across countries, leading to incomparability [16]. The same concept (e.g., blood glucose) may be represented in various ways from one setting to the next. The World Health Organization (WHO) has developed a data architecture to support countries' capacity to collect, manage, analyse, and use health data from population-based sources such as household surveys and institutional sources such as health facilities [17]. Similarly, Digital Health Europe attempts to develop comprehensive data standards, including international patient summaries that provide basic medical data for supporting cross-border care [18]. The European case of regional harmonisation is a model for regional organisations such as the Association of Southeast Asian Nations (ASEAN), a political and economic union of 10 Southeast Asian states, to work towards fostering data exchange and improving data comparability between countries.

Lastly, moving from paper to digital records raises the risk of data breaches and unauthorised access to sensitive health data, which poses ethical and legal dilemmas. Some countries have tightened regulations to raise protection. Singapore's Personal Data Protection Act is a regulatory model for safeguarding personal health data [19]. In Thailand, Indonesia, and Vietnam, data protection was embedded in several laws before its personal protection law was passed in 2019, 2022, and 2023, respectively [20-22]. India has adopted the Digital Personal Data Protection Act, which empowers individuals and specifies requirements for any data fiduciary involved in handling personal data, as well as for the National Health Authority, which serves as a consent manager rather than a data repository [23]. India's ABDM also includes a consent artefact that empowers users to decide how, when, where, and what record types they allow to be shared between one health provider and another.

However, inadequate data protection regulations in some countries risk the security and privacy of health data [24], which could undermine individuals' willingness to engage with digital health platforms. An example is the apprehension surrounding Indonesia's new Health Bill, which allows for collecting and using health data, including genomic data, outside the country [25]. Clear guidelines for data collection, storage, and sharing, along with measures to safeguard sensitive health information, are critical.

Marketplace – Digital Health Solutions

The genuine excitement surrounding digital healthcare solutions stems not from data architecture but from the services they enable. Data architectures are not a final use case for a technology; they are merely an enabler of a broader digital healthcare services ecosystem. Digital services use an underlying data architecture to provide patient information, tools, reports, and recommendations. Digital services can be built on a standard data architecture or stand-alone solutions. The former requires a means to access and potentially update or add to the data, while the latter runs the risk of creating non-interoperable data silos. We advocate for adopting both approaches while systematically assessing the latter and designing in anticipation of interoperable solutions in the near future. Digital solutions must be tested to ensure they perform as expected, including concepts such as the user interface; data access, storage, manipulation, and reporting; and clinical validity.

A vibrant ecosystem of applications shown to be effective in different settings, in turn, lays the foundation for a "marketing strategy" to disseminate and encourage the take-up of digital health solutions such as digital health records among individuals and organisations, patients, and providers. Building the personal health report system means little if patients and providers do not engage. To drive meaningful adoption and use, the digital health ecosystem must create value for every player or stakeholder, fostering trust and spurring curiosity about the possibilities for more manageable, cheaper, higher quality, more accessible, and more resilient services. The patients and providers need evidence from use cases that improve their lives, transforming inertia and fear of new technology into excitement and fear of missing out. Digital solutions must also easily integrate into existing workflows and systems, reducing the barriers to uptake.

For example, the Indian government started by ensuring that all the government programmes, such as ABDM-enabled health and laboratory management information systems for government hospitals, are ABDM-enabled. Such deployment creates the demonstration space to study integration into existing workflows and make these low-cost "plug and play" solutions available to all participants so that even the smallest local provider need not invest much time and money to adopt

them.

While the goal is to avoid creating siloed platforms – an HIV platform, a TB platform, and so on – as much as possible, health systems may benefit from a vibrant ecosystem or “marketplace” of local applications and experiments generating shared experience about what works in diverse settings to enhance access while reducing disparities. One noteworthy example from Southeast Asia comes from a recent randomised controlled trial that demonstrated the benefits of digital health interventions for accessing healthcare and support services among female entertainment workers, a social and gender-marginalised population in Cambodia [26]. The study employed a mobile intervention to connect the vulnerable population to critical health and gender-based violence services, showcasing the transformative potential of digital health in addressing pressing societal challenges even without a national-level integrated digital health ecosystem.

The potential of digital health to bridge geographical gaps, extend healthcare services to underserved populations, and support the health system in moving care from hospitals to communities is promising. In archipelagic countries like Indonesia and the Philippines, where healthcare delivery is complicated by geographies, as well as in countries such as Cambodia, where 75% of the population lives in rural areas (2), digital health interventions such as teleconsultation can be used to improve healthcare accessibility. Digital health additionally holds potential in countries reliant on community health workers to bridge geographic gaps. One example is Accredited Social Health Activist (ASHA) workers in India employed by the Ministry of Health and Family Welfare through India’s National Rural Health Mission. ASHAs have successfully leveraged mHealth for disease surveillance and treatment in a country where low-cost smartphones are increasingly prevalent [27,28].

A mobile phone can be considered a valid medical device equipped with multiple sensors: a camera, a microphone, a screen, a global positioning system (GPS), and data. Organisations like BMGF are working with local partners to develop applications leveraging the ubiquity of mobile phones to enhance care in low-income settings, such as scanning to assess a newborn’s anthropometrics and monitor malnourishment. mHealth has been proven effective in health education, disease screening, and linkages to care and treatment services [29-33], while wearable devices can increase physical activity and improve health [34], and IoT-enabled systems can support community eldercare [35]. An application for counselling women about contraceptive methods showed that personalised information could be just as effective and far cheaper than subsidies for the informed adoption of unfamiliar technologies [36]. The power of social media as a platform for health education also holds considerable promise, both for large-scale public health campaigns and

specifically tailored interventions that are culturally sensitive and build on trusted community figures or institutions [37].

Likewise, artificial intelligence has shown tremendous potential to support precision health, including large language models like GPT-4 in diagnosing complicated medical conditions [38]. Integrating a deep learning algorithm into the national diabetic retinopathy screening programme in Thailand found that the deep-learning system can deliver real-time diabetic retinopathy detection capability similar to retina specialists in community-based screening settings [39]. Another study in India employed deep-learning to classify diabetic foot ulcer risk using thermal and visual spectrum scans [40]. The models performed with more than 80% accuracy, another successful demonstration of AI's potential in screening and diagnostics [41]. However, AI-enabled solutions for precision public health extend beyond diagnostics to realms like clinical decision support and healthcare delivery in low-resource settings where staffing, training, funding, and equipment are often limited. While AI-enabled solutions may seem dependent on expensive academic and industry partnerships, non-governmental organisations (NGOs) can play a central role in data acquisition and technology adoption [42].

Ultimately, digital health solutions aim to augment, not replace, the services provided by frontline health workers—we need to avoid the "Turing Trap" [43] and focus on innovations that augment the social value created by the existing health workforce. In the most recent and rigorous studies, generative AI and related technologies tend to boost the productivity of new and less-experienced health workers more than their more-experienced counterparts [44]. The potential for AI and other digital health assistants to upskill and extend the limited health professional resources of LMICs underscores the social value of experimenting and assessing real-time effectiveness without waiting for the design of national architecture where it is lacking.

Digital health innovation also needs to consider the financing levers in both the public and private sectors to understand the feasibility of adopting and scaling up digital health interventions. A private philanthropy like BMGF can provide catalytic funding to de-risk the technology early and gather evidence about what works in practice before turning over implementation at scale to governments and civil society. For example, BMGF successfully helped deploy a platform developed in India in two other countries, Cambodia and Nigeria [45,46]. The use of technologies to support health system strengthening through health financing also holds promise for increasing healthcare efficiency, accountability, and transparency [47]. Digital technologies have been used to collect health insurance premiums and taxes through mobile wallet services, support pay-for-performance strategic purchasing models, and raise awareness of benefit packages and costing schedules [47].

Digital Health Innovations – A Cycle of Learning and Improvement

The rapid proliferation of digital health technologies requires rigorous research and impact evaluation to generate the evidence to assist LMICs in identifying the most effective strategies. Mobile phones and their voice and AI applications provide many opportunities to enhance individual health knowledge and deliver helpful information. They also call for careful ongoing research to address inappropriate advice or information concerns. For example, standard smartphone voice systems (e.g., Siri or S Voice) have failed to recognise issues about mental health, interpersonal violence, or physical health [48]. The accuracy of ChatGPT information about diabetes is also questionable [49]. Many ethical issues need to be addressed when adopting monitoring devices or contactless sensors and contact-based wearable devices installed in healthcare settings, otherwise called “ambient intelligence,” to collect data in health and elderly care [50]. Artificial intelligence or machine learning also relies on models that require significant amounts of data for development and attention to the potential errors introduced by data that may be flawed or biased [51]. Validation of the models across healthcare markets and populations is essential [52].

Digital health research requires an interdisciplinary team of researchers in public health, data science, information technology, social sciences, and engineering. Researchers must work with policymakers and end-users such as healthcare professionals, communities, and individuals in designing interventions that are problem- or need-driven and set in the broader policy environment. The principle of equity must guide the innovation cycle to prevent inadvertently deepening health disparities through underdiagnosis and undertreatment of individuals historically with limited access to care or who face biases due to language, race, or education. For example, using medical spending to predict medical needs can result in significant racial bias [53]. Strategies to reach marginalised populations, including migrants and underserved communities, are imperative. Initiatives such as using mobile phones to deliver health information to key HIV population communities in Cambodia reflect a commitment to advancing health equity [26,54].

In addition, ensuring participants comprehensively understand the implications of digital health research, especially in linguistically and culturally diverse contexts, is paramount. Countries in the region have taken steps to develop culturally sensitive informed consent processes to uphold ethical standards and respect individuals’ autonomy [26]. The digitisation experience of the banking and financial industry in the region can also offer valuable lessons for digital health research and interventions. The banking sector has learned that retaining a human touch in the technological interface with customers is essential [29]. In some countries where public health services have been

underutilised due to the lack of trust in the system,[30] the introduction of digital health interventions must be carefully designed to instill confidence in the intent, quality, and integrity of the technology. Retaining a human element in digital health interventions could be one way to instill confidence.

A key to success will be alacrity in the stewardship of health sectors to address priority population health needs and improve equity while addressing the “innovators’ dilemma” and supporting the generation of evidence to interpret the results of studies assessing digital health applications so that patients, providers, and policymakers can ask and answer the right questions in the suitable timeframe to enable a virtuous cycle of learning and improvement. In LMICs, where governments lack resources to try many new things, private philanthropy can bring resources, take the risk, and generate evidence about “what works” and scalability.

One example of the importance of local context comes from maternal and child health. Many Indians, especially in rural areas, are not born in their parents’ houses or even their parents’ towns but rather in their maternal grandparents’ houses or communities. Typically, in the third trimester of pregnancy, the pregnant woman will move to her parents' house, and the baby will be born there. Since the third trimester is a critical time for the mother and child, software customised to the context alerts community workers to gather two addresses for each pregnant woman and then sends an alert to the maternal grandparents’ community in the third trimester to allow follow-up care and management continuity. Much of the software developed in India takes this social custom into account so that healthcare workers in each jurisdiction know about incoming cases, and fewer pregnant women are lost to follow-up at a critical time.

Similarly, it is essential to understand the purposes behind existing traditions or policies before attempting to change them. “Chesterton's Fence” is a principle articulated by the writer G.K. Chesterton [55]: “If you come across a fence blocking a road and do not know why it was built, you should not remove it until you understand its purpose.” This principle suggests that reforms or changes should not be made until the reasons for the current situation are fully understood. It emphasises the value of historical knowledge and cautions against hasty or uninformed decision-making, advocating for a deeper understanding of the context and reasons behind existing practices or structures before making alterations.

For digital health innovation, Chesterton’s Fence suggests the importance of actively involving local communities, respecting local decision-making processes, and partnering with local governments, NGOs, and other stakeholders to tailor proposed solutions to the cultural, economic, and environmental context. Moreover, implementing small-scale pilot projects can provide valuable insights, allowing for adjustments before broader application, considering both the direct and indirect

consequences for the community. Ongoing evaluation and willingness to adapt strategies based on feedback are critical for the success of any initiative. Sustainable change requires enhancing local skills and institutions to ensure long-term effectiveness. Patience and persistence are vital in these efforts to harness the potential of digital technology to improve the health of disadvantaged individuals and communities.

Conclusion

Digital health programmes and research in South and Southeast Asia illustrate that innovation necessitates a comprehensive understanding of technological, cultural, and ethical dimensions. While technological challenges persist, opportunities for leapfrogging traditional healthcare, strengthening health systems, and enhancing epidemic preparedness hold promise. We are at an unprecedented time in humanity's digital transformation, making these discussions topical and urgent. Ethical considerations underscore the importance of equitable access, cultural sensitivity, and robust data governance. Collaborative efforts among researchers, policymakers, healthcare professionals, and communities within and outside the health sector will be instrumental in harnessing digital health's potential to improve health outcomes and promote health equity in LMICs.

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Conflict of Interest

None declared.

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