International Journal of Medical Informatics 150 (2021) 104456

Contents lists available at ScienceDirect

International Journal of Medical Informatics

journal homepage: www.elsevier.com/locate/ijmedinf

Leveraging data and AI to deliver on the promise of digital health

Ann Aerts [a,*], Doreen Bogdan-Martin [b,c]

[a] Novartis Foundation, Switzerland
[b] Telecommunication Development Bureau of the International Telecommunication Union, Switzerland
[c] Broadband Commission for Sustainable Development, Switzerland

ARTICLE INFO

Keywords:
Digital technology
Intersectoral collaboration
Health systems
Noncommunicable diseases
Sustainable Development Goals

ABSTRACT

Rising rates of NCDs threaten fragile healthcare systems in low- and middle-income countries.

Fortunately, new digital technology provides tools to more effectively address the growing dual burden of disease. Two-thirds of the world's population subscribed to mobile services by the end of 2018, while the falling price of connectivity and the 5G networks rollout promise to accelerate the use of digital technology. Properly leveraged, we can employ digital solutions and applications to transform health systems from reactive to proactive and even preventive, helping people stay healthy. With artificial intelligence (AI), health systems can be made more predictive by detecting risk factors and helping health professionals respond faster to prevent disease.

Yet this rapid pace of growth has also complicated the digital health landscape. Myriad digital health apps compete and overlap in the public and private sectors, and significant gaps in the collection and analysis of digital data threaten to leave some behind.

Established in 2010, the Broadband Commission for Sustainable Development is led by ITU and UNESCO and advocates for the transformational impact of broadband technologies for development. Its working group on digital and AI in health, co-chaired by the Novartis Foundation and at different times Nokia, Intel and Microsoft, identifies best practices for countries to realize the potential of digital technology in health and care. Interviewing more than 100 key stakeholders and reviewing over 200 documents, the Working Group set out to identify common challenges that countries face in implementing digital health solutions, and to develop a framework that countries can use to build systems for supporting digital health solutions.

Common challenges include a lack of coordination leading to fragmented digital health solutions; lack of systems and workforce capacity to manage data and digital technology, and inadequate financing to support digital health. The working group proposes six building blocks for digital health systems: formulate and execute a national digital health strategy; create policy and regulatory frameworks that support innovation while protecting security and privacy; ensure access to digital infrastructure; ensure interoperability of digital health system components; establish effective partnerships; and sustain adequate financing.

1. Introduction

The imperative to achieve universal health coverage (UHC) was enshrined in the Sustainable Development Goals (SDGs), and the need to make greater progress toward UHC is acute in low- and middle-income countries (LMICs). Rising rates of NCDs, driven by social changes in employment, diet and lifestyle accompanying rapid development and urbanization, threaten fragile healthcare systems in LMICs.[1,2]

From 1980–2019 the global prevalence of diabetes more than doubled to 9.3 % and is projected to continue rising to 10.9 % by 2045.[3]

* Corresponding author at: The Novartis Foundation, Novartis International AG, Campus Forum 1-3.99, CH-4056, Basel, Switzerland.
E-mail address: ann.aerts@novartis.com (A. Aerts).

[1] Popkin, Barry M. "Nutrition Transition and the Global Diabetes Epidemic." *Curr Diab Rep.* 2015 Sep; 15(9): 64. Doi: 10.1007/s11892−015-0631−4

[2] Anand, Sonia, et al. "Food Consumption and its Impact on Cardiovascular Disease: Importance of Solutions Focused on the Globalized Food System: A Report From the Workshop Convened by the World Heart Federation." *Journal of the American College of Cardiology*, Volume 66, Issue 14, 6 October 2015, Pages 1590−1614. Doi: https://doi.org/10.1016/j.jacc.2015.07.050

[3] Saeedi, Pouya, et al. "Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition." *Diabetes Research and Clinical Practice*, VOLUME 157, 107843, November 01, 2019. Doi: https://doi.org/10.1016/j.diabres.2019.107843

https://doi.org/10.1016/j.ijmedinf.2021.104456
Received 11 February 2020; Received in revised form 26 April 2020; Accepted 2 April 2021
Available online 10 April 2021

Approximately 1.13 billion people have hypertension, mostly in LMICs, causing more than 7.5 million deaths each year.[4,5] Although mortality rates from coronary disease have stabilized in high-income countries, prevalence in LMICs leaves hundreds of millions vulnerable.[6]

COVID-19 is just the latest example of comorbidity with infectious disease and NCDs: across the developing world 336 million people with diabetes are more likely to contract a range of infectious diseases including HIV, influenza, tuberculosis, and dengue, and to suffer worse outcomes.[7] Similarly, the roughly 175 million people around the world living with chronic obstructive pulmonary disease (COPD) are more vulnerable to any respiratory infection.[8]

1.1. Digital opportunities and obstacles

Fortunately, digital technology provides tools to address the growing dual disease burden more effectively and at lower cost. Digital health can empower patients to take control of their own health, while enabling health providers and managers to coordinate data and care at the individual and community level. More broadly, digital health can assist LMICs toward achieving UHC by increasing access and quality of care, and by making health systems more efficient and care more affordable.

Two-thirds of the world's population owns a mobile phone.[9] Mobile data usage has soared from 2.5 petabytes per month in 2014 to 38 exabytes per month in 2019, a 15,000-fold increase. Falling prices and the rollout of 5G networks promise to accelerate these trends.[10,11,12] Over the same period, a wave of innovation has turned phones into digital health platforms. New capabilities combine mobile connectivity with artificial intelligence (AI), cloud computing and Big Data.[13]

Yet this rapid pace of growth has also complicated the digital health landscape. Myriad digital health apps compete and overlap in the public and private sectors, and significant gaps in the collection and analysis of digital data threaten to leave some behind.

Established in 2010, the Broadband Commission for Sustainable Development is led by ITU and UNESCO and advocates for the transformational impact of broadband technologies for development. Its working group on digital and AI in health, co-chaired by the Novartis Foundation and at different times Nokia, Intel and Microsoft, identifies best practices for countries to realize the potential of digital technology in health and care. (See Acknowledgments for list of members.)

Fig. 1. Features of sustainable digital health solutions.

2. Methods

The Working Group set out to 1) identify common challenges that countries face in implementing digital health solutions, and 2) develop a framework that countries can use to build systems for supporting digital health solutions. Its purview encompassed all concepts and activities at the intersection of health and information and communications technologies (ICTs), including mobile health, health information technology, electronic health records, and telehealth; key innovations including cloud platforms, open integration layers, and the development of 5G; and leadership, policy and regulatory issues related to governance, security, privacy, and spectrum allocation for digital health services. This was the first time that a diverse group of experts and stakeholders representing public, private and non-profit expertise assembled to develop a roadmap for the development of digital health systems.

With a focus on sustainability, the Working Group sought to identify digital health solutions that are fully integrated, scalable, and financially viable (Fig. 1).[14]

The Working Group met quarterly to review outputs from literature review and stakeholder interviews adjust the strategic trajectory of the project in an iterative, collaborative process. The first phase of the research consisted of key interviews with government officials and other stakeholders, along with a literature review and expert consultations. More than 100 digital health leaders from around the world were interviewed about local conditions and challenges, including experts from Bangladesh, Brazil, Canada, Chile, Estonia, Gabon, Ghana, India, Kenya, Malawi, Malaysia, Mali, Mexico, Nigeria, Norway, Pakistan, the Philippines, Rwanda, Singapore, and South Africa, as well as international organizations. The Working Group collected and analyzed primary and secondary research material from more than 200 reports and compiled the resulting insights and recommendations. Members of the Working Group also contributed their own expertise in key areas.

3. Results and discussion

The Working Group's analysis identified common challenges that countries face with respect to building digital health systems.

Digital health solutions, projects and initiatives are often uncoordinated, resulting in fragmentation, unnecessary duplication

[4] World Health Organization. "Hypertension." Fact Sheet. 13 September 2019 https://www.who.int/news-room/fact-sheets/detail/hypertension

[5] World Health Organization. Global Health Observatory Data. "Raised Blood Pressure". https://www.who.int/gho/ncd/risk_factors/blood_pressure_prevalence_text/en/

[6] Lewis, Dara K. Lee. "How does cardiovascular disease increase the risk of severe illness and death from COVID-19?" *Harvard Health Blog*, April 2, 2020.

[7] Dunachie, Susanna, and Parinya Chamnan. "The double burden of diabetes and global infection in low and middle-income countries." Transactions of The Royal Society of Tropical Medicine and Hygiene, Volume 113, Issue 2, February 2019, Pages 56–64, Doi: https://doi.org/10.1093/trstmh/try124

[8] "Global, regional, and national deaths, prevalence, disability-adjusted life years, and years lived with disability for chronic obstructive pulmonary disease and asthma, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015." *The Lancet Respir Med*, Vol. 5, Issue 9, p. 691–706, September 1, 2017. Doi: https://doi.org/10.1016/S2213–2600(17)30293-X

[9] ITU. (2019). Measuring Digital Development: Fact and Figures 2019. https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2019.pdf

[10] Cisco Systems. "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2014–2019 White Paper." April 2015. Online: https://ec.europa.eu/futurium/en/content/cisco-visual-networking-index-global-mobile-data-traffic-forecast-update-2014-2019-white.

[11] Ericcson. "Mobile data traffic outlook." Published November 2019.

[12] Web Foundation. October 1, 2019. "Mobile data prices fall across low and middle income countries." Online: https://webfoundation.org/2019/10/mobile-data-prices-fall-across-low-and-middle-income-countries/

[13] Phaneuf, Alicia. December 4, 2019. "How mHealth apps are providing solutions to the healthcare market's problems." *Business Insider*. Online: https://www.businessinsider.com/mhealth-apps-definition-examples

[14] "The Promise of Digital Health: Addressing Non-communicable Diseases to Accelerate Universal Health Coverage in LMICs". Broadband Commission for Sustainable Development Working Group on Digital Health Report, September 2018.https://broadbandcommission.org/Documents/publications/DigitalHealthReport2018.pdf

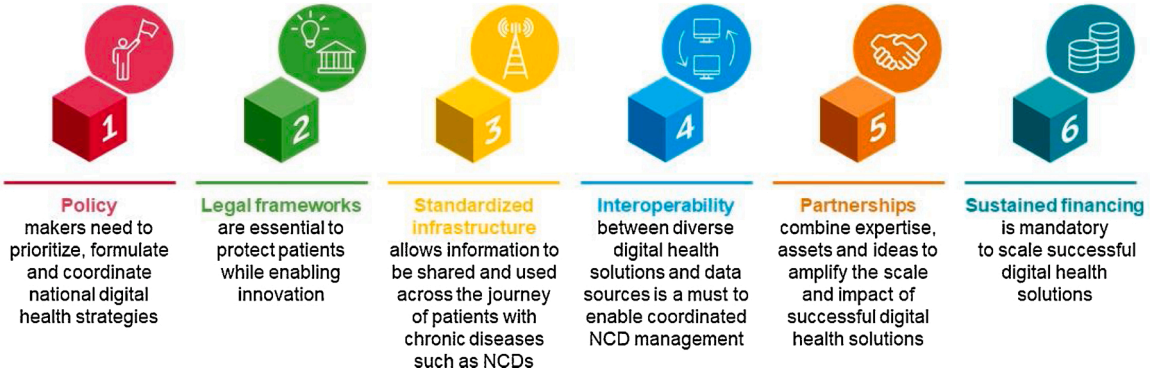

Fig. 2. Six building blocks for digital health systems.

and data silos. Common contributors to fragmentation include:

- Proliferation of digital health pilot projects and initiatives
- Donor dependency characterized by a lack of coordination among external funders
- A lack of common regulatory standards, often mandated by outdated or inflexible policy and regulatory frameworks
- Lack of interoperability between digital health applications, making it more difficult to migrate from legacy (often paper-based) systems to new digital architecture; common reasons include reliance on proprietary elements or commercial software instead of open standards, and inconsistent use of existing standards.
- Lack of alignment between national digital health strategies and national ICT plans

Lack of systems and workforce capacity to develop and manage digital health systems. Common challenges include:

- Lack of technical literacy and management capability among healthcare providers
- Lack of sufficient human and technical capacity to collect and analyze data
- Lack of capacity for ICT professionals to manage, maintain and improve the system through a dedicated management team or unit
- Need for health workers to spend time using multiple systems that are often unable to communicate with each other
- ICT architecture that suffers from connectivity gaps and network quality and performance issues

The development of digital health systems is restricted by a lack of sustained funding. Common funding challenges include:

- Fluctuations in health ministry budgets
- Competing priorities and initiatives across agencies
- Short-term budget cycles not aligned with long-term health-system goals
- In LMICs, reliance on external donor support

Informed by these findings, the Working Group identified six actions that policymakers, in collaboration with stakeholders, can take to create favorable environments for advancing a sustainable, national digital health agenda. These six actions should be seen as building blocks, where all are necessary and each one reinforces the others Fig. 2. The recommendations are illustrated by brief real-world case studies identified by the commission.

1. Formulate and execute a national digital health strategy that lays out a compelling vision and provides clear direction to all stakeholders in the health system. A national strategy should provide a supportive, predictable operating environment for solution providers. High-level leadership and multisector collaboration are essential to articulating the vision that guides the content of the strategy. The strategy should include a well-defined monitoring process to track implementation, impact and cost-effectiveness. An efficient monitoring system that generates relevant, actionable data will create a learning system that guides continua improvement.

Case study: In Tanzania, an eHealth Steering Committee responsible for delivering the National Digital Health Investment Road Map[15] is co-chaired by Permanent Secretaries from the Ministry of Health and Ministry of Local Government and includes additional leaders from the eGovernment Agency, the Ministry of Communications and Technology, local governments, private hospitals, donors and other partners. It oversees digital health implementation and makes policy decisions. Specific teams within the steering committee are responsible for advising on program management and technical issues, governance, and investments).

2. Institute regulatory and policy frameworks to enable digital health solutions while protecting patients and driving innovation. Three categories of regulation are needed:

A) Data management regulation, which securitizes data and safeguards patients' privacy.
B) Device regulation, which ensures that only safe, cost-effective, high-quality devices are approved for use, with the degree of regulation kept in proportion to the risk that devices pose to patients
C) Regulation of the delivery of care, which ensures that medical practices complemented by digital technology are safe and high-quality.

Regulators should consider prioritizing applications for improving prevention and early detection, supporting task-shifting, telehealth and telemedicine, and e-prescription of medicines. The rapid pace of software innovation and especially AI demands that agencies continuously adapt regulatory approaches to ensure safe digital health tools can reach patients quickly.

Case study: In the United States, the Food and Drug Administration (FDA) was the first agency to regulate certain health-focused mobile apps by classifying them as medical devices. The agency has since taken several steps to adapt its medical-device regulations to digital health. For example, it provides a streamlined process for launching apps developed by manufacturers with proven quality standards.

3. Ensure access to digital communication infrastructure by

[15] Government of Tanzania. The Journey to Better Data for Better Health in Tanzania: Tanzania Digital Health Investment Roadmap 2017–2023. Online: https://path.azureedge.net/media/documents/Tanzania_Digital_Health_Investment_Road_Map.2017_to_2023.pdf

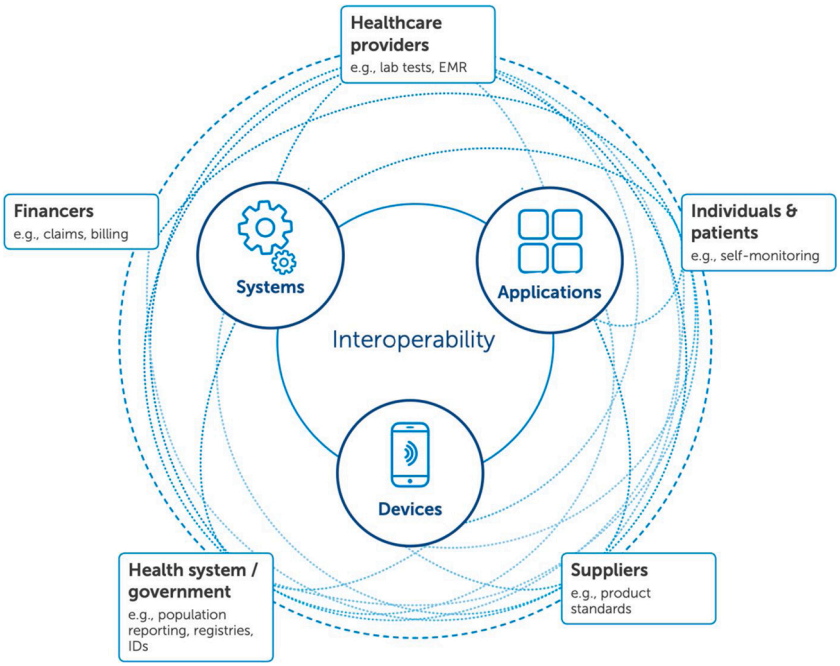

Fig. 3. Interoperability ecosystem for digital health.

making connectivity affordable for all. Communications infrastructure should provide common platforms that connect people with solutions and enable the efficient sharing of information and functionalities. High-priority infrastructure includes health information exchange architecture, unique citizen or patient IDs, electronic health records or registries, Application Programming Interfaces, and health management information systems that integrate data across regions and diseases. Governments and mobile network operators can accelerate access by promoting the public access points, stimulating competition and incentives for operators to enter new markets, promoting infrastructure-sharing, and more efficiently managing radio frequencies.

Case study: The government of Estonia has overseen the development of a nation-wide digital health platform with two critical features. First, an electronic health record system with an online portal stores a unified health record for every patient, which is uniformly populated with data from doctors and hospital workers. Every patient has an online medical history with records accessible to both doctors and them. Second, the platform includes an electronic prescription system connecting every hospital and pharmacy in the country and is used to process 99 % of all prescriptions issued to patients. Physicians prescribe medicines electronically, and patients retrieve their prescriptions at the pharmacy using their ID card. In both systems, data integrity and privacy are protected by blockchain technology.

4. Ensure components of digital health systems are interoperable. Interoperability allows different ICT systems, software applications and devices to communicate and exchange data (Fig. 3). Integrating digital health solutions into national health reimbursement systems is crucial for addressing NCDs, which require lifelong treatment that can lead to catastrophic health expenditures. Because creating interoperability involves making both technical and organizational decisions, interoperability coordinating bodies should include diverse stakeholders.

Case study: In Chile, until 2008 electronic health records were used only at individual hospitals and academic medical centers that could afford them. There were no national interoperability standards, data were not shared, and there was a significant data disconnect between public and private health centers. After several years of incremental progress in promoting interoperability, in 2016 the Chilean Public Development Agency (CORFO) created the Centro Nacional en Sistemas de Información en Salud (CENS) to promote nationwide software interoperability, build health workers' digital health capability, and provide procedures for certifying software and healthcare workers. CENS now works with international standard-setting organizations and local stakeholders to apply recognized interoperability standards in the Chilean market.

5. Establish and maintain effective partnerships between governments and relevant external stakeholders. While governments lead planning and management and are ultimately responsible for securing infrastructure and financing, other partners bring critical expertise, delivery capacity, access to markets and understanding of the needs of target populations. Mobile network operators and fixed and wireless operators are especially important partners because they offer infrastructure, market expertise, and a mass of customer relationships that are essential for scaling. Governments can build bridges to new partners through health innovation events, support to help small companies bid for contracts, and by creating forums that allow stakeholders to meet and build working relationships.

Caset studies: In 2013, Brazilian telecom Telefónica acquired a significant stake in AxisMed, a chronic-care provider, to deliver remote monitoring for chronic patients. Under the service, patients' blood glucose levels and other health data are send to health workers tasked with supporting respective patients. Through this arrangement, AxisMed leverages Telefónica's nation-wide base of customers, who can be reached via mobile apps, SMS and video. By providing this service, Telefónica has improved new-subscriber acquisition and retention.

Since 2013, the ITU-WHO Be He@lthy Be Mobile (BHBM) initiative is using the empowering potential of ICT, harnessing the reach of mobile phones to deliver health information to the people who lack access to conventional services.[16] Its goals include tobacco cessation, diabetes prevention and cervical-cancer awareness, and the initiative reached more than 2.5 million people in ten countries. Based on its insights, the ITU-WHO partnership developed handbooks to provide guidance and technical expertise on integrating mobile health interventions in

[16] https://www.itu.int/en/ITU-D/ICT-Applications/Pages/mhealth-for-ncd-behealthy-bemobile.aspx

national health systems.[17]

In Kenya, the MoH, Amref, the MPesa Foundation, Mezzanine, Safaricom and Accenture Development Partners (ADP) developed a partnership that created a scalable platform called Leap. Through SMS text messages and voice recordings, Leap provides community health workers (CHW) access to learning information on relevant topics, such as hypertension and diabetes. Kenya's MoH provided regulatory oversight and shared strategic direction responsibilities with Amref, who also provided project management and community engagement. Safaricom provided extensive use of telecom infrastructure and data centers. ADP provided consulting expertise in areas including program strategy, delivery, technical design, mobility and learning modules, and co-funded the project with the M-Pesa Foundation. As of 2020 Leap has trained more than 53,000 CHWs with a 92 % completion rate. Training through the platform has led to an 88 % attrition rate, helping to reduce the costs associated with replacing CHWs.[18]

6. Sustain adequate national financing necessary to bring digital health solutions from proof-of-concept to scale. Public or private insurance can ensure access to digital health solutions while protecting patients and users from financial hardship. If no health insurance schemes exist, other financing models can be used in combination with reimbursement schemes or as a financing bridge until health insurance is established. Donor grants are useful to cover start-up costs. External government financing is also typically used for time-limited public health campaigns. Pay-as-you-use or licensing models can generate a constant revenue stream for providers while matching users' needs. Out-of-pocket payment is least preferred but can cover specific needs with a quick adoption rate, and payments for lower-income groups can be subsidized, including through a "freemium" approach. Smart design, local integration and maintenance, and bulk purchases can help reduce costs.

Case study: The Senegalese national health agency, Agence de la Couverture Maladie Universelle (ACMU) has developed the Integrated Information System for the Management of Universal Health Coverage (Système d'Information de Gestion Intégré de la Couverture Maladie Universelle). It is digitalizing health insurance by integrating data from health plans, claims and biometric identification systems, with data input from health posts, public health institutions, pharmacies, private clinics and health insurance funds. The ACMU has developed an innovative approach to generating ongoing revenue from all participating stakeholders. This includes financing via user fees collected from participating institutions, transaction fees levied on each electronic payment, and crowdfunding from civil society, the Senegalese diaspora, business and NGOs. Financial projections suggested that this financing approach could produce an US$12.5 million of revenue annually, helping the system to become self-sustaining over time.[19]

3.1. Creating an enabling environment for building digital health systems

We found that three conditions are necessary for creating an enabling environment for implementing these recommendations at a national level. The first is visionary national leadership that is committed to digital health. Leaders must understand that significant financing is required, and they should invest political capital in mobilizing it. Investments need to be guided and safeguarded by effective governance mechanisms.

Second, national leaders need to oversee a governance mechanism and a process of effective intersectoral collaboration between different governmental ministries, particularly ministries of health, IT and finance, and between ministries and external partners. Roles must be clearly defined and governance mechanisms must allow for efficient decision making.

Third, investment and collaboration need to be executed within the context of a sound national ICT legislative, policy and regulatory framework—including, importantly, regulatory standards for interoperability. This ICT framework needs to facilitate alignment between the health sector and the ICT sector and be flexible enough to promote innovations that will inevitably reshape the marketplace for digital health solutions.

3.2. Digital health system governance

The Working Group found three primary governance mechanisms that governments are using based on where the locus of coordination and accountability lies with respect to the national health ministry. Each offers advantages and drawbacks and should be adapted to the local environment. Countries can also transition between mechanisms as needed.

Health ministry mechanism: The MoH—typically a unit or department that leads on digital health—is responsible for delivering a digital health solution and mobilizes technical capacity and skills from other ministries, agencies, firms and organizations in order to build and deploy the system. The ICT ministry or agency plays a supportive role in implementation.

Government-wide digital agency mechanism: An intragovernmental technology agency provides ICT infrastructure, services and capacity building to all government ministries. MoH drives the digital health strategy and programs but acts as a client of a government-wide technology agency.

Dedicated digital health agency mechanism: A designated third-party agency or directorate with substantial financial and technical capacity is responsible for enabling and delivering digital health services and programs. Health and ICT policy and strategy is often led by the MoH and a cross-sector ICT ministry or agency.

3.3. AI: setting the stage for future research and advocacy

By building digital health systems, countries lay foundations for AI-enabled health systems. Implementing common standards and promoting interoperability, for example, is essential for gathering the massive quantities of data necessary for running AI applications. Machine learning and natural language processing can make health systems more efficient and help to overcome their weaknesses, including the pressing challenge of ameliorating the global shortage of health professionals. AI's potential to transform the delivery of health and care makes it critical for policymakers to invest now in the data and digital infrastructure and capacities that will enable countries to roll out AI-based solutions.

The ITU/UNESCO Broadband Commission's third Working Group on Artificial Intelligence for Global Health, co-chaired by the Novartis Foundation and Microsoft has explored the potential of AI to optimize health systems, close resource gaps, and improve patient health. The working group has summarized its analysis and recommendations in a third report, "Reimagining Global Health through AI: the Roadmap to AI maturity", launched in 2020.[20]

4. Conclusion

Digital and AI technology promises to change the way health and care are provided and has the potential to accelerate the achievement of

[17] https://www.itu.int/en/IU-D/ICT-Applications/Pages/handbooks.aspx

[18] Leap: the mhealth platform. Our Solution. Online: https://www.leaphealthmobile.com/our-solution

[19] Sy, M. (2018). *Business Model Workshop, Paris.*

[20] "Reimagining Global Health through Artificial Intelligence: The Roadmap to AI Maturity". Broadband Commission for Sustainable Development Working Group on AI in Health, September 2020. https://www.broadbandcommission.org/Documents/working-groups/AIinHealth_Report.pdf.

Summary table

What was already known on the topic:

- NCDs present a growing challenge for health and care systems in low- and middle-income countries (LMICs) and may hinder timely achievement of SDG3.
- Digital technology and AI present significant opportunities for LMICs, but face a number of challenges in designing, financing and implementing data and digital health systems that lay the groundwork for AI applications.

What this study added to our knowledge:

- The most common specific challenges countries face with respect to realizing the promise of digital health arise from poorly developed and executed digital health strategies, a lack of systems and human resource capacity, and inadequate financing for digital technology in health.
- Six building blocks that countries can use to effectively develop and manage digital health systems: national strategy, policy and regulatory framework, infrastructure, interoperability, partnerships and financing.
- Three essential factors that create an enabling environment for developing and managing digital health systems include visionary leadership committed to digital health, a governance mechanism and process of effective intersectoral collaboration, and a sound national ICT legislative, policy and regulatory framework—including, importantly, regulatory standards for interoperability.
- The three most common governance mechanisms for digital health systems are those lead by the ministry of health, a government-wide digital agency, or a dedicated digital agency.

SDG3. By applying six practical building blocks, policymakers, private companies, donors, health consumers and civil society can work together to strategically build health and care systems that help accelerate the achievement of the health SDGs, reduce the burden of NCDs, and aid countries in their path toward UHC. Leadership and regulatory coordination at the national and international levels must play a central role, while solutions should have a human-centered design and be flexible to adapt to local contexts. With growing opportunities to apply AI, health and care systems can better predict highest-risk patients, help health professionals respond faster to prevent disease and support policy makers allocate resources for the greatest impact. This can ultimately transform health systems from being reactive to proactive, predictive and ultimately preventative, to keep populations healthy instead of waiting for people to present when they are sick. Ultimately, the most effective approach to building digital health systems is to deploy a combination of established digital technology while allowing flexibility to innovate with emerging technologies.

Authors contribution

Ann Aerts and Doreen Bogdan-Martin both contributed to the coordination of the Broadband Commission Working Groups on Digital Health, to the research conducted, and to the writing of this manuscript.

Declaration of Competing Interest

The authors report no declarations of Interest.

Acknowledgments

We gratefully acknowledge the following Broadband Commissioners and external experts:

Broadband Commission Working Group on Digital Health[21] : Co-chairs: Novartis Foundation, Nokia. Commissioners: GSMA, ITU, Inter-American Development Bank (IDB), UN Foundation, Government of Rwanda, Intel, Microsoft, Bharti Airtel, KT Telecom, Cisco, IDA Singapore, UNESCO, UN Sustainable Development Solutions Network, Sam Pitroda, Huawei. External experts: WHO, PAHO, World Bank, mPowering, NORAD, DIAL, Rwanda eHealth unit, Asia eHealth Information Network (AEHIN), Dimagi, PATH, Vital Wave.

Broadband Commission Working Group on Digital Health 2[22] : Co-chairs: Novartis Foundation, Intel. Commissioners: ITU, Government of Rwanda, Government of Ethiopia, Government of Pakistan, European Commission, UN−OHRLLS, the African Union, GSMA, UN Foundation, Nokia, KT Corporation, Global Partnerships Forum, Microsoft, Huawei Technologies, UN Global Pulse, America Movil, Inmarsat. External experts: WHO, World Bank, PAHO, Vital Strategies, The Union, USAID, PATH, AEHIN, NCD Alliance, Norad, Praekelt, Gates Foundation, Orange, Axa, Digital Health Partnerships, the Digital Impact Alliance, Accenture Development Partners, Endeva.

Broadband Commission Working Group on AI for Global Health[23] : Co-chairs: Novartis Foundation and Microsoft, with more than 15 Commissioners and external experts including AeHIN, IntraHealth, Graduate Institute Geneva, Gates Foundation, Columbia University Mailman School of Public Health, MIT Media Lab, AI4Health Focus Group ITU/ WHO ITU[24], AdaHealth, USAID, Rockefeller Foundation, Massachusetts Institute of Technology, Accenture Development Partners.

The Novartis Foundation provided financial support for the conduct of the research of the Broadband Commission Working Groups and for the writing of the Working Group reports. The corresponding author had full access to the data and both authors had final responsibility to submit for publication.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://doi.org/10.1016/j.ijmedinf.2021.104456.

[21] https://broadbandcommission.org/workinggroups/Pages/digitalhealth.aspx

[22] https://www.broadbandcommission.org/workinggroups/Pages/digitalhealth-ncd.aspx

[23] https://www.broadbandcommission.org/workinggroups/Pages/WG3-2019.aspx

[24] The AI4Health Focus Group of ITU and WHO https://www.itu.int/en/ITU-T/focusgroups/ai4h/Pages/default.aspx.