BMJ Open

Role of digital technology in epidemic control: a scoping review on COVID-19 and Ebola

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To cite: Abebe GF, Alie MS, Yosef T, *et al*. Role of digital technology in epidemic control: a scoping review on COVID-19 and Ebola. *BMJ Open* 2025;**15**:e095007. doi:10.1136/bmjopen-2024-095007

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2024-095007).

Received 12 October 2024
Accepted 06 January 2025

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ABSTRACT

Objective To synthesise the role of digital technologies in epidemic control and prevention, focussing on Ebola and COVID-19.

Design A scoping review.

Data sources A systematic search was done on PubMed, HINARI, Web of Science, Google Scholar and a direct Google search until 10 September 2024.

Eligibility criteria We included all qualitative and quantitative studies, conference papers or abstracts, anonymous reports, editorial reports and viewpoints published in English.

Data extraction and synthesis The Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews checklist was used to select the included study. Data analysis was performed using Gale's framework thematic analysis method, resulting in the identification of key themes.

Results A total of 64 articles that examined the role of digital technology in the Ebola and COVID-19 pandemics were included in the final review. Five main themes emerged: digital epidemiological surveillance (using data visualisation tools and online sources for early disease detection), rapid case identification, community transmission prevention (via digital contact tracing and assessing interventions with mobility data), public education messages and clinical care. The identified barriers encompassed legal, ethical and privacy concerns, as well as organisational and workforce challenges.

Conclusion Digital technologies have proven good for disease prevention and control during pandemics. While the adoption of these technologies has lagged in public health compared with other sectors, tools such as artificial intelligence, telehealth, wearable devices and data analytics offer significant potential to enhance epidemic responses. However, barriers to widespread implementation remain, and investments in digital infrastructure, training and strong data protection are needed to build trust among users. Future efforts should focus on integrating digital solutions into health systems, ensuring equitable access and addressing ethical concerns. As public health increasingly embraces digital innovations, collaboration among stakeholders will be crucial for effective pandemic preparedness and management.

STRENGTHS AND LIMITATIONS OF THE STUDY

⇒ Screening, charting, collating and summarising were done by more than one author independently.
⇒ The scoping review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews checklist.
⇒ We only included English-language articles.
⇒ We synthesised evidence based on their findings' relevance to the review question, rather than the studies' individual quality.
⇒ Most of the evidence comes from high-income and upper-middle-income countries, limiting its contextual relevance to low-income countries with different health system contexts.

INTRODUCTION

The world has faced unprecedented challenges with global pandemics, including, SARS pandemic in 2003,[1] Avian Influenza in 2006,[2] Swine influenza or H1N1 influenza in 2009,[3] Middle East Respiratory Syndrome in 2012,[4] Ebola in 2014,[5] the Zika virus in 2015[6] and most recently, the COVID-19 pandemic.[7] These pandemics have posed a significant threat to global health and well-being.[1–7]

The 2014 Ebola Virus Disease outbreak in West Africa posed a catastrophe, with over 13 500 cases and 4900 fatalities.[8] The magnitude of the epidemic devastated already fragile healthcare systems in Liberia, Guinea and Sierra Leone.[9] Disinformation, a dearth of crucial information, and insufficient training and resources for healthcare workers impeded the response efforts.[10] The severity of the epidemic, which incurred economic losses of up to $33 billion, calls for the swift adoption of cutting-edge technology. For instance, mobile phone data were used to model travel patterns,[11] while handheld sequencing devices facilitated more effective contact tracing and a deeper understanding of outbreak dynamics.[12]

Similarly, the COVID-19 pandemic is rapidly spreading worldwide due to increased globalisation, a longer incubation period and subtle symptoms.[13] Emerging health technologies such as artificial intelligence (AI), telemedicine, mobile health, big data, 5G and the Internet of Things have proven invaluable in pandemic prevention and control efforts.[14 15]

Even though these pandemics are linked to modern socio-technical developments and processes of globalisation, digital technology has played a crucial role in the Ebola outbreak[16] and the COVID-19 pandemic.[17] The use of contact tracing apps, remote patient monitoring and telemedicine has allowed healthcare providers to track the spread of the virus, monitor patients' vital signs and symptoms, and provide medical care remotely.

The digital revolution has brought a transformation across numerous facets of daily existence. As of 2022, a staggering 5.2 billion individuals worldwide have subscribed to mobile devices, with mobile connectivity in Sub-Saharan Africa propelling digital transformation and socioeconomic progress. In fact, as of 2023, an estimated 489 million individuals in Sub-Saharan Africa have subscribed to mobile apps, while 287 million people have used mobile internet.[18] In 2022, 142.6 billion apps were downloaded,[19] and as of 12 September 2023, 4.9 billion people used social media globally, meaning 60.49% of the global population use social media.[20]

The main aim of this comprehensive review is to shed light on the crucial role that digital technologies play in epidemic control and prevention, with a specific focus on the Ebola outbreak and COVID-19 pandemic. It explores the wide range of applications and evaluations of these technologies, as well as the practices and health delivery services that have been implemented during epidemics using digital technologies.

METHODS

We conducted a scoping review of the literature on the role of digital technologies in epidemic control and prevention, focused on the Ebola outbreak and COVID-19 pandemic. The scoping review is important for mapping emerging topics and identifying gaps. It has six steps: stating the research question, searching relevant studies, selecting studies, charting data, summarising and reporting results, and consultation (optional).[21] To ensure comprehensive reporting of methods and findings, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist (Table 1).[22 23]

Identifying the research question

We identified the research question focussing on the impact of digital technologies in epidemic control and prevention during the Ebola outbreak and COVID-19 pandemic. The key research question was to review and synthesise evidence on the applications and evaluations of digital technologies, as well as the practices and health delivery services that have been implemented during epidemics using these technologies. These concepts guided us in identifying search terms under each concept and developing search engines. We assumed that the proposed research question is broad to provide a breadth of issues to be investigated in the review. To determine the research question and agree on the scope and significance of the topic, preliminary discussion was made between the authors.

Identifying relevant studies

PubMed, HINARI, Web of Science, Google Scholar and direct Google search were used to access relevant studies for this scoping review. All studies reporting the impact of digital technologies on epidemic control and prevention in the case of an Ebola outbreak or COVID-19 pandemic were the target of this review. All studies published before 10 September 2024 were included. The search was done using keywords such as "impact of digital technology, or role of digital technology, or importance of digital technology, and Ebola, or Ebola outbreak, or COVID-19, and COVID-19 pandemic". Combinations of Boolean Operators (AND, OR), free keywords and MeSH terms were used in the search process (table 2). No country-related limitations were imposed.

Study selection and eligibility criteria

We included all qualitative and quantitative studies, conference papers or abstracts, anonymous reports, editorial reports and viewpoints published in English. Three authors (GFA, MSA and TY) were involved in the title and abstract screening process, and further assessment were made by the other three authors (DA, DD and AA). Full-text screening was then conducted by the first author (GFA), with evaluation from the fifth and seventh authors (DD and DG). Any discrepancies were resolved through discussion among the authors (GFA, DA and DG). The inclusion of studies in this review is based on their findings' relevance to the review question, rather than the studies' individual quality. The scoping review followed the PRISMA-ScR checklist.[22] The selection of studies was primarily guided by their findings and interpretation, rather than the inclusion criteria.[24 25]

Charting, collating, summarising and reporting results

A form for data charting was created to extract information from each study, including the author, year, study objective, country and study type (table 3). Data was extracted by the first author (GFA), which was double-checked by the third and last authors (TY and DG). Data analysis was conducted by the first author, with guidance and support from the last author, using Gale's framework method.[26] The analysis involved multiple steps, including raw data collection, data familiarisation, paraphrasing, application of the analytical framework, charting data into a matrix and interpretation. Important categories were extracted and grouped into different components, with themes generated within each component by grouping similar categories and concepts. We presented the findings in

Table 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist

Section	Item	PRISMA-ScR checklist item	Page #
Title			
Title	1	Identify the report as a scoping review.	Page 1
Abstract			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results and conclusions that relate to the review questions and objectives.	Page 2
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	Pages 3–4
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (eg, population or participants, concepts and context) or other relevant key elements used to conceptualise the review questions and/or objectives.	Page 4
Methods			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (eg, a Web address); and if available, provide registration information, including the registration number.	NA
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (eg, years considered, language and publication status), and provide a rationale.	Page 6
Information sources	7	Describe all information sources in the search (eg, databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	Page 5
Search	8	Present the full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Page 5
Selection of sources of evidence	9	State the process for selecting sources of evidence (ie, screening and eligibility) included in the scoping review.	Page 6
Data charting process	10	Describe the methods of charting data from the included sources of evidence (eg, calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	Page 6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Page 6
Critical appraisal of individual sources of evidence	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Pages 6–7
Synthesis of results	13	Describe the methods of handling and summarising the data that were charted.	Page 7
Results			
Selection of sources of evidence	14	Give number of sources of evidence screened, assessed for eligibility and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	Page 7, flow chart
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Pages 7–12
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	NA
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Pages 6–7
Synthesis of results	18	Summarise and/or present the charting results as they relate to the review questions and objectives.	Pages 7–12
Discussion			
Summary of evidence	19	Summarise the main results (including an overview of concepts, themes and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	Page 13
Limitations	20	Discuss the limitations of the scoping review process.	Page 12
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	Page 13
Funding			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Page 14

Table 2 Summary of search strategies

Database	Query	Items found
PubMed	((((((Impact of digital technology) OR (role of digital technology)) OR (importance of digital technology)) AND (Ebola)) OR (Ebola outbreak)) OR (COVID-19)) AND (COVID-19 pandemic)	4567
HINARI	Impact of digital technology OR role of digital technology OR importance of digital technology AND Ebola OR Ebola outbreak AND COVID-19 pandemic OR COVID-19	1203
Web of Science	Impact of digital technology OR role of digital technology OR importance of digital technology AND Ebola OR Ebola outbreak AND COVID-19 pandemic OR COVID-19	234
Google Scholar	Impact of digital technology OR role of digital technology OR importance of digital technology AND Ebola OR Ebola outbreak AND COVID-19 pandemic OR COVID-19	454
Google	Impact of digital technology OR role of digital technology OR importance of digital technology AND Ebola OR Ebola outbreak AND COVID-19 pandemic OR COVID-19	42
		6500

three forms: a flow chart of database search results, a summary of the data charting and narrative paragraphs describing and interpreting the generated themes under each analytical framework component.

Patient and public involvement

Patients and/or the public were not involved in the design or conduct or reporting or dissemination plans of this research.

RESULT

Characteristics of the included studies

Out of the 6500 articles identified through search strategies, 3291 records were eliminated due to duplication. An additional 3089 articles were excluded after a review of their titles and abstracts. Then, only 120 articles remained for a full-text assessment. Further 56 articles were excluded due to the content, concept and context were not relevant to the role of digital technology. Finally, 64 articles were included in the final review (figure 1). Of the included articles, 26 were reviews, 14 were experimental studies, 11 were cross-sectional studies, 7 were expert recommendations, 5 were qualitative studies and 1 was a cohort study.

Public health importance of digital technology in Ebola and COVID-19 control and response

A. Electronic disease monitoring

A well-functioning public health outbreak prevention and management are important to determine infection transmission in time, place and person, and to investigate its determinants. To enhance and interpret key epidemiological data collected by public health authorities for COVID-19 and Ebola outbreaks, a variety of electronic data sources are being employed.

Interactive data representation tools for decision facilitation

We identified that the control and response of the Ebola and COVID-19 pandemics are supported by interactive data representation tools. Data visualisation tools, such as data dashboards, have played a pivotal role in consolidating real-time public health data on cases, deaths and testing, empowering policymakers to refine interventions and informing the public.[27–30] The dashboards feature dynamic time-series charts and geographic maps, showcasing region-level statistics and case-level data.[28 31] Certain dashboards showcase clinical trials, policy measures and economic interventions.[32 33] However, few incorporate contact tracing or community surveillance data, and challenges persist in data quality and consistency. Global comparisons are hindered by the lack of standards and government reporting inconsistencies. Access to up-to-date and accurate statistics remains a concern. Novel visualisation approaches like the NextStrain open repository provide a global infection spread map by openly sharing viral sequence data and open-source code,[29] setting an unprecedented pace in data sharing compared with past outbreaks.[34]

Web-based data repositories for early disease identification

Population surveillance systems usually use health data from labs, case notifications from clinicians and syndromic surveillance networks. Syndromic surveillance networks collect reports of clinical symptoms, like 'influenza-like illness', from hospitals and selected healthcare facilities. Detecting undetected cases would provide valuable insights into the scale and features of the outbreak,[35] as well as minimise further transmission.[36]

In the past two decades, various data sources such as online news sites, social networks and web searches have been used to fill gaps in epidemiological surveillance. Data-aggregation systems like the Factiva database,[37] ProMED-mail,[37 38] Global Public Health Intelligence Network (GPHIN),[39] HealthMap[40] and Epidemic intelligence from open sources[41] have been developed to process and filter online data using natural language processing and machine learning. These sources have been integrated into formal surveillance systems[42] and have played a role in monitoring Ebola and COVID-19. For instance, the WHO's Expanded Programme on Immunization - Brain (EPI-BRAIN) platform combines

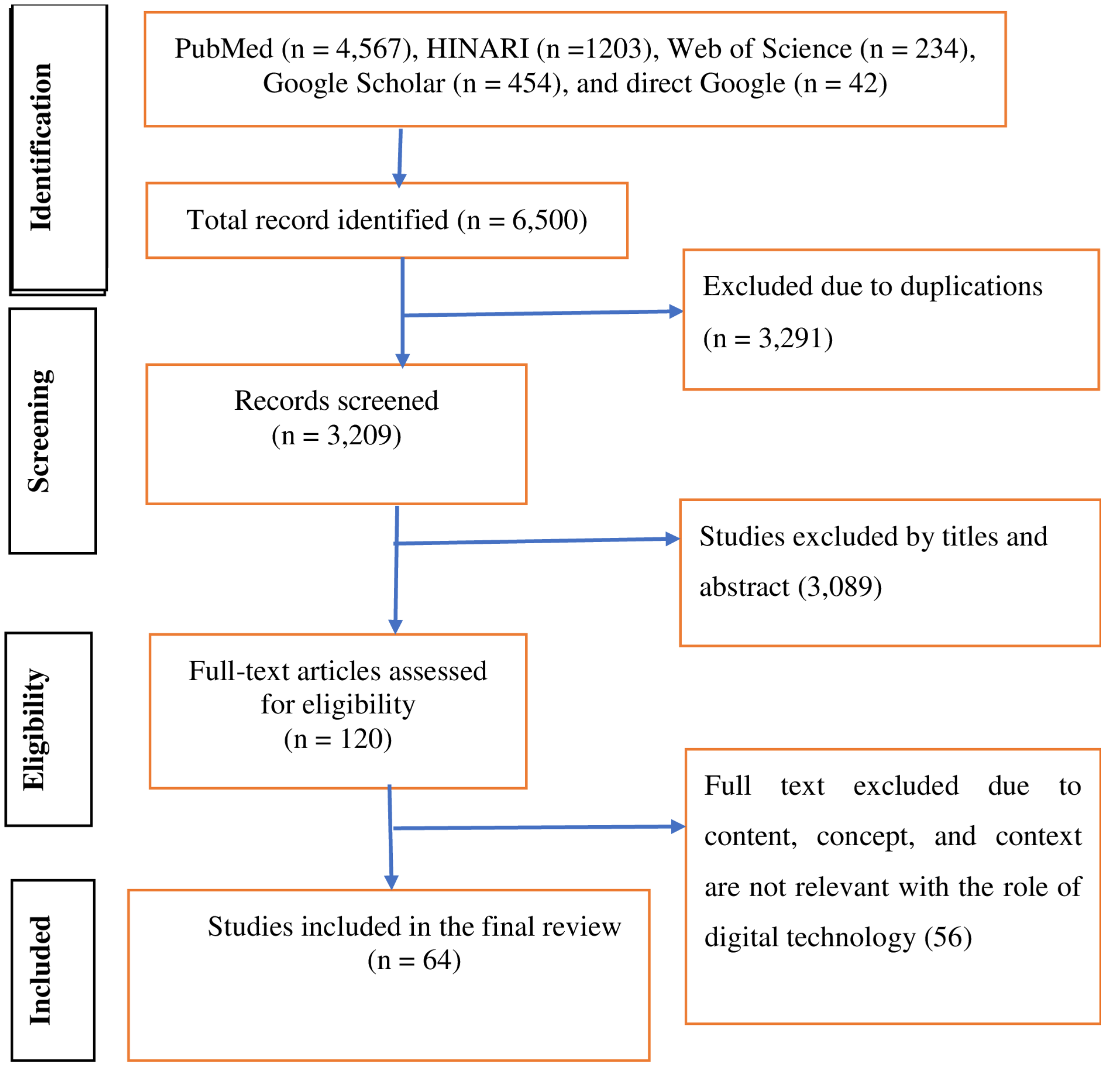

Figure 1 PRISMA-ScR flow chart showing the selection process of studies for the review. PRISMA-ScR, Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews.

diverse datasets for infectious disease preparedness, including environmental and meteorological data.[43] Crowdsourced data,[38 44] news reports[38 44] and automatic syndromic surveillance systems[45] have also been used to detect early disease reports and estimate community spread. However, selection bias and lack of integration with official national surveillance are among the reported challenges.

B. Swift identification of cases

Early and rapid case identification is vital during a pandemic to isolate cases, trace contacts and mitigate further transmission.[46] Digital technologies can enhance clinical and laboratory notification by enabling symptom-based case identification, community testing, self-testing and automated reporting to public health databases.

Online symptom reporting for case identification for Ebola[37] and COVID-19 as seen in Singapore[47] and the UK,[48] now provides advice on isolation and referrals for further healthcare services.[49] Sensors like thermal imaging cameras are used for fever detection,[50–52] but false-positive and false-negative results limit their effectiveness. Wearable technologies are explored for detection and monitoring.[53 54] Decentralised rapid digitally connected diagnostic tests and point-of-care PCR tests are being developed to widen access to testing.[14 55] Rapid diagnostic antibody tests linked to smartphones can provide quick results and facilitate reporting.[56 57] For COVID-19, antibody testing is crucial for population-level surveillance and evaluating interventions like social distancing, but performance and long-term efficacy remain uncertain.[58] The concept of 'immunity passports' for seropositive individuals is debated due to operational and clinical challenges.[59] Machine-learning algorithms are being developed to differentiate COVID-19 from community-acquired pneumonia using hospital chest scans.[60–62] Further evaluation of their effectiveness is recommended.[63 64]

C. Halting community transmission

Following the identification and isolation of cases, it is imperative to trace and quarantine contacts in order to prevent further transmission.[65] In regions with high rates of transmission, the execution and oversight of these interventions must be implemented on a larger scale, which is becoming progressively impractical or, at the very least, challenging through conventional methods.[66]

Electronic contact tracing

Electronic contact tracing automates tracing at a scale and speed difficult to replicate without digital tools.[66] It reduces reliance on human memory, particularly in crowded areas with mobile populations. However, contact-tracing apps raise privacy concerns, necessitating evaluation of their accuracy and effectiveness.[67]

To trace contacts of confirmed cases, linked location, surveillance and transaction data were used,[68] along with the Ebola Contact Tracing application,[69] AliPay Health-Code app[70 71] and voluntary contact-tracing apps that collect location data via Global Positioning System (GPS) or cellular networks,[72] proximity data via Bluetooth[73] or a combination of both.[74 75] Emerging international frameworks, including Decentralised Privacy-Preserving Proximity Tracing,[76] the Pan-European Privacy-Preserving Proximity Tracing initiative[77] and the joint Google–Apple framework[78] are also being developed, each with varying levels of privacy preservation.

A mobile phone-based digital contact tracing solution, the Corona Warn App, prevented 1.41 million infections, 17 200 hospitalisations, 4600 intensive care treatments and 7200 deaths between June 2020 and April 2022.[79] The COVIDSafe app also played a role in reducing transmission rates, with contact tracing efforts leading to a decrease in cases by around 30%.[80]

One major limitation of contact-tracing apps is the need for a significant portion of the population to use and follow app guidance to effectively halt community transmission (achieving an effective reproduction number (R) of <1).[66] Adoption is hindered by smartphone ownership, user trust, usability and handset compatibility.[81] Practical challenges persist, including determining the proximity and duration necessary for transmission to trigger an alert. The effectiveness of these systems in identifying transmission events is not well-documented, suggesting the continued importance of human interpretation.

Assessing interventions with mobility data

Smartphones, Google and Apple can collect aggregated location data via GPS, cellular networks and Wi-Fi to monitor real-time population flows, identify transmission hotspots and evaluate public health interventions like travel restrictions on actual human behaviour.[82–85] Nevertheless, obtaining this mobility data presents a notable challenge,[86 87] as concerns over breaches of civil liberties arise when individuals are tracked to monitor adherence to quarantine and social distancing protocols. The use of wearable devices[88] and drones[89] also raises ethical and privacy concerns.

D. Public messaging to educate populations

The use of online data and social media has been critical in public communication.[90] To ensure the dissemination of reliable information, public health organisations and technology companies are increasing their efforts to prioritise trustworthy news sources. For example, Google's SOS alert intervention[91] prioritises reputable sources such as the WHO at the top of search results. Chatbots are also providing information to reduce the burden on non-emergency health-advice call centres,[92] and clinical practice is being transformed by the rapid adoption of remote health-service delivery, including telemedicine, especially in primary care.[49]

Digital communication platforms are playing a crucial role in promoting compliance with social distancing measures.[93] Video conferencing enables remote work and online learning,[94] while online services provide support for mental health.[95] Additionally, digital platforms facilitate community mobilisation efforts by offering assistance to those in need.[93 96] However, the security and privacy of widely accessible communication platforms remain a concern, particularly regarding the confidentiality of healthcare information.

E. Clinical care

The tutorial applications for mHealth demonstrated great potential in disseminating information and providing training to frontline health workers during Ebola outbreaks.[97 98] Additionally, healthcare providers have been practising telemedicine as a means to effectively control and prevent the spread of the COVID-19 virus.[99] Telemedicine is gaining popularity as a valuable tool in managing and preventing communicable diseases, with the potential for full integration into the healthcare system. However, the utilisation of telemedicine is influenced by factors such as internet accessibility, the availability of information technology support staff, the frequency of searching for health information and the use of social media.[100] These factors have a significant impact on the adoption and utilisation of telemedicine services.

DISCUSSION

For centuries, public health innovations have played a crucial role in preventing and containing diseases, and digital technologies are the latest addition to this lineup. However, compared with other sectors, public health has been slower in adopting digital innovations.[101] The WHO only published its first guidelines on digital health interventions for health-system strengthening in 2019.[102] Nevertheless, the unprecedented humanitarian and economic challenges posed by the Ebola outbreak and COVID-19 pandemic have driven the development and adoption of new digital technologies at a rapid pace.

Potential advancements in digital technology that could enhance public health responses in future epidemics include AI and machine learning, which improve outbreak prediction and response; telehealth services that provide immediate access to healthcare, allowing for quicker diagnosis and treatment; wearable health devices that enable real-time health monitoring to detect early symptoms of infectious diseases and facilitate timely interventions; blockchain technology that maximises data security, accuracy and accessibility; user-friendly mobile health applications that assist with contact tracing, symptom tracking and providing accurate health information to the public; drones and robotics for delivering medical supplies in hard-to-reach areas, disinfection in public spaces and reducing human exposure; and data analytics platforms that help public health officials make informed decisions based on real-time data, improving resource allocation and response strategies.

The identified themes could be better integrated to control disease spread. Digital epidemiological surveillance collects real-time health data from sources like hospitals and laboratories, enabling health authorities to quickly identify new cases and outbreaks. Geospatial mapping visualises disease spread, helping to identify hotspots and high-risk areas for targeted interventions. Digital tools also facilitate contact tracing by tracking interactions, allowing for quick notifications to those exposed, thus reducing transmission. Advanced analytics predict potential outbreaks by analysing trends, aiding in the deployment of resources and preventive measures before cases surge. In addition, digital platforms disseminate vital information about symptoms, testing sites and preventive measures, empowering communities to act responsibly.

Despite these advantages, there are still barriers to the widespread use of digital solutions. To address these challenges, stakeholders in the digital sector, including technology companies, should invest in digital infrastructure in underserved areas for equitable access to technology, provide training programmes for healthcare professionals and the public to enhance their confidence in using digital tools, implement strong data protection measures to build user trust, foster partnerships between governments, tech companies and public health organisations for effective digital solutions, and design tools with user feedback to ensure accessibility and user-friendliness for diverse populations.

For the successful implementation of digital technologies, public trust and acceptance are crucial. When people feel confident in these technologies' security, privacy and utility, they are more likely to adopt and use them effectively. To enhance the overall understanding of how to maximise the impact of digital innovations, a discussion on strategies to build trust such as transparency, user education and robust security measures should be maintained.

Our scoping review has some limitations. First, we only included English-language articles. Second, we synthesised evidence without grading its quality. Third, most of the evidence comes from high-income and upper-middle-income countries, limiting its contextual relevance to low-income countries with different health system contexts.

CONCLUSION

The future of public health is poised to become more digital, and the recognition of digital technology's significance in this field and pandemic preparedness planning has become imperative. Therefore, key stakeholders in the digital sector have to be long-term partners in preparedness, rather than only during emergencies. Viruses transcend borders, and so do digital technologies and data. The regulation, evaluation and utilisation of digital technologies should align with international strategies to enhance pandemic management and future preparedness for infectious diseases.

Future researchers should focus on comparing the effectiveness of different digital technologies, exploring how these technologies can be sustained and integrated into regular health systems, identifying barriers to access and strategies to ensure equity in digital health initiatives among underserved populations, addressing ethical considerations and privacy concerns related to public health data during pandemics, and examining how digital technologies can complement traditional public health strategies to ensure a holistic approach to pandemic management. Future researchers also focus on examining the role of digital technology in low-income country settings.

Contributors GFA comprehended and conceptualised the study design. All authors (GFA, MSA, TY, DA, DD, AA and DG) contributed to the data extraction, analysis, interpretation of the result and drafting of the article. All authors participated fully in revising the article, agreed on the journal to which the article will be sent for publication, gave final approval of the version to be published and agreed to take responsibility for all aspects of the work. GFA is the guarantor.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design or conduct or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. Not applicable.

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