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Legacy of COVID-19 Innovations: Strengthening African Primary Health Care through Pandemic Innovations

Chipo Nancy Ngongoni, William Wasswa and Moredreck Chibi *

World Health Organization, African Region, Brazzaville P.O. Box 06, Congo; ngongonic@who.int (C.N.N.); wwasswa@must.ac.ug (W.W.)
* Correspondence: chibim@who.int

Abstract: The COVID-19 pandemic led to a global surge of health care innovations aimed at curbing the pandemic. Some of the innovations were newly developed whereas others were modifications of existing technologies to suit the COVID-19 response. With the world achieving some level of normalcy, the question is what will become of these innovations. This study reviewed and analysed 1003 innovations that were utilised for the COVID-19 response to assess if they are still being utilised to strengthen health systems. The paper goes on to identify, profile and showcase 48 innovations and trace their evolution to support and strengthen Primary Health Care. Through this analysis and narration, four strategic pillars of collaboration, governance, innovation design and strategy emerge as factors that help explain the successful integration of these innovations in Primary Health Care. Under these pillars emerged nine key aspects of strategic inter-industry collaborations, standardisation and supportive policies, minimalistic and modular designs, off-grid capabilities, interoperability, data infrastructure, interoperability, data analytics including security and privacy, and the design of technology around ecosystems and platforms. The overall aim of this study is to inform the dynamics around the improvement of scaling and increase the sustainability of innovations across the African region to strengthen health systems and promote innovation.

Keywords: COVID-19 technologies; primary health care; innovation; health innovation ecosystems

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1. Introduction

Globally, innovation played a significant role in the effective response to and recovery from the effects of the COVID-19 pandemic [1]. The pandemic led to the development and spur of systemic, process and technological innovations in health, and the uptake of these innovations played a significant role in the response to the pandemic [2]. These innovations were used across various continuums of the response, which included surveillance, contact tracing, point of entry, risk communication, community engagement, infection prevention and control, case management and laboratory services. Notably, some of these innovations are still being used currently and are redefining business and health workflows.

Some systemic innovative changes have included frameworks that push for governments to be prepared and agile whilst facing pandemics [3]. To push the preparedness narrative, various initiatives were formulated around COVID-19 innovations by key organisations. This included the African Centre for Disease Control (Africa CDC) asking key questions that need to be addressed around health system strengthening, research and development across Africa in the wake of the needs surfaced by the pandemic [4], whilst the World Health Organisation in the African region consolidated a compendium of COVID-19 innovations [5] and UNICEF launched a venture fund for startups that use emerging technologies such as machine learning and AI to address health and health care needs [6]. These activities served as a basis for health system resilience by strengthening data and knowledge hubs that are essential parts of building agile learning health systems that quickly customise and integrate innovations.

Health financing for innovation in Sub-Saharan Africa is largely characterised by high dependence on external (donor) funding and low government spending [7]. This has resulted in a myriad of technological innovations being utilised and supported by various donors across various health campaigns, only for the tools to be redundant after the funding cycle has ended. When looking to increase local ownership and integration of innovation into the systemic processes of health service delivery, working with technologies and tools that have been utilised in various other types of health campaigns is a starting point. Hence, the African Union Commission and Africa Centres for Disease Control and Prevention (Africa CDC) launched the New Public Health Order for Africa and called on governments and multilateral organisations to support increased domestic investment in health, including the domestic mobilisation of financial resources, human capital and technical resources [8]. Coming from the nexus of low resource capacity, it is important to see how best to implement scalable, sustainable and integrated technological solutions in a coordinated manner, which is necessary to experience the benefits of technological innovations in health systems. Without proper integration of digital and technological innovations, this leads to a form of e-chaos, as identified by Karamagi et al. [9].

Considering that a high level of investment has gone into the development of these innovations, a key question that this study is aiming to answer is *'how are innovations that were primarily developed for COVID-19 being utilised to strengthen Primary Health Care?'* This question is based on the premise that utilising proven innovations in various other contexts can be an important way of pushing for localised innovations and a health system that suffers less disruption in the face of pandemics. The study aims to add to the discourse around the recurring issue of the sustainable integration and scaling of health innovations to support health system strengthening, especially across the African region [10]. Hence, this study not only highlights some key technological innovation use cases designed for tackling COVID-19 but also gives a narrative on how they have now evolved to being used in various other contexts. The overall aim of the study is to provide insights about the elements that are essential in supporting these innovations to strengthen PHC.

This paper will start with an overview of Primary Health Care (PHC) and the key challenges that plague PHC, especially in Africa. This will be followed by an outline of the methodology used to identify the innovations. An analysis and discussion of the identified innovations that were utilised to circumvent the effects of COVID-19 will be presented, with emphasis on how the innovations have adjusted to support PHC. The paper concludes by providing insights and recommendations for innovators and policy makers at the core of innovative technologies, especially in addressing pandemics for future preparedness.

2. Literature Review

2.1. Disparities and Opportunities in Primary Health Care

Primary Health Care (PHC) is at the core of improving the accessibility, affordability and quality of health care. PHC, especially in Africa, is plagued with a number of challenges that several researchers have highlighted. A study by Oleribe et al., [11], showed that the three major challenges affecting PHC in Africa were inadequate human resources, low budgetary allocation to health initiatives and poor leadership aligned with organisational management. Mash et al. [12] reported inadequate human resources, medical supplies and infrastructure challenges as the major obstacles to PHC. The challenges facing PHC in Africa were also summarised in a McKinsey report that highlighted that the Tanzania health system was plagued with financial disparities, weak governance and a demoralised and under-supported workforce, together adding up to poor performance [13]. On the other hand, Lokotola et al. [14] investigated the amount of scholarship that looked at the effects of climate change on PHC in Africa. The study went on to propose 10 key research questions that might help increase evidence that can inform health systems and policy makers. Interestingly, from an innovation angle, the authors highlighted the need for tools to evaluate the emergency preparedness of PHC facilities and services to withstand climate-related risks whilst bridging the urban–rural divide.

With the need to address these challenges and operationalise how to strengthen PHC, the United Nations International Children's Emergency Fund (UNICEF) and the World Health Organisation formulated an operational framework for PHC aimed at ensuring alignment amongst key stakeholders in order to support PHC-related national policies, strategies and plans [15]. The framework consists of 4 strategic levers and 10 operational levers to ensure that contextualised strategies are developed to strengthen health systems and make strides towards attaining UHC. The operational levers consist of elements such as physical infrastructure, models of care, digital technologies for health, systems of improving quality of care and monitoring and evaluation. These are all elements that can be enabled and supported by innovations. For any health intervention to align with this, there needs to be multisectoral planning, policy and action, along with integrated services that prioritise primary care and essential public health functions and the empowerment of people and communities [15]. This has guided other researchers such as Peiris et al., 2021 [16], who used the PHC operational framework as a basis to synthesise key learnings and determine areas of best practice. They reiterated that the strongest evidence of improvements in access, coverage and quality were related to service delivery models that promote integrated services, workforce strengthening and the use of digital technologies.

Scaling up PHC interventions across low- and middle-income countries could save over 60 million lives and increase average life expectancy by 3.7 years by 2030 [15]. Hence, countries have committed to strengthening Primary Health Care, with Science, Technology and Innovation (STI) being key players in strengthening PHC across different contexts [17]. The use of STI to improve service delivery and improve the resilience of health systems is nothing new, as a plethora of digital technologies have already been developed to support the three components of PHC, with several health information management systems being established to strengthen PHC in several African countries [18]. However, as we move towards learning health systems, improving sustainability and rebuilding after the impact of the COVID-19 pandemic, a key point of inquiry is what has happened to the various technologies that were utilised in the quest to 'flatten the curve' and lessen the disruption of health care systems [19].

2.2. Innovation in the Era of COVID-19

Emphasis on a multisectoral approach to innovation is one of the key messages that emerged since the beginning of the pandemic. Though this is something that had been lobbied for years, the dynamics of restricted travel and having to share intellectual property (IP) around vaccines pushed for open innovation whilst improving localised innovation [20]. The pandemic also served as a catalyst for the wider adoption of innovative approaches in drug development, vaccine delivery and clinical research, notably the use of mobile or remote services and digital technologies. The COVID-19 pandemic has highlighted the need for innovative health care solutions in Africa, including rapid testing, contact tracing and vaccine distribution, in order to build health system resilience. To address these challenges, African innovators have developed a range of solutions, from low-cost ventilators and portable oxygen concentrators to AI-powered chatbots that can screen patients for COVID-19 symptoms.

Of interest is a study that was conducted by WHO AFRO (https://innov.afro.who.int/uploads/media-corner/who_afro_covid_19_lessons_for_africa_20201203074859.pdf (accessed on 14 June 2023)) on the analysis of one thousand key technological innovations that were developed worldwide, targeting different areas of COVID-19 intervention. The study revealed that more than half of the innovations (63%) were deployed to support and augment preventive interventions. These innovations included personal protective equipment (PPE), automated sanitiser dispensers, social distancing and risk communication platforms. Twenty-six percent (26%) of the innovations were deployed to support case detection and investigation, and these included tools used for surveillance, contact tracing and laboratory services, whereas only twelve percent (12%) supported the treatment and management of COVID-19 cases that required hospitalisation. Other researchers have also looked at digital

health technologies (DHT) that were used to deliver PHC during COVID-19 to mitigate the impact of the pandemic. These technologies were used to support the provision of health services such as palliative care and telehealth visits, driving literacy through communicating, informing and educating, monitoring and surveillance, vaccination and drugs as well as PHC system decision making [21]. However, the study solely focussed on technologies utilised for PHC service delivery. Hence, this study aims to offer discourse on the evolution of some of the innovative technologies that were developed and utilised primarily to curb the COVID-19 curve and their levels of integration in mainstream health care.

3. Research Design and Methodology

This study analysed 1003 innovations from two compendiums and a database compiled by the World Health Organisation to showcase various innovations. The global COVID-19 innovations database contained 945 innovations [22], and the first compendium had 25 innovations from Africa [5] and the second compendium had 33 innovations that had been identified for use in low-resource settings but not restricted to only the COVID-19 response [23]. The selection and inclusion criteria considered innovations that were developed or customised to respond to COVID-19 but have now been specifically integrated into any of the three primary PHC response areas of integrated health services, multisectoral policy and action and essential public health functions. It was also important to include and engage communities to support the continuum of patient care in Primary Health Care across Africa (Figure 1).

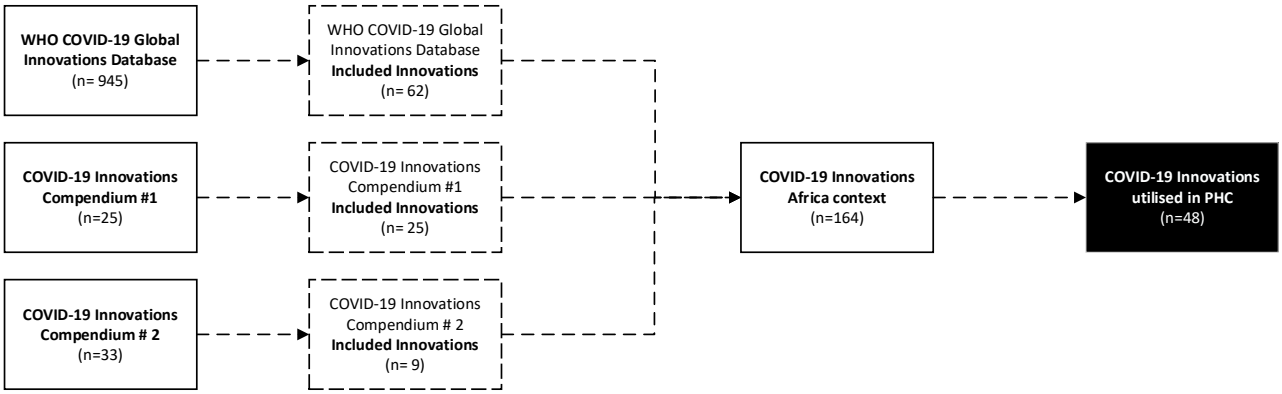

Figure 1. Selection of the COVID-19 innovations supporting PHC.

4. Results and Analysis

The 48 technological innovations in this study were further grouped into the following six broad categories: (i) 10 medical devices and equipment, (ii) 11 health management and information systems, (iii) 8 information dissemination tools, (iv) 2 supply chain and logistics platforms, (v) 11 telemedicine platforms and (vi) 6 tools to perform triage. The foundational technologies that were noticed across the majority of innovations were the integration of mobile applications, machine learning, artificial intelligence, data visualisation and data analytics as a basis of the innovations or introducing device portability. Additionally, over 70% of the innovations aligned with the PHC pillar of integrated health services with an emphasis on high-quality primary care and essential public health functions. This can be attributed to the rapid technological advancements in computing power, advanced manufacturing, rapid prototyping and state-of-the-art development tools and techniques. Health care innovators have the potential to provide efficient, safe and effective solutions that can be used beyond the target use cases.

4.1. Medical Devices and Equipment

The pandemic led to a push for isolation and ramping up of WASH campaigns [24]. This saw innovations such as SWAP, Shesha Geza and SaveIdeas designing contact-free

hand washers [25,26]. SaveIdeas looked at the utilisation of a foot-operated pedal, whilst Shesha Geza added an element of portability to their models. Notably, the design of these hand washers has not changed, but rather the way that they have been systemically integrated into PHC. There has been the formation of partnerships with key institutions like schools which has helped the integration of the devices and enabled good WASH practices. For example, SWAP partnered with PATH in order to facilitate testing of their low-cost models in primary schools. To address the shortage of personal protective equipment, there were also companies like Ultra Red Technologies and 3DIY that 3D-printed equipment. Currently, the ventilator splitters printed by 3DIY are still quite functional, and 3DIY has now even evolved to promote capacity building by holding 3D printing training sessions and even extending its services to include 3D printing of medical equipment spare parts and biology toolkits. An interesting innovation was the one by the University of Cape Town, which 3D-printed door openers that have been tested in various scenarios [27].

Erratic power supplies are an issue that plagues the African region. Innovations like Majik Water are looking to circumvent that by utilising solar grid filters for the generation of water from hot air [28]. Of interest is how oxygen concentrator innovations have evolved to not only be concentrator supplies but also to be fully functional with solar power, as exemplified by the solar-powered medical oxygen system that has now changed its business model to partner with local suppliers, contractors and development agencies to build systems from the ground up, ensuring proper implementation, monitoring and evaluation. UNICEF has even further developed the Oxygen-Plan-in-a-Box innovation to be a source of power for remote health facilities that have erratic power supplies, hence improving service delivery [29].

4.2. Health Management and Information Systems

When it comes to systems that have been used for information management in health ministries like District Health Information System 2 (DHIS2), OpenData Kit (ODK), CommCare, and the Surveillance, Outbreak Response Management and Analysis System (SORMAS), most of the innovation was around reconfiguration, modifications and the development of new modules. Some of these modifications, like the SORMAS disease outbreak surveillance module, are now core modules that support other parts of routine patient care and the national health information management system. For DHIS2, it has been mentioned that these modules have enabled data-driven real-time microplanning and disease surveillance which improve the way health campaigns are planned or monitored [30]. For sustainability, most of these modules were based on health standards such as HL7 and FHIR to achieve interoperability in patient health records. Additionally, DHIS2 designed an immunisation kit in collaboration with the WHO, making sure that standards are kept whilst integrating it into national health management and information systems (HMIS).

On the other hand, some generic applications are expanding to become platforms. This is exemplified by how CommCare is now creating a platform called CommCare Connect that acts as a knowledge hub that offers frontline workers additional services for further catalysing their impact at scale [31]. NextGenCoviaAI has also changed from being an integrated digital national COVID-19 health information management tool to NextGenHMIS, which is a state-of-the-art integrated hospital, patient and disease information platform. Such evolutions show how the health system is truly evolving into a learning health system [32]. Other tools like Real-time Vaccination Monitoring and Analysis (RT-VaMA) have evolved from just focusing on COVID-19 to being used to support any vaccination campaign [33], whilst mTrac has diversified from just disease surveillance to being integrated into Uganda's eHMIS, and the indicators now include stock levels for eight tracer medicines and maternal and neonatal deaths [34]. mTrac is also linked to DHIS2.

To address the power issues of these platforms, the service upSCALE is also working on how the digital platform can be reachable by testing solar-charged solutions from various partners so that the system is reachable during long periods of power outages [35].

One interesting aspect is tools that have been used across various sectors and industries like ODK. This makes the utilisation of the One Health approach, which is a core part of PHC, a bit easier in diverse contexts based on sharing the same technological foundation.

4.3. Information Dissemination

The spread of misinformation greatly affects PHC; hence, some tools like the COVID-19 Health Alert were developed under the stewardship of the South African National Department of Health. Currently, this app is being used to check and download vaccination certificates as well as disseminate health-related information such as monkeypox alerts or cholera outbreaks. Similarly, the Fact Check communication tool that was developed by the WHO for COVID-19 is not only providing science-driven information to the public but also providing a portal for the public to report any misinformation. Other tools such as mHero and the Vula Mobile app are now being used for teleconsultations. The A360 digital tool, a platform that was cocreated with young designers, had additional integrations of WhatsApp and bulk SMS so as to reach a wider audience with sexual and reproductive health information for adolescents [36]. In terms of building or joining an ecosystem, the application PROMPTS developed by Jacaranda Health is now looking to share best practices across countries and also is part of the Kenya Quality Ecosystem Project that links maternal health solutions with available funds and data [37].

4.4. Supply Chain and Logistics

A lot of supply chains were disrupted by the pandemic, and creative ways to offer medical supplies were needed. Zipline started by using drones in countries like Rwanda and Kenya to deliver supplies and vaccines in hard-to-reach areas [38]. To expand its reach, Zipline has entered a strategic partnership with Jumia, which is an e-commerce platform that is available in countries like Nigeria and Ghana, hence creating a wider reach for health products that can be accessible to citizens [39]. Similarly, SafeBoda in Uganda was utilised for COVID-19 vaccination drives and it is still currently being used in other vaccination campaigns in various ways.

4.5. Telemedicine

Telemedicine has been reported to be very useful in Africa, especially with the dynamics of brain drain resulting in a low doctor-to-patient ratio and a limited number of experts [40]. Platforms like Rology in Egypt, T-sense in Kenya, Remote Doctors 4 Africa app in South Africa and Babyl in Rwanda were utilised during COVID-19 to provide teleconsultation and teleradiology services due to the COVID-19 movement restrictions. However, telemedicine was mainly limited to distance consultations during the pandemic using telephone calls or videoconference [41]. Post-COVID-19, a number of these platforms are strengthening health care systems beyond just connecting patients and health care workers remotely but also responding to the shortage of experts and devices. With the advance in AI and the availability of imaging datasets, these platforms are being used to provide automated chest X-ray interpretations for respiratory diseases and diagnoses other than COVID-19 [42]. These platforms are also being used to create networks of professionals and users for knowledge sharing. An example of this is the Kena Health app, which launched 'Child Profiles' as a way for parents with children over 2 years old to conduct a consultation for their children with a doctor, nurse or mental health professional. Some apps like mPharma started as supply chain disruptors by stocking pharmacies without any upfront payment. Now, mPharma has virtual centres where it delivers quality primary care to communities by providing medical examination structures. mPharma combines teleradiology and AI to allow hospitals without radiologists to send images to remote radiologists for a swifter diagnosis of patients.

4.6. Triage

Undertaking contactless triage was important during the pandemic. Some tools utilised for this purpose have been used in various other cases. Wellvis is now offering digital solutions promoting primary care by improving the health of the public through continuous access to personalised health information based on national screening guidelines [43]. Vaxiglobal has improved its Health and Immunisation Verification tool to spread further than just COVID-19 vaccinations and be an equitable and robust vaccination certification system that offers vaccine-preventable disease (VPD) surveillance, and the platform facilitates broadly effective vaccination campaigns [44]. InstaRad now has a web and desktop radiology diagnostic viewer [45], whilst the Smart Health app is now an integrated platform that has remote supervision, peer supervision and easy-to-read dashboards. The platform is now used as a capacity-building application for community health workers [46].

5. Discussion

To further gain insights from the 48 innovations in this study, the authors went on to draw out four thematic areas to enable the evolution of some of these innovations and determine how health system builders can integrate these innovations. These cover collaboration, governance, innovation design and strategy, as shown and further elaborated upon in Figure 2.

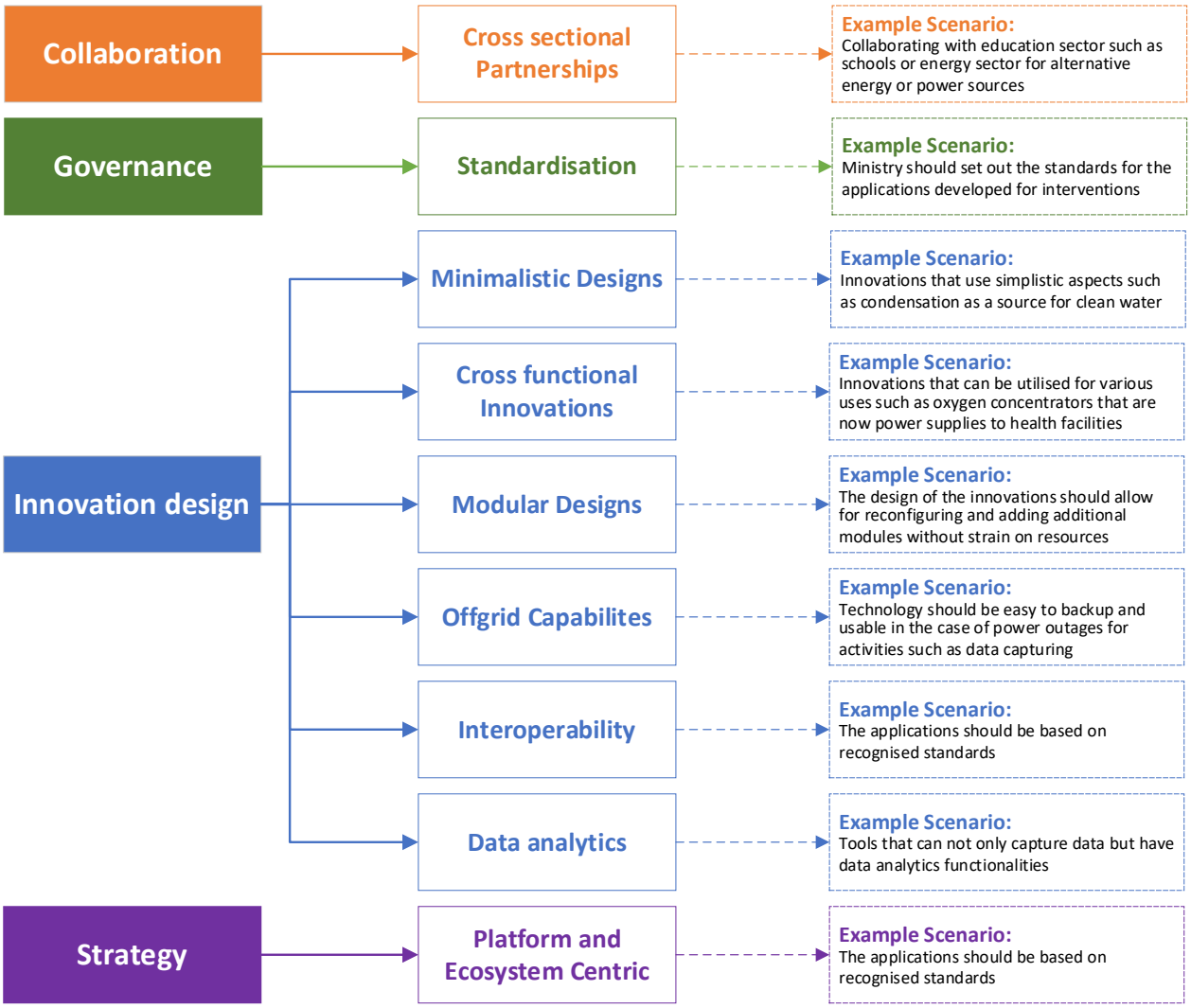

Figure 2. Core thematic areas of technological innovations in PHC.

This study has identified that most of the innovations impacting PHC are those that were upgraded to include elements of data analytics, developing innovations that leverage existing technologies and infrastructure in the health system with an emphasis on the use of interoperable standards, the creation of platforms or incorporating strategic partnerships in expansion plans. Moreover, ensuring alternative sources of power has become paramount in the continuity of services, especially in Africa; hence, technologies that offer solutions to such concerns also become less resource-intensive to invest in.

Implications of the Study

Considering the aspects identified above, this study recommends the following activities to support the scaling up of technological innovations in Africa:

- *Stakeholder engagement*: This entails engaging all levels of the health system, especially at the grassroots level, through a transparent, interactive process in which localisation and ownership are key in the integration of technological innovations.
- *Localisation strategies*: Ensure capacity building of the community's health workers and health ministry staff to ensure that technologies are still utilised even when the implementing partners are no longer in the implementation contexts.
- *National health innovation clusters*: Establish national health innovation clusters that could streamline and strengthen the health care innovation landscape in the respective countries.
- *Foresight and technology readiness assessments*: Countries should have comprehensive, standardised and continuous technology readiness assessments for the adoption of emerging technologies, including robotics, 3D printing, 5G and AI.
- *National digital health profiles*: African nations should have well-established national digital health profiling, including the mapping of all national digital platforms, in private, public and research institutions. This is important so that in case of an infectious disease outbreak, the country knows the readily available national digital tools that can be leveraged to respond to the pandemic. This can reduce the duplication of systems in health care leading to wastage of resources.
- *Open international standards*: There is a need to promote the development and adoption of interoperable platforms that have been developed using international open standards like HL7 and FHIR to promote data sharing and intercommunication among platforms. This will ensure system dependability and hence adoptability for several use cases; for example, putting the COVID-19 module with other disease program modules.
- *National data centres*: The establishment of national data centres to host data from national digital innovations supporting the health care system is of paramount importance. From this research, we have identified several platforms that were used to collect data during COVID-19, but once these projects are shut down or discontinued, many of these data are lost. Hence, African nations are always data-deficient despite the data that have been collected over the years, with no data to support policy decision making or the prediction of best practices in the future in case of similar outbreaks.
- *National innovation and research networks*: These will enforce the development of digital initiatives that can easily obtain funding from health ministries and other key policy makers. It will also reduce duplication of efforts in developing similar projects and innovations in the same country.
- *Financial funding mechanisms*: Needless to say, some innovations have not succeeded beyond the height of the pandemic. Some of the systemic reasons why include the fact that some of these innovations were run as projects with seed grants for a fixed period but lacked a sustainability model and hence ended after the project was concluded, especially those that originated from research institutions like universities. Some of the innovations did not attract funding from health ministries, partners or potential clients; hence, these tools were abandoned after a while, especially some of the freely

available apps. Additionally, some of the innovations lacked resources to advance technology development, including funds, ICT infrastructure and human capital. It is important to have financing mechanisms in place for sustainability.

6. Conclusions

This study has reviewed some notable COVID-19 technologies that are being used to support PHC in different countries. The analysis has revealed various COVID-19 technological applications that have been developed in response to COVID-19 that are supporting Primary Health Care along the continuum of patient care. With the impacts that the pandemic had on service delivery, countries are aiming to utilise technologies at the forefront of making strides towards initiatives, such as reaching zero-dose children, which rests on the health system's resilience. The authors of this study acknowledge that this review is a starting point and not conclusive and hence has some limitations. It would be suggested to undertake reviews of the various technologies that have been identified in this study as a way to build a holistic picture of the dynamics around the innovation instead of just relying on secondary data sources. Additionally, other types of methodologies can be utilised to assess the findings, which can include undertaking meta-analyses of the innovations in terms of the areas of use or the types of technologies that are easily integrated into health systems. It is also important to note that the compendiums and databases focused on technologies that were described in English, so there is a possibility of widening the dataset to other languages.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su151512073/s1, WHO AFRO COVID-19 Innovations Database: https://innov.afro.who.int/emerging-technological-innovations/1-covid-19-innovations (accessed on 14 June 2023), COVID-19 African Innovation Compendium: https://innov.afro.who.int/uploads/media-corner/who_afro_covid_19_african_innovation_compendium_20201203075453.pdf (accessed on 14 June 2023); WHO compendium of innovative health technologies for low-resource settings 2022: https://www.who.int/publications/i/item/9789240049505 (accessed on 14 June 2023).

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