Digital Transformation and the Role of Technology in Building Healthier Populations

Submission to the Reform for Resilience Commission Call for Evidence

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Introduction

The Covid-19 pandemic has demonstrated the enabling role that digital health plays in health system resilience, as stakeholders across the health system relied on existing and novel digital tools to support research, policy, clinical practice, and public engagement, testing, and care. Indeed digital tools have reinforced the links across these domains during this crisis, enabling decision-makers in each domain to draw necessary information from across civic and health sources.

Governments will play an integral role in enabling health system resilience through the post-pandemic period. This role will include emerging priorities such as creating the networked technological infrastructure to support public health and healthcare, acting as a platform to support decentralised health innovators in academia and industry, and building trust in emerging health technologies to support their adoption. The forms these initiatives take will differ across contexts, but health system resilience depends on coordination at the local, regional, and international levels. The incentive for this collaboration was evident in the Covid-19 context due to the dynamics of infectious disease, in which "virus anywhere is virus everywhere" (Woodcock 2021). Despite this incentive and despite many examples of cooperative and altruistic behaviour among decentralised actors (Hattke and Martin 2020), narrower self-interest predominated in certain cases, as collaborative structures, particularly at the international level, were not sufficient to overcome the collective action problem of the incentive to pursue unilateral self-interest at the individual or governmental levels (Harring, Jagers, and Löfgren 2021). How these incentives will change as policymakers shift attention from the infectious disease context to broader health concerns is as yet to be seen, and what structures they will implement to benefit from the lessons from Covid-19 while adapting to the chronic realities of health system resilience beyond acute shocks.

Governments addressing health system resilience in the post-pandemic period will need to take a systems view, creating the foundations for resilience within—and across—the research, policy, and clinical domains. We highlight three areas in which governments can facilitate health system resilience: by supporting *technology development* to support decision-making in the research, policy, and clinical domains, *setting standards and coordinating* across the local, regional, and international levels, and establishing mechanisms for *implementation, communication, and education*—of clinicians,

policymakers and the public—to inform health decision-making at the individual and system levels in real-time. The Covid-19 pandemic demonstrated the importance of real-time research and dissemination and the necessity of coordinated decision-making among organisations and populations to reduce spread. These factors are equally important in responding to chronic disease and population health, though coordinated action may be even more challenging without the clear social costs of inaction in the case of infectious diseases.

The World Economic Forum Partnership for Health System Sustainability and Resilience (PHSSR) provide a framework for health system resilience including 5 domains: health system governance, financing, workforce, medicines and technology, and delivery (Wharton et al. 2021). We highlight successes and challenges during the Covid-19 pandemic response across these five domains to underscore their interconnected effects on resilience.

A Systems View: Creating the Research, Policy and Clinical Foundations for Resilience

The Covid-19 pandemic demonstrated the ability of the academic, public, private, and health sector communities to innovate and coordinate under constraint. These mechanisms included new channels for coordinating across domains, including academic advisory committees (such as the UK government's SAGE), deidentified clinical data portals for researchers and policy analysis, such as the WHO Global COVID-19 Clinical Data Platform and Covid-19 Genomics UK Consortium, coordination, cooperation, and collaboration across decentralised state-level public and private actors in Germany (Hattke and Martin 2020), and attention to translational science to implement research findings in clinic, such as via the NIH National Center for Advancing Translational Sciences and the Covid-19 Technology Access Pool. These include programmes to facilitate collaboration, a targeted approach to minority/underserved populations and rare disease comorbidities, and collaboration with industry particularly on rethinking the sequential research translation pipeline (Grobler et al. 2020).

The Reform for Resilience Commission presents resilience as "a core value component" of Health, Environment, and Economic systems. This framing rightly underscores the interaction effects among those systems and the necessity of internalising effects on one domain in models governing decision-making in others (e.g. incorporating health and environmental externalities into economic models). We further note that public and corporate policy play a control function that mediates these systems interactions, and this framing expands the remit of government agencies that may not traditionally be responsible for health policy to take positions in support of health system resilience by recognising and regulating these interactions.

This logic underlies for example public health experts' validation of social justice protests in the wake of the George Floyd killing, recognising the ongoing public health risks to black and minority communities due to structural racism despite the marginal increase in acute Covid-19 risk due to mass gathering during these protests (Chappell 2020). This systems view of public health was exemplified by the U.S. Centers for Disease Control and Prevention (CDC) declaring structural racism as a serious public health threat (Centers for Disease Control and Prevention 2021). In "Racism is the public health crisis," Kehinde

Andrews (2021) describes reframing a research project he was involved in as a junior researcher from a narrow health educational intervention—teaching parents how to administer an asthma inhaler—to address the broader environmental health challenges—the disproportionate respiratory effects on minority populations of air pollution, poor housing conditions, and other environmental factors in the inner city. A recent study by the Social Market Foundation found that over a million UK residents live in food deserts—in which a lack of local supermarkets and limited public transit limit residents' access to fresh foods—and food swamps—in which a lack of healthy options are compounded by overaccess to fast food—further demonstrating the effects of economic systems on both environmental systems—including the built environment—and health, and the mediating effects of corporate and public policy (Corfe 2018).

Development of Technologies in Real Time

If health system resilience depends on the interactions across the health, environment, and economic systems, and coordination across sectors and institutions, robust data infrastructure emerges as a necessary condition for resilience as the conduit for information exchange across domains. During the pandemic, governments and academic institutions created the foundational infrastructure for data management and sharing across disciplines, organisations, and sectors. Internationally, governments have taken a wide range of approaches to designing and implementing data infrastructure to support the pandemic response, both creating novel data management systems and adapting existing ones in real time to combine the civic and health data necessary to make policy decisions (Dace 2021; Fingerhut 2021). These tools enable both health system governance, for example as administrators allocate resources and plan for shocks at the population level, and delivery, as systems like the UK National Pathology Exchange enable pathological tests to be dispatched to different labs based on availability and results shared with the consulting physician.

During the Covid-19 pandemic response, data infrastructure provided the foundation for both policy and clinical decision-making. In the UK, Health Data Research UK (HDR UK) coordinates datasets across institutions for use by researchers, NHS, and policy analysts. HDR UK has established a dedicated portal for Covid-19 data, linking the biological, epidemiological, operational, economic and civic data relevant to Covid-19 policymaking. HDR UK also served as a conduit for scientific findings based on these data to policymakers via fortnightly reports to the Scientific Advisory Group for Emergencies (SAGE). Similarly, researchers internationally relied on open data portals such as Gisaid and EBML-EPI, which provided access to whole genome sequences of the coronavirus as early as January 2020, and over 450,000 genome sequences of observed coronaviruses to enable vaccine development (EMBL-EBI 2020; van Noorden 2021). In the UK, the Covid-19 Genomics UK Consortium centralises over 370,000 sequences identified through UK testing programmes, informing research and regular reports to SAGE on virus mutation that was essential for both policy planning and vaccine development (COVID-19 Genomics UK Consortium 2020).

Novel technological infrastructure was also rapidly developed to support healthcare delivery through the Covid-19 pandemic, including the U.S. Vaccine Administration Management

System (VAMS) that was developed to support allocation, scheduling, and tracking of vaccines among clinics and patients. The early challenges this system faced demonstrate the broader difficulty of large-scale technological system implementation, as local users were unable to adapt the system to their context and needs, for example in logging in, sending customised pre-appointment messages, and using the system with different browsers and devices. These design parameters made it difficult to adapt to the needs of specific patient populations, particularly elderly patients for whom the user interface could be unintuitive. Whole clinics developed workarounds from the system, using tools built in house, online invitation sites like Eventbrite, or even paper forms to track vaccines because they did not find the technology sufficiently adapted or adaptable to their own context (Ferguson 2021). Especially in decentralised health systems like the U.S., intertwined organisational and technological factors drove programme and technology implementation, demonstrating the importance of organisational and systems context in the implementation of digital health technologies (Petracca et al. 2020).

Multi-Level Standards and Coordination

Data infrastructure enables standard setting and coordination across levels of governance. While the interaction effects across health system levels are particularly salient in the case of Covid-19 due to its high infectiousness, long-term health system resilience depends on managing interactions and externalities across the health, environmental, and economic systems. Linking data across sectors and institutions enables holistic health and social decision-making in both the clinical and political settings. Going forward, approaches used in the pandemic response could be replicated to sustain continued investment in coordination and technology transfer in light of collective action problems when dealing with illnesses and health system challenges that may be more localised or when costs borne by individuals or underserved communities predominate the societal costs (e.g. due to infectiousness).

In both research and policy settings, the disease and testing dynamics of Covid-19 required analysts to weigh the use of novel data, methods, and techniques to improve the decision-making timescale versus established epidemiological approaches. Researchers and policymakers coordinated in new ways between levels, and challenges of centralised vs local decision-making, particularly at the international level. Academic researchers have collaborated in new ways across disciplines, institutions, and nations to address a health system threat that spanned traditional boundaries. Researchers independently established ad hoc groups like the Covid-19 Dispersed Volunteer Research Network and the Covid-19 Mobility Data Network to identify emerging problems, share novel datasets, and coordinate solutions (COVID-19 Mobility Data Network 2020; Majumder 2020).

In the policy setting, academic coordination is supported by institutional processes to identify priorities and data to support and communicate these decisions. With respect to Covid-19, the fortnightly HDR UK report to SAGE communicates key research findings by area of research (biological, epidemiological, clinical), ensuring awareness of research activity across groups and dissemination of policy-relevant findings directly into practice. More broadly, programmes like Pharos and the Common Fund Data Ecosystem in the U.S. improve access to data across research projects and identify key NIH innovation priorities in areas including genomics and other ‘omics’, precision medicine, treatment planning, and

global health, aligning researchers with funding and data resources in areas of academic and practical importance (National Institutes of Health n.d.).

The Covid-19 pandemic demonstrated the challenges of international health governance and delivery, as governments were often incentivised to prioritise their national interest over international coordination, particularly regarding international travel bans, given the limited enforcement powers afforded to the World Health Organisation (Berman 2020; Habibi et al. 2020). At the same time, the expert opinion informing WHO policy against travel bans was called into question following the successful experiences of countries that maintained them, such as Vietnam (Belluz 2021). Given this tension between public health expertise and emergent information, resilient health systems going forward will need to balance planning and preparedness based on expert analysis with real-time adaptation in the face of unexpected phenomena, particularly in light of the rarity of system shocks of this magnitude and therefore the limited historical examples available.

Implementation, Communication and Education – of Clinicians, policymakers, and the public

The experiences highlighted in this paper underscore the importance of implementation, communication, and education in implementing digital health technologies and infrastructure to support health system resilience. While governments and health systems developed the institutions, research programmes, and data infrastructure in short order to respond to the pandemic, the challenges they faced demonstrated the difficulties in policy and programme implementation at large, particularly in an infectious disease context that required programme uptake and compliance by decentralised organisations and individuals across local contexts. Health systems policy during the pandemic operated at the intersection of policy implementation and implementation science (concerned with the implementation of specific programmes and technologies), as it depended on both administrative and legislative policy and the design and implementation of specific programmes, technologies, and practices. Though the challenges of policy implementation and programme implementation are similar, the research agendas in these areas have developed separately, making it difficult to evaluate the implementation of large-scale programmes in policy and practice systems (Nilsen et al. 2013).

The design of digital health technologies such as contact tracing apps demonstrated the interactions between technologies, individuals, and institutions – particularly the ability to command broad stakeholder attention toward the design of practical approaches to health ethics in an urgent context (Leslie 2020). The close attention to this problem—and the emphasis on ethics and privacy as a design criterion—elicited a broad range of technological actors, who coalesced on two principal technological mechanisms, a decentralised and a centralised model (Zastrow 2020). Both the emphasis on ethics as a primary design criterion and the emergence of strategies to take practical approaches (such that the ethical concerns do not preclude action, are promising lessons going forward for digital health technologies, and research should be done to identify and apply these lessons to other chronic health system challenges.

From a clinical standpoint, the pandemic demonstrated the challenge of Evidence-Based Practice, as this was a health challenge characterised by a quickly changing evidence landscape, with high degrees of ambiguity, scientific findings emerging in real time, and, on certain issues of propagation and treatment, difficulties achieving scientific and clinical consensus. Despite exhortations to "follow the science"—and indeed governments made certain decisions contrary to the scientific consensus—clinical and political action inherently involves inference on limited information and value judgements outside the purview of scientific knowledge, such that legitimate conclusions based on the same scientific research could be ambiguous or seemingly contradictory (Pearce 2020; Pielke Jr 2021). Most recently, an open challenge from researchers to the WHO on categorising Covid-19 as an airborne disease demonstrates both the disagreement that may arise within the scientific community as well as the public health impacts of such uncertainty, as accurate labelling of the disease is essential to the public health response (e.g. in prioritising mask wearing over surface sanitisation) (Greenhalgh et al. 2021). These experiences demonstrate the nuance of evidence-based decision-making, in which stakeholders legitimately use evidence in different ways, leading to contradictory decisions and implementation challenges, both in clinical and policy applications (Fingerhut 2020).

From an individual standpoint, the pandemic demonstrated the challenges in health communication and health literacy, particularly around issues of risk. The pandemic response featured successes in health communication, as novel approaches to health communication from governments and media such as dashboards and data journalism enabled the general public to come up to speed quickly on public health considerations and decision-making criteria. For example, the GOV.UK dashboard (UK Government 2020), daily briefings from public figures, and novel approaches to data journalism (The New York Times Company 2021), were quickly developed to communicate the breadth of relevant epidemiological and operational data and visualizations interactively, in real time, and at scales that enable individuals to both hold government to account and make informed behavioural decisions. Nevertheless, public compliance with measures adversely reflected on both confidence in public sector decisions as well as communication or comprehension gaps of important public information (Asimakopoulou et al. 2021). For example, the question of how to communicate absolute and relative risk has persisted in research circles as the risk of an intervention cannot be fully understood without both measures (Noordzij et al. 2017); at the very low rates of side effects of Covid-19 vaccines, the use of relative risk rather than absolute risk overemphasises the risk of side effects, distorting public perception and confidence in the vaccines (Wain and Miller 2021).

Finally, in terms of healthcare delivery, the reliance on telemedicine during the pandemic has demonstrated the health system's capacity for large scale system change. This delivery mechanism has traditionally faced implementation and uptake challenges, due to legal (e.g. limitations on the provision of care across state lines in the U.S.), social (e.g. compatibility with existing care frameworks), and technological constraints (e.g. Ohannessian, Duong, and Odone 2020; Stevenson et al. 2018). These challenges were quickly overcome when risk of Covid-19 infection required virtual consultations, for example as states adapted licensing requirements to enable interstate consultations (Department of Health and Human Services 2021). Going forward, what role will telemedicine play in healthcare delivery alongside more established mechanisms? Prior to the pandemic, telemedicine played an important role in

care provision for underserved populations, such as U.S. rural veteran population, who benefit from specialty expertise despite the prohibitive distance to the closest Veterans Affairs centre. As the role of telemedicine evolves following the pandemic, for example its use in triage by case difficulty among the general population rather than for specific subpopulations, it will be increasingly important to use telemedicine in a way that ensures equitable access.

Recommendations

Strengthen public sector capacity for digital health system design and implementation
The pandemic has demonstrated the fragility of the US and UK health systems in particular due to the outsourcing of public health capabilities (for example to consultants in the US VAMS and NHS Test and Trace programmes) and supply chains for food, medicines, ventilators, protective equipment, and testing kits (Mazzucato and Kattel 2020). Going forward, governments should develop informed strategies to strengthen public sector capacity to provide essential services directly, improving health system resilience by enabling service continuity in response to shocks, especially given the public sector's role in ensuring care for those populations underserved by private providers. Governments and academic partners should review existing capabilities in order to align them with desired strategic capabilities that support resilience.

A focus on Digital Health policy and programme implementation
Over the shift in focus from healthcare to health, health system outcomes will increasingly depend on communication and engagement with individuals. In this decentralised, highly diverse environment, policy and programme implementation should be a core focus of governments – even well-designed policies and programmes will not lead to better health system outcomes unless individuals are aware, engaged, and supportive of these changes to their lifestyle and care. Digital health technologies are an important component of this approach, as they will enable individuals and their doctors to tailor a health plan to their needs in new ways. However, their use and effectiveness in practice depend integrally on how they are implemented, including open questions of access, ethics, data management, clinician training, and adaptation of algorithms post-implementation to real world conditions.

Governments should consider designing structures to centralise public sector knowledge and practice in implementation science and programme delivery, so that digital health programmes, policies, and technologies lead to better health outcomes for all. For example, the UK's NHSx, jointly administered by the Department of Health and Social Care and NHS, brings together implementation experts, digital service designers, and clinical service providers at the national and local levels to design, identify, evaluate, and disseminate digital transformation initiatives across the health service. More broadly, governments should expand the public sector capability to deliver digital health programmes equitably and effectively, including mechanisms to centralise on-the-ground expertise from local agencies and disseminating best practices for service delivery.

A renewed focus on translational research

Upstream of healthcare delivery, the Covid-19 pandemic response demonstrated the strengths of the public, private, and academic sectors working together to develop scientific and medical knowledge, apply these findings to clinically-relevant medicines, technologies, and practices, and produce medicines, vaccines, and tools quickly and safely. The engagement of universities and private pharmaceuticals in translational research, and the public sector's ability to provide clear and effective funding mechanisms, enabled the development of new medicines and tools, for example a diverse portfolio of vaccine candidates including the novel mRNA platform.

Given these ad hoc successes in both technology development and local experimentation, researchers and health systems should jointly develop ground-up mechanisms to identify the critical health technology infrastructure and innovations developed or adapted across the translational pipeline and at the local level over the pandemic period. These mechanisms should identify the critical technologies that should be integrated into national health systems going forward and the processes for adapting, validating, and disseminating existing technologies in practice. Technologies should be used equitably and responsibly to ensure they improve health outcomes for all.

Similarly, academic institutions should expand translational research initiatives, including collaborations with private companies, accelerators, and healthcare systems, to develop promising precision and predictive health technologies and complement these initiatives with implementation research programmes to enable uptake at scale.

Conclusions

The Covid-19 pandemic elicited a sea change in the use of digital health technologies that contributed to the ability of health systems across the world to respond to the Covid-19 shock while adapting to provide service continuity for broader health needs. Going forward, the experiences of global health systems during the pandemic provide important lessons to improve the resilience of health systems to adapt to shocks and ensure both service coverage and population health.

These recommendations should all be considered within the context of incentivising health rather than healthcare, including an emphasis on preventive care, healthy lifestyles and community health. Both system-level changes, such as the UK transition to Integrated Care Systems that link local social services with NHS providers, and individual changes, such as the increased availability and use of digital health technologies to track and manage daily health, will contribute to this effort. But while increased availability of these technologies is promising, attention to implementation will be increasingly important as health systems adapt to accommodate these new tools, and the degree of an individual's uptake and use of these technologies will affect health outcomes as health programmes increasingly depend on decentralised individual actions outside the clinic. This coordination will be more challenging to achieve over the long-term, when the acute dynamics of the pandemic have subsided, and when more of the costs of health maintenance are individually borne, as compared with the societal costs imposed by coronavirus propagation.

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