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COVID-19 and beyond: Use of digital technology for pandemic response in Africa

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ABSTRACT

The use of technology has been ubiquitous in efforts to combat the ongoing COVID-19 pandemic. In this perspective, we review technologies and new approaches developed at the start of the pandemic; efforts earmarked by a flexible approach to problem solving, local tech entrepreneurship, and swift adoption of technology. We performed a systematic review of the use of technology during the initial wave of the COVID-19 pandemic in most African countries. We identified relevant articles by searching for mentions of technology, COVID-19, and specific country names. Articles were included if they specifically mentioned the use of technology or novel innovations in the response to the COVID-19 pandemic in an African country. The article search was conducted in August and included articles published between January and August 2020. We retrieved articles from journals, trusted news, government, and organization websites on Google, Google Scholar and PubMed. A total of 80 articles were retained and categorized under Disease Prevention (19 articles), Disease Surveillance (30 articles), and Clinical Supplies and Management (31 articles). African nations used technology and innovative techniques to manage patients, monitor cases and disseminate information to counter the spread of COVID-19. The nature and outcomes of these efforts sometimes differed in Africa compared to other regions of the world due to its unique challenges and opportunities.

Introduction

Since the emergence of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in China, there have been varied, and sometimes conflicting narratives regarding its spread in African nations. Seroprevalence and postmortem tests suggest that there have been widespread exposure of SARS-CoV-2 in some African countries [1,2]. Mwananyanda and colleagues found a 19.2% positivity in 10% of deaths reported at the University Teaching Hospital morgue in Lusaka, Zambia, from June to September 2020 [1,3]. Seroprevalence surveys conducted in Kenya, Zambia and Mozambique reported rates higher than recorded infections at the time of the studies [2,4–6].

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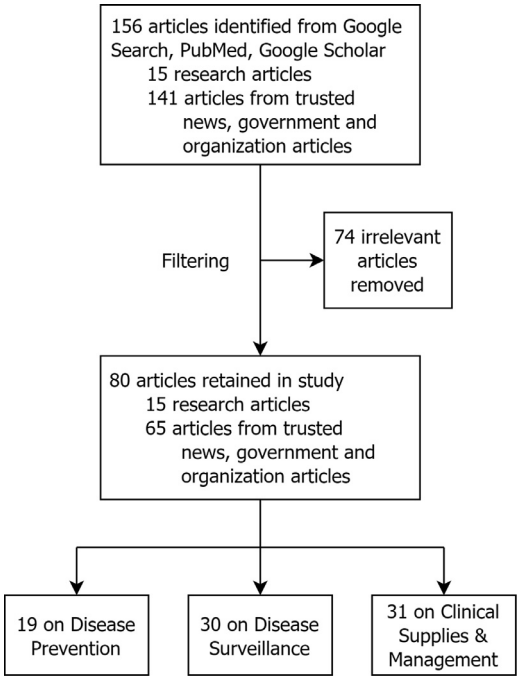

Fig. 1. Flowchart of article selection and categorization for the systematic review.

While the response to the COVID-19 pandemic has varied across countries, there have been coordinated efforts by organizations such as the Africa CDC to limit both the public health and economic impact [4]. Additionally, local governments, non-governmental organizations and individuals have repurposed existing technologies and created novel innovations to fight COVID-19. In this perspective, we review the use of these technologies and other innovations for disease prevention, disease surveillance, and healthcare management. Specifically, we aim to provide a comprehensive review of how technology has been used during the early stages of the pandemic in Africa with a focus on highlighting significant lessons and areas where there is potential for technology to strengthen local and national response to natural disasters.

The paper is organized into four sections. In Section 2, we discuss our approach for article selection. We divide the articles into three different categories i.e., Disease Prevention, Disease Surveillance and Clinical Supplies & Management, and discuss our findings from the review for each of the categories in separate sub-sections in Section 3. Next, we discuss how healthcare systems in Africa can benefit from the local technologies that have emerged in response to COVID-19, and the associated challenges in Section 4. Finally, we conclude with a summary of future recommendations in Section 5.

Methods

In this systematic review, we conducted a literature search in August 2020 using Google, Google Scholar and PubMed. We searched for articles using the following search terms: "[Country] AND Coronavirus OR COVID-19 AND Technology". The search was conducted for each of the 54 African countries. To supplement this search, we also searched for "Africa AND Coronavirus OR COVID-19 AND Technology" to identify articles that were missed in the country-specific searches. We included articles that mentioned the use of technology in the control of COVID-19 in any of the countries. We only included articles from journals, trusted news, government, and organization websites such as the United Nations and the World Health Organization (WHO). A flowchart of our article selection process is available in Fig. 1.

Results

We discuss the use of technology and innovations in the COVID-19 pandemic response under three subsections: disease prevention, disease surveillance and clinical supplies and management. Summaries of our findings are presented in Tables 1–3. See a demonstration of example technologies in Fig. 2.

Disease prevention

Disease prevention is a major component of epidemic control and African nations have used technology in different ways to support preventive efforts. Physical distancing interventions were implemented early in the pandemic in many countries,

Table 1
Summary of the different types of technologies used for disease prevention (Section 3.1) in combating COVID-19 throughout Africa.

Technology	Examples and Usage for Disease Prevention	Countries
Cashless Payment	Internet-based payment, Electronic pass	Ethiopia [9], Sierra Leone [8]
Drones	Issue warning, awareness messages and disinfectants	Ghana [14], Morocco [12], Rwanda [15], Sierra Leone [10], South Africa [13], Tunisia [11]
Mechanical	Contactless soap dispensers, Solar-powered hand washing sink, Thermal imaging, Plastic motorcycle shields	Ethiopia [17], Ghana [18], Senegal [16], Uganda [19,69]
Software Platforms	Bot for COVID-19 questions	Morocco [21]
GIS-Powered	Ushahidi	Kenya [20]
Low-Tech	SMS & caller ringtones	Guinea [22]
Machine Learning	Text-to-speech radio monitoring	Uganda [23]

Table 2
Summary of the different types of technologies used for disease surveillance and diagnosis (Section 3.2) in combating COVID-19 throughout Africa.

Technology	Examples and Usage for Disease Surveillance & Diagnosis	Countries
Mechanical	Thermal imaging	Uganda [49]
Software Platforms	COVID-19 case dashboards, Tableau dashboard for emergency calls, Vulnerability mapping dashboard using satellite imagery	Ghana [26], Nigeria [25], Sierra Leone [24], Somalia [37], South Africa [27], Tunisia [28]
GIS-Powered	GIS-based tracking dashboard, GIS-powered handsets, Hot-spot tracking using additional data sources	Rwanda [29], South Africa [30,40]
Low-Tech	Open Data Kit	Rwanda [41]
Machine Learning	Text-to-speech radio monitoring of public opinion	Tunisia [48]
Phone Apps	Recording travel info, Checking symptoms, Risk assessment, Contact tracing	Algeria [36], Ethiopia [31], Ghana [34,38], Nigeria [35], Sierra Leone [32,33], Tunisia [39]
Genomics (e.g., Nanopore Sequencing)	Virus sequencing	Gambia [44], Ghana [42], Zambia [43]
Tests	Sample pooling, Home-grown swab kits	Rwanda [46], Uganda [47], Senegal [45]

Table 3
Summary of the different types of technologies used for clinical supplies and management (Section 3.3) in combating COVID-19 throughout Africa.

Technology	Examples and Usage for Clinical Supplies & Management	Countries
Mechanical	3D printing for PPE and ventilators, Indigenous low-cost ventilators	Egypt [53], Ethiopia [71], Gambia [52], Kenya [51], Nigeria [70], Sierra Leone [72]
Software Platforms	Information exchange platform for Healthcare professionals, Medical Supplies Platform	Africa [82], Benin [65], Morocco [64], Nigeria [77]
Low-Tech	Repurposed phone-based HIV self-care	Uganda [66]
Machine Learning	Chest X-rays analysis	Tunisia [48]
Phone Apps	Assisting pregnant women, Ride-hailing apps for providing medical supplies	Egypt [75], Uganda [63,74]
Robots	Dr. Car, Police robot, Robot for clinical assistance	Rwanda [54], Senegal [57], Tunisia [55,56]
Telehealth	Video recording, Digital-first care, Triaging	Egypt [62], Eswatini [58], Ghana [60], Libya [73], Rwanda [59], Uganda [61]
Miscellaneous	Online training of health professionals	Africa [80,81]

sometimes before official confirmation of the first COVID-19 case [7]. However, enforcing these physical distancing interventions was challenging. Countries such as Ethiopia and Sierra Leone used Internet-based payment systems and electronic pass management to enforce distancing between travelers and limit movement to essential workers during national lockdowns [8,9]. South Africa, Morocco, Sierra Leone and Tunisia used drones to issue warnings and announcements, and to question people on the street about their reasons for being out during lockdowns [10–13].

Similarly, drones were used to spread awareness messages in Rwanda, and for disinfecting public places in Ghana [14,15]. Locally designed interventions like contactless soap dispensers and solar-powered hand washing sinks were used to promote hygiene in Senegal, Ethiopia, Ghana and Uganda [16–19].

In addition, technologies that allow for mass communication were used to spread messages on disease prevention. For example, Ushahidi, a decade-old Kenyan tech innovation, was used worldwide to ask and receive help during lockdown, and gather information about the virus [20]. Likewise, a startup in Morocco released a bot which answered COVID-19 related questions in Arabic [21]. While in Guinea, the government capitalized on bulk SMS messaging and broadcasted information through caller ringtones in the various regional languages [22]. In Uganda, the UN Innovations Data Lab used machine learn-

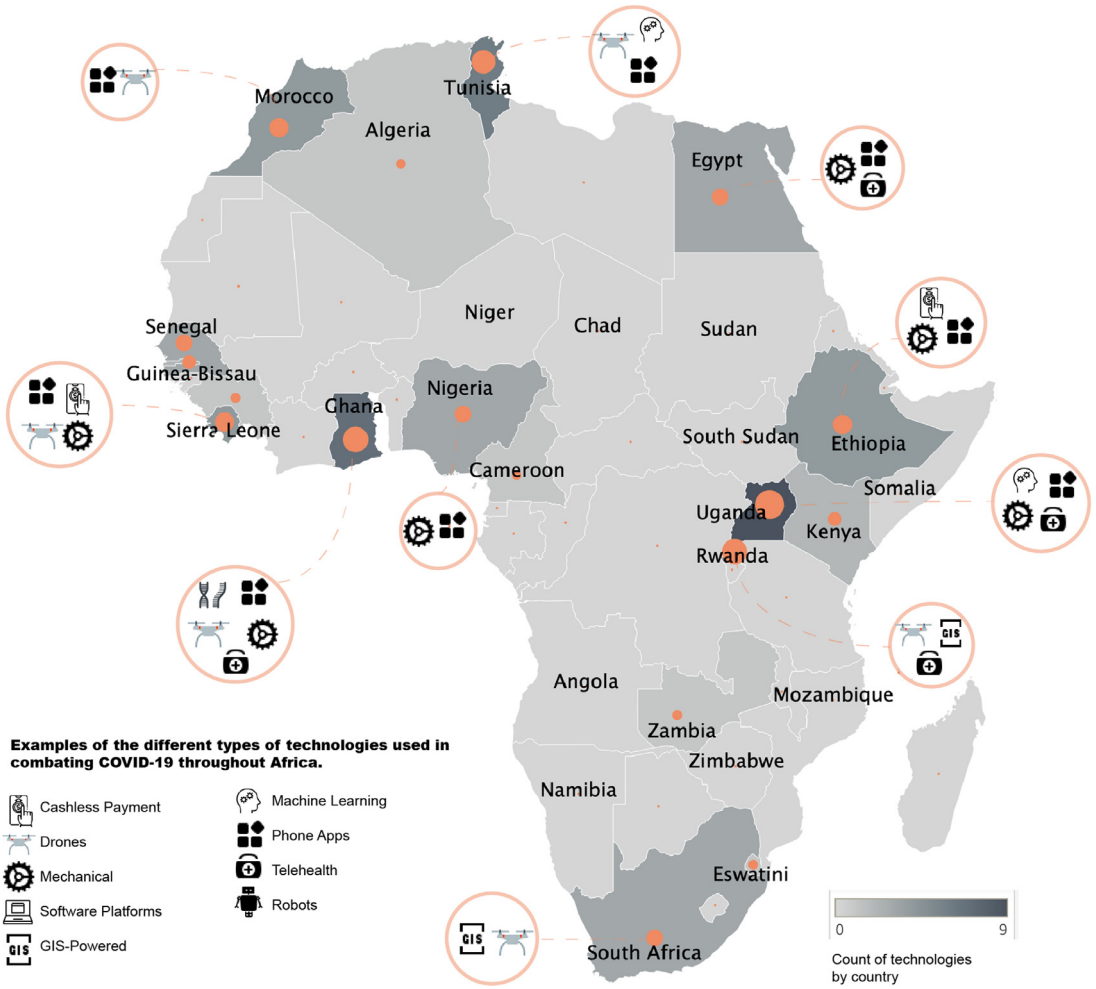

Fig. 2. Demonstration of various technologies in ten African countries with the highest count of tech-driven solutions used for combatting COVID-19.

ing to deploy a text-to-speech radio monitoring technology to gather first-hand incidents, local opinions and beliefs about the pandemic [23]. The data gathered using these tools could be used to identify areas with greatest need for healthcare resources, combat misinformation and gauge the social and economic impacts of lockdown.

Disease surveillance

Like preventive measures, several countries implemented tools (such as dashboards) to monitor the number of cases, tests and deaths [24–27]. For instance, Tunisian agencies used Tableau dashboards to analyze calls made to the country's general emergency number (which saw two years' worth of calls in less than a month) to find patients who needed immediate attention [28]. These tools were especially useful for household and community-level surveillance, because it can enable timely detection of new outbreaks. For example, in Rwanda, a GIS system was used to track cases at the household level and the data was used to assess the need for lockdown measures and other public-health interventions [29]. In South Africa, a technology used for identifying rhinoceros poaching hotspots was used to capture health and location data to spot new COVID-19 case clusters in communities [30]. Also, Ethiopia developed mobile phone apps for recording personal identification information and temperature at ports of entry, information that was used by a COVID-19 surveillance system for contact tracing activities [31].

Similarly, systems for reporting and checking symptoms were implemented in Sierra Leone and Ghana [32–34]. In Nigeria and Algeria, mobile tools were also used to track cases, assess the user's risk of COVID-19 based on responses to a curated questionnaire and enforce adherence to quarantine rules [35,36]. The data collected (e.g., symptoms, age, and travel history) could be analyzed to predict population- or community-level response and adherence to public health interventions. Humanitarian agencies also used satellite imagery and other sources of data to map and identify high-risk areas to generate situational awareness and capacity [37]. These tools took advantage of the widespread adoption of mobile phones in most

African countries, but some were more accessible than others - they did not require an Internet connection or a smartphone [34].

Contact tracing and genomics

Contact tracing apps were developed in some countries (e.g., Ghana and Tunisia), however, similar to other countries around the world, their adoption and impact was uncertain [38,39]. Alternatives to contact tracing apps included handsets equipped with location-tracking technology which were distributed in the hardest-hit areas in South Africa for contact tracing [40]. Similarly, in Rwanda, contact tracing was performed by tracing infections through the paperless Open Data Kit application [41].

Genomic epidemiology also played a significant role in understanding the spread of COVID-19 in some countries. Ghanaian scientists were among the first to sequence the SARS-Cov-2 in Africa [42]. Zambian scientists used nanopore sequencing to track mutations in SARS-CoV-2, understand the origin of cases and track people in the chain of infection [43]. Similarly, Gambian scientists traced the origin of the first six cases in their country by sequencing the virus strain from cases and mapping it to eleven other strains of Asian, American and European origin [44].

Disease diagnosis

Testing capacity remains a challenge in some African countries. However, there have been efforts to increase testing supplies and develop at-home tests [4,45]. Also, techniques such as sample pooling which involves testing samples from many people at once and other group testing techniques were proposed in countries like Rwanda to significantly reduce testing cost per person [46]. Home-grown swab tests in Uganda were recommended to reduce the cost of COVID-19 testing and point-of-care deployment in remote areas [47]. Other innovations in this area included an open-source software developed in Tunisia, which was used to compare chest X-rays of patients suspected of having the virus to X-rays of patients with confirmed COVID-19 disease [48], and thermal imaging for detecting COVID-19 developed at Makerere University in Uganda [49].

Clinical supplies and management

Medical supplies including personal protective equipment (PPE) (such as, masks, face shields, gowns and gloves) and tests are important for diagnosis and managing disease epidemics. Many countries lacked adequate supplies of PPE due to a lack of in-country production and global dependence on a few countries for production. To address the challenge posed by a lack of medical supplies, some countries adopted technology in the printing and distribution of medical supplies such as masks, test kits, and ventilators. 3D printing and drones were used to make and deliver medical supplies, respectively. For example, drones were used to deliver medical products, testing samples, PPE and COVID-19 test kits to labs in Rwanda and Ghana [37,50]. 3D printing was also used to develop personal protective equipment in Cameroon, Egypt and the Gambia, and affordable ventilator adaptors in Kenya [37,51–53].

Clinical management

Several innovative techniques involving robots and mobile phones were used throughout Africa in the clinical management of patients. For example, in a bid to minimize contact between health workers and COVID-19 patients, robots were deployed in healthcare settings in Rwanda and Tunisia to perform simple tasks like taking temperature, monitoring the health of patients, delivering food and medicine [54–56] etc. Student engineers in Senegal designed a small robot called 'Dr. Car' to measure the temperature and blood pressure of infected patients at hospitals, reducing the risk of exposure to healthcare workers. Additionally, the robot could also ease patient-doctor communications during treatment, especially in hard-to-reach rural areas [57].

Furthermore, digital solutions played an important role in the provision and management of health care for COVID-19 and other patients. First, telehealth was adopted in innovative ways in several countries for clinical management. In Eswatini, in-person care of Tuberculosis and HIV patients was modified to involve no-contact by asking patients to film a video while taking their required medications and send it to a nurse [58]. In Rwanda, a digital-first solution was developed to encourage COVID-19 patients to self-care at home instead of overcrowding their healthcare system, leaving the urgent care free for critically ill patients [59]. Telehealth usage also surged in Ghana and Uganda, demonstrating that time consuming manual clinical management could be replaced with a less stressful technology-driven solution [60,61]. Egypt's broadband network was leveraged to support telehealth solutions for primary care units [62].

Second, mobile apps and platforms were used in supporting patients and medical professionals during the pandemic. For example, an app for pregnant women in Uganda provided up-to-date guidelines on practicing social distancing during pregnancy [63]. The Moroccan Ministry of Health introduced a platform for healthcare professionals to exchange COVID-19 knowledge [64]. While in Benin, a healthcare platform was used to connect hospitals and different healthcare stakeholders thereby reducing time spent on procuring patients' medical records [65]. Lastly, a voice and SMS messaging system for HIV patients was repurposed by Ugandan researchers to support quarantined individuals and flag potential concerns [66].

Discussion

The lack of vaccine supplies, the emergence of new outbreaks and variants implies that nations in Africa are still at risk for recording significant morbidity and mortality due to COVID-19. Many lessons and recommendations have emerged regarding the need for developing resilient health systems globally [67]. Healthcare systems could benefit from the novel and repurposed technologies that were adopted during the early days of the COVID-19 pandemic in Africa in at least four ways.

First, technology developed in response to the pandemic can be adopted for future outbreaks. For example, GIS and other web-based tools developed for monitoring and reporting COVID-19 cases can be used for communicating about disease cases, deaths, risk and overall situational awareness during other natural disasters. Timely dissemination of reliable and necessary information can lead to more population awareness, increased transparency and trust in institutions [68]. If maintained, these systems would be at the ready in future natural disasters. Furthermore, context-specific telehealth approaches that adopt existing public health platforms can also be useful especially if these solutions can take advantage of mobile phone infrastructure, community approaches to addressing infectious diseases with a high burden, local culture and language. Approaches that aim to minimize access barriers (such as, Internet and smartphones) while providing healthcare services to remote regions, where health centers are lacking, would be extremely beneficial.

Second, technology can drive local community action and can be combined with community engagement to drive population response. The success of public health interventions such as, social distancing and masks wearing, requires active community participation. Community engagement using technology and innovations at the early stage of the pandemic resulted in many contextualized approaches. For example, local inventors in Uganda created plastic motorcycle shields to keep motorcycle taxis running during the pandemic [69]. Young inventors and students in Nigeria, Ethiopia and Sierra created ventilators to combat the shortage of ventilators [70–72]. A telehealth platform, created by a Libyan entrepreneur to connect healthcare professionals in the diaspora to patients in their home countries, became the go-to app for triaging of COVID-19 patients in Libya[73]. Other community driven innovations included medicine delivery by connecting COVID-19 patients with pharmacies in Egypt and ride-hailing apps that offered doorstep delivery services for medical necessities such as contraceptives, pregnancy and HIV tests in Uganda [74,75]. In most cases, these local innovations appeared siloed from government response. A more coordinated approach that involves the government and innovators and engineers in local institutions would help sustain community engagement and interest in creating technological solutions to healthcare challenges.

Third, investing in science education and adopting “home grown” technology would also help sustain gains in the promotion of science and technology, and its potential to solve local health problems. Solutions to health crises should not be left to local and international experts, youth and community health workers should be included in pandemic planning and response conversations. The median age across the African continent is 19 years, and many of these young people have innovative ideas and are passionate about developing technology and using data to address local problems [76]. For example, tech startups were funded in Nigeria to develop innovative solutions that promote primary care, improve efficiency of health processes, communicate health risks, and assist patients with self-triage [77]. Morocco had a dedicated industrial base for unmanned flight technology, however most of its drones were imported from China. The pandemic prompted the rise of startups with the aim to build drones in Morocco for thermal surveillance and disinfectant-spraying [78]. Startups in Morocco were also funded to develop solutions to challenges associated with the pandemic, including the use of 3D printers to develop masks, PPE and ventilators for hospitals. The Tunisian entrepreneurial ecosystem also financed several scientific ideas related to addressing pandemic [36]. Egyptian IT Agency’s dedicated innovation and entrepreneurship center supported hackathons for building different parts of a COVID-19 response system that helps people, disrupted businesses and health agencies [79]. If sustained, these technological advances can lead to long-term improvements in public health infrastructure in Africa.

Fourth, technology can be used to expand research capacity and infrastructure such as, remote learning platforms, national and international collaborations, and the democratization of public health knowledge. For example, during the pandemic, organizations such as the Africa CDC and the African Society for Laboratory Medicine developed and offered training online [80,81]. Also, in response to the COVID-19 pandemic, the African Union created the Africa Medical Supplies Platform, a collaborative platform that operates across national boundaries and partners with African governments at all levels to connect COVID-19 response teams with medical supplies [82,83].

Challenges

While technology has been adopted to address many COVID-19 related concerns, it is difficult to measure their impact on controlling the pandemic because most efforts have been decentralized. Furthermore, challenges still persist that limit the adoption of new technologies. For example, telehealth has gained traction as a safe alternative to in-person clinical visits; however, its widespread adoption is impeded by internet connectivity and geographical limitations to accessing medicine deliveries and lab sample pick-ups [84]. The COVID-19 pandemic has brought a focus to the need for data, digital connectivity and technology among countries in Africa. For digital health solutions to succeed and be accessible to everyone, barriers to widespread distribution of the internet need to be addressed and all stakeholders must cooperate to come up with a resilient, affordable, scalable, long-term plan that enables rapid deployment.

Furthermore, limitations identified during this pandemic can be used to spur the development of better public health surveillance systems. The creation of genomic hubs in well-placed locations throughout the continent will enable Africa to rapidly generate and curate genomic data related to outbreaks [85]. It should be paired with the deployment of portable genomic technologies for rapid surveillance of local outbreaks [86]. Point-of-care diagnostic services (on-location healthcare including testing, scanning etc.) supplemented with machine learning and information systems should be prioritized in combating the ongoing pandemic and future outbreaks, since they have proved their necessity in previous healthcare epidemics like HIV [87]. The development of reliable disease detection systems including, diagnostics, monitoring and developing well-equipped health facilities can help countries to prepare for future outbreaks [88].

Conclusion

Africa has a long history of combating disease epidemics, which has proven extremely useful in combating the COVID-19 pandemic across the continent. This experience in fighting epidemics has been channeled to build resilient public health responses to COVID-19 elsewhere in the world [89]. However, to create significant advances in healthcare, African nations must invest in technologies that have the potential to improve health care. This should include investment in human capital, and establishing legal and regulatory frameworks that govern the use of these technologies. This will facilitate innovation, encourage financial investment and foster entrepreneurship. Combining technology with well-established public health techniques for combating epidemics would enable governments to solve problems quicker and more robustly if used sensibly and ethically.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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