

The dawn of digital public health in Europe: Implications for public health policy and practice

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Summary

The COVID-19 pandemic has highlighted the importance of digital health technologies and the role of effective surveillance systems. While recent events have accelerated progress towards the expansion of digital public health (DPH), there remains significant untapped potential in harnessing, leveraging, and repurposing digital technologies for public health. There is a particularly growing need for comprehensive action to prepare citizens for DPH, to regulate and effectively evaluate DPH, and adopt DPH strategies as part of health policy and services to optimise health systems improvement. As representatives of the European Public Health Association's (EUPHA) Digital Health Section, we reflect on the current state of DPH, share our understanding at the European level, and determine how the application of DPH has developed during the COVID-19 pandemic. We also discuss the opportunities, challenges, and implications of the increasing digitalisation of public health in Europe.

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The Coronavirus disease 2019 (COVID-19) pandemic is among the most severe crises facing society this century. The rapid speed of transmission has forced countries to adapt their national healthcare systems at an

unprecedented rate. With remote work, surveillance, and care delivery as new societal norms, there has been an ever-increasing spotlight on digital health technologies.¹ COVID-19 has emphasised the importance of establishing effective surveillance systems for public health at all levels.² Governments must adopt digital public health (DPH) strategies in their national health policy and healthcare to coordinate and manage those systems.³ As representatives of the European Public Health Association's (EUPHA) Digital Health Section, we share our understanding of DPH at the European level. In this viewpoint, we reflect on the understanding and application of DPH during the COVID-19 pandemic and in a wider context, as well as discuss the opportunities, challenges, and implications

Abbreviations: EUPHA, European Public Health Association; DPH, Digital public health; UHC, Universal health coverage; ICT, Information and communications technologies; RCT, Randomised control trial; WHO, World Health Organization; UNICEF/ERACO, United Nations Children's Fund/Europe and Central Asia Regional Office; UK, United Kingdom; NHS, National Health Service; PHWF, Public health workforce; GDPR, General Data Protection Regulation; UN, United Nations

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of the increasing digitalisation of public health in Europe.

As a discipline, ‘public health’ traces back to the beginnings of human civilisation when communities first started promoting health and combating diseases. Contemporary public health has undergone rapid transformations to respond to modern threats and opportunities. Among these are the digital transformations of the health sector, which have led to the establishment of ‘digital health’ with a vital role in strengthening health systems, increasing equity in access to health services, and working towards universal health coverage (UHC).⁴ More recently, these digital transformations have given rise to the concept of ‘digital public health’.⁵ This concept combines the already defined terms of ‘public health’ and ‘digital health’ (Box 1) and is not considered a novel field of itself, but the adoption of digital tools to achieve public health goals, such as preventing disease, empowering citizens, promoting value-based healthcare, or achieving UHC.^{5–8} The central aim of DPH is to improve the health of populations from the individual to the population level by using information and communications technologies (ICT).^{2,6,9} This is one of the key factors differentiating DPH from ‘digital health’, the latter being predominantly focused on individual health.¹⁰ Evidence- and needs-based approaches should characterise interventions.^{9,10} An inclusive, participatory approach to designing, developing, and implementing digital technologies will improve not only their acceptance but also their effectiveness.^{6,11,12} DPH technologies must ensure that inequalities are not exacerbated due to varied access to and/or competence of a digital intervention amongst different demographic groups.⁹ Interventions in DPH should collect data for

public health surveillance, whether it be for public health emergencies or monitoring risk factors for widespread diseases at the population level.^{6,13,14}

Amidst the ongoing COVID-19 pandemic, we have seen glimpses of the transformational potential of DPH to accelerate responses to various public health emergencies (Box 2). The perception of digital health tools rapidly moved from being seen as “opportunities” to “necessities”, which kickstarted a sequence of rapid developments in the healthcare and public health domains – that still retained their pre-digital structures and were stagnated and eroded:^{7,18} changes to policy and regulation facilitated rapid changes to reimbursement, training for health professionals, and unprecedented investment in technical infrastructure.¹⁹ Several countries and communities have effectively leveraged pre-pandemic digital investments in public health and applied them to their pandemic management.² The development and adoption of digital technologies made critical contributions to many public health functions: epidemiological surveillance, contact tracing, case identification, mass immunisation service delivery, and public communication.

One of the domains of DPH impact is epidemiological surveillance. The development of tools for international real-time public health data has supported policymakers in planning and refining containment strategies. These tools allowed for the evaluation of the real-time effectiveness of interventions. Concerning community transmission, the possibility to collect location data (GPS) and proximity data (Bluetooth) from mobile devices pushed several countries to support the development of digital contact tracing apps. These apps speed up contact tracing and quarantining contacts.^{28,29}

Another relevant field to pandemic response concerns public education. Digital platforms of health authorities and national agencies use the Internet to enable a rapid engagement and education of the population through prompt dissemination of trusted and tailored public health information, limiting at the same time the visibility of news from unreliable sources.³⁰

System readiness for digital public health

The conceptualisation of digital health in Box 1 already alluded to the notion that digital health is part of the overarching health ecosystem. Over the course of the COVID-19 pandemic, the health ecosystem has digitalised out of a need to survive rather than a desire to innovate; this is indicated by the rapid shift from a traditional to a digital paradigm and subsequent series of changes when COVID-19 became a pandemic.¹⁹ However, this widespread digital transformation also allowed the risks and benefits of digital health services to be experienced in an unprecedented manner and data on the efficacy and efficiency of digital health services to be gathered. As a result, the digital health

Term	Definition
Health	Health is defined as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” by the constitution of the World Health Organization (WHO). ¹⁵
Public Health	Public health is conceptualised as “the art and science of preventing disease, prolonging life and promoting health through the organised efforts of society” by Acheson in 1988. ¹⁶
Digital Health	Digital health is framed as the “the convergence of the digital and genomic revolutions with health, health care, living, and society” by Paul Sonnier in his 2017 book <i>The Fourth Wave: Digital Health</i> . ¹⁷ Digital health, as a concept, can refer to a technology, a user experience, a service, a product, a process, an ecological system of itself, and part of the ecological system of health services. ¹²

Box 1: The respective conceptualisations of health, public health, and digital health.

COVID-19	<p><i>HealthBuddy+</i>: a chatbot created through a joint initiative of the WHO/Europe and the United Nations Children's Fund Europe and Central Asia Regional Office (UNICEF/ECARO). It is accessible in Europe and Central Asia and its goal is to provide access to up-to-date and evidence-based information on COVID-19.²⁰</p> <p><i>Digital epidemiological surveillance</i>: an umbrella term for the so-called 'coronadashboards' that are created by European countries to provide continually updated information on the state of COVID-19 in the respective country.²¹</p>
Primary care	<p><i>My Health</i>: a personal space of digital health that allows the citizens of Catalonia to interact in a non-contact way with the Health System of Catalonia. It facilitates its users to consult clinical reports, diagnoses and results of clinical analyses and tests that are part of its medical history. Users can also access their current Medication Plan to go directly to the pharmacy, request a primary care visit, or access various non-face-to-face care services (e.g. eConsult: a system that allows health professionals to ask health-related questions, carry out procedures, and send documents).²²</p> <p><i>AccuRx</i>: a digital healthcare start-up supported by Innovate UK who developed and rolled out video consultation software that enabled United Kingdom (UK) healthcare providers to communicate remotely with their patients, thus minimising infection risk from seeing patients with COVID-19. Within a few months, it was used to conduct over one million video consultations and was used in 6700 GP practices. It protected National Health Service (NHS) professionals and patients and increased NHS efficiency, saving each user approximately 40 minutes per day.^{23,24}</p>
Mental health	<p><i>Now I Can Do Heights</i>: a software application by Oxford VR that seeks to help users with acrophobia overcome their fear of heights. The application is for adults older than 18 years and designed to be used without a supporting therapist.²⁵ In a randomised control trial (RCT) of 100 participants, <i>Now I Can Do Heights</i> has demonstrated the capability of producing large clinical effects (mean change of the Heights Interpretation Questionnaire score -24.5 [SD 13.1] in the VR group versus -1.2 [7.3] in the control group).²⁵</p> <p><i>GET.ON Mood Enhancer Prevention</i>: a web-based, guided self-help intervention based on psychoeducation, problem-solving therapy, and behavioral activation. In a RCT of 406 participants in Germany, <i>GET.ON</i> produced a hazard ratio of 0.59 [95% CI: 0.42-0.82] in participants with subthreshold depression. <i>GET.ON</i> could also potentially prevent one clinical case of major depressive disorder within a 12 month period after 5.9 sessions.²⁶</p>
Obesity	<p><i>Esporti Family</i>: a mobile application whose objective is to treat childhood obesity which allows sharing information among professionals, patients and families. It teaches kids and their families healthy habits and nutrition through gamification and encourages them to increase their level of physical activity. A two-month trial of 67 users in Murcia, Spain showed an overall 44.4% reduction in fast food consumption, 38% of users increased their weekly physical exercise, and 27% of users increased their sleep hours.²⁷</p>

Box 2: Case examples of DPH services in Europe.

literature – previously on the scarcer end in terms of longitudinal articles – is slowly growing richer and more diverse as more health sub-domains experiment with the capabilities of digital health.

The results of digital health services are slowly becoming more apparent in various domains. For instance, in a study of 143 people aged 10-17 with chronic pain, people using the *WebMAP* Mobile App perceived greater improvements post-treatment (Cohen's d : 0.54; $P < 0.001$) and at a 3-month follow-up (Cohen's d : 0.44; $P = 0.001$). It also emphasised the importance of patients remaining engaged in their treatment process. Greater engagement was associated with significantly greater reductions in pain and disability from pre-treatment to post-treatment (Cohen's $d = -0.57$; $P < 0.01$) and follow-up (Cohen's $d = -0.38$, $P = 0.02$).³¹ A non-randomised control trial of 1064 participants testing the effectiveness of digital health interventions in preventing readmission after an acute myocardial infarction showed that the digital health intervention group had fewer all-cause 30-day readmissions compared to the control group (6.5% compared to 16.8%). After adjustments, the digital health intervention group was found to have a 52% reduced risk of

readmission (hazard ratio: 0.48; 95% CI: 0.26–0.88).³² Finally, a multicenter RCT of 891 participants at moderate to high risk of cardiovascular disease evaluated the effect of a consumer-focused digital health intervention on guideline-recommended medication adherence, cardiovascular risk factor control, and lifestyle behaviors at one year. Although no difference was observed between groups in medication adherence (RR: 1.07; 95% CI: 0.88-1.20) and a miniscule improvement in attaining risk factor targets (RR: 1.40; 95% CI: 0.97-2.03), physical targets were attained significantly more (87.0% intervention vs. 79.7% control, $P = 0.02$) and e-health literacy developed more as well (72.6% intervention vs. 64.0% control, $P = 0.02$).³³

While these examples are more in line with digital health services at the individual level than at the population level, it is important to acknowledge that – in order for new or repurposed DPH tools to be taken up at larger scale – the receiving system needs to be ready to assimilate the innovation, both in terms of technological compatibility and restructuring of work processes and pathways.^{34–37} System readiness, in this line of reasoning, is fostered by exposure to and awareness of successful innovations in either the same domain elsewhere or

a different domain within the same overarching system (i.e. healthcare or public health) and can occur at a national, organisational, community, and individual level.^{35,36}

Another point to consider is the readiness of the general population to structurally adopt digital health services. According to a recent analysis of digital skills in the European Union, there are clear discrepancies in digital skills across the European regions: the majority of highly digitally skilled people are found in the Northern and North-Western parts of Europe, while South-Eastern Europe shows less than 20% of individuals being highly digitally skilled. Certain population groups also seem to fare more favourable in a digital world: people who are younger, higher educated, male, live in urban regions, are either a student or employed, or are employed consistently report higher internet access and digital skills.³⁸ These findings suggest that – if digital health services were structurally introduced now – only certain population groups would be able to benefit from these services. Ironically, population groups that could potentially benefit most from these innovations are the ones that would experience the highest barriers to access, creating a digital health paradox.¹²

Opportunities & Challenges

While recent events have rapidly accelerated progress towards the expansion of DPH, there remains significant untapped potential in harnessing, leveraging, and repurposing digital technologies (and data) for public health. International real-world data can boost large-scale observational studies at the European level (thus ameliorating current constraints presented by a lack of high-quality data surrounding digital health and DPH interventions), tackle cross-border epidemiological questions, and accelerate the implementation of shared European public health policies. However, the effectiveness of the implemented strategies depends on the active involvement of the population. That said, in order for the population to become actively involved in DPH and for DPH to improve the social health experience,³⁹ a more horizontal design of DPH needs to be normalised and healthcare pathways need to be reconsidered in light of existing and emerging technologies.^{37,39} For instance, a DPH initiative using the technology currently in use to detect information relating to COVID-19 in social media posts could make use of the habit of the general population to search for health-related information through (social) media networks in order to provide them with contact details for relevant health professionals.⁴⁰ To develop these technologies, public and private actors should not only ensure their technological infrastructure is compatible, but also align their values, vision, and resources.⁴¹

To fully embrace the potential of DPH, social determinants also need to be considered to ensure access to

DPH for all population segments and overcome geographic and socioeconomic barriers to achieving good health and well-being.^{12,42} Digital connectivity is a major prerequisite for accessing DPH and vast digital divides in the European region continue to exist.³⁸ Integrating DPH into curricula and training remains of paramount importance to develop the capacity to support the sustainable development of DPH systems and infrastructure. Whether this is through the inclusion of DPH modules within existing academic courses or implementing additional educational initiatives, such a focus is vital to identifying potential areas for future digital health uptake and the continual strengthening of digital health systems.⁴³

Young professionals – namely, youth – constitute an untapped resource within the public health workforce (PHWF) and present a great opportunity for strengthening both the digital health capacity and digital readiness of (public) health systems in which they are employed.^{43,44} Additionally the involvement and engagement of youth via multidisciplinary public-private partnerships between academia, governments, civil society, and other relevant stakeholder groups can further strengthen governance processes related to DPH. However, youth must be enfranchised to structurally contribute to the promotion and adoption of DPH technologies (e.g. by means of digital health literacy initiatives) so that existing health inequalities and digital divides are not exacerbated.^{12,45} Only by harnessing the digital potential of the current and future generation of the PHWF can DPH interventions achieve maximum uptake and spread across Europe.⁴³

A key challenge to the effective implementation of European DPH strategies is the concept of interoperability (Box 3).⁴⁶ Interoperability requires a shared technical, legal and organisational framework and is a prerequisite for using digital tools and data-driven technologies to their full potential in the public health landscape.⁴⁷ The COVID-19 pandemic has highlighted the

Interoperability refers to the ability of two or more systems or components to exchange information and to use the information that has been exchanged.⁴⁶ It can be construed as a wicked problem as it can be defined in multiple dimensions:^{47,48}

Technical interoperability: the basic data exchange capabilities between systems.

Structural or syntactic interoperability: two or more systems have data formats that are compatible.

Semantic interoperability: two or more systems use a shared language and terminology and can therefore understand, process, and interpret each other's data.

Organisational interoperability: the legal, political, and organisational facilitators of data exchange of two or more systems are compatible.

Box 3: The definition and dimensions of interoperability.

importance of timely access to health data in ensuring the rapid development of digital tools (e.g. mobile health apps, wearable sensors) to collect large volumes of data. However, due to unstructured data and isolated data infrastructures, it is challenging to combine datasets and run comprehensive analysis, severely limiting the ultimate potential of these technologies from a public health perspective.

Pursuing interoperability – especially cross-country – requires data protection to be considered. The General Data Protection Regulation (GDPR) established requirements that data operators have to comply with, which are more stringent when dealing with personal data.⁴⁹ As such, interoperability must be in compliance with the current legal system, while digital health systems should be designed prospectively to guarantee adherence to data protection legislation.⁵⁰ That being said, with the GDPR, the EU has set a precedent to legislate in the field of health data, which could enable them to create more targeted legislation related to data protection and interoperability. The recommendation of the European Commission to adopt a standard format in their electronic health records is a first step in this process.⁵⁰

Implications for Policy & Practice

The extraordinary momentum and progress witnessed worldwide regarding DPH led us to acknowledge the broader implications for policy and practice extending beyond the current public health emergency.

The COVID-19 pandemic has led us to recognise the pivotal role of surveillance in deepening our understanding of infection transmission and identifying risk factors for the disease to guide effective interventions. Strengthening digital epidemiological surveillance through digital tools to support operations (e.g. case identification, contact tracing, and other strategies for pandemic control) represent perhaps the most crucial area of DPH in the future epidemic preparedness and more widely. Increased recognition of the role of non-health data in providing novel insights for public health remains a significant step to ensuring DPH interventions reflect the field's interdisciplinary nature.² This contains developing ways of systematically integrating data sources, including social media data, mobility data, and survey data, into DPH surveillance and monitoring tools.^{38,40}

From a top-down perspective, the effectiveness of DPH interventions fundamentally rests upon their ability to be communicated to individuals.²¹ Guiding individual decisions and behaviour towards effective public health practices through timely and targeted communication strategies remains a pivotal role of DPH. This will enable the success of digital interventions and in the broader public health field more generally.² Timely interventions would limit existing divergences and accelerate the path towards two critical goals of DPH

technologies: (1) optimisation of healthcare services provision and patients' accessibility to health data (primary use of health data) and (2) implementation of research, policymaking, and regulatory activities (secondary use of health data). In contrast, DPH interventions should be designed with the individual at the centre of the design process, meaning a comprehensive focus on understanding the factors that support people (professionals and patients) to use technology should be included and the importance of cultural and organisational change recognised.^{12,35,36,51}

As the generation which stands to gain – or lose – the most from digital transformations in health, youth must be enfranchised (e.g. through digital literacy initiatives) to contribute to policymaking processes. Youth can simultaneously play a key role in enabling and enriching policy initiatives by helping to increase the uptake and spread of digital transformations across demographics. One such example is the work of the recently adopted United Nations (UN) Convention on the Rights of the Child general comment No. 25 (2021) setting out children's rights in the digital world, in which children and young people were consulted at every stage.^{52,53} Another example is the work of The *Lancet* and Financial Times Commission on Governing health futures 2030: growing up in a digital world (hereafter “GHFutures2030”), which set a new benchmark for meaningfully including youth in the design, development, implementation, and evaluation of digital health policies, programmes, and services.^{54,55}

Conclusion

There is a growing need for coordinated, multidisciplinary approaches and strategies for regulating, evaluating, and using digital technologies, particularly in the context of public health emergencies.²¹ Moreover, there are broader implications for applying DPH measures, which extend beyond the epidemiological management of COVID-19 (e.g. other concurrent public health crises like domestic violence).⁵⁶ Such applications can help improve the efficiency and effectiveness of public health prevention, surveillance, and responses. To safeguard health futures for generations to come, governments, stakeholders, and experts need a concerted effort to establish an appropriate technical, legal, and governance framework, as proposed by the GHFutures2030 Commission.⁵⁷ This will lead to interoperable systems and accessible health information by accessing and exchanging health data. We call upon all stakeholders to show political commitments, set up a normative and regulatory framework supported by technical infrastructure and sustainable financial investments. To transform this journey into a sustainable and long-term reality we also believe that academic and private institutions need to invest in training, education, research, and collaboration with national and regional authorities

to establish robust monitoring and evaluation to support continuous improvement efforts.

Declaration of interests

All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work (except the research grants listed in funding); no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Author contributions

The corresponding author confirms that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. The contributions of all authors are outlined using the CRediT statement. BLHW: Conceptualisation, Investigation, Formal Analysis, Writing - Original Draft, Writing - Review & Editing, Supervision. LM: Investigation, Formal Analysis, Writing - Original Draft. AV: Investigation, Formal Analysis, Writing - Original Draft. RVK: Investigation, Formal Analysis, Visualisation, Writing - Review & Editing. SS: Investigation, Formal Analysis, Writing - Original Draft. SB: Investigation, Formal Analysis, Writing - Original Draft. AO: Investigation, Formal Analysis, Writing - Original Draft.

References

- 1 Peek N, Suján M, Scott P. Digital health and care in pandemic times: impact of COVID-19. *BMJ Health Care Inform.* 2020;27:e100166.
- 2 Murray CJL, Alamro NMS, Hwang H, Lee U. Digital public health and COVID-19. *Lancet Public Health.* 2020;5:e469–e470.
- 3 Whitelaw S, Mamas MA, Topol E, Spall HGC. Applications of digital technology in COVID-19 pandemic planning and response. *Lancet Digit Health.* 2020;2:e435–e440.
- 4 World Health Organization. Digital health. 2021. <https://www.euro.who.int/en/health-topics/Health-systems/digital-health>. Accessed 14 December 2021.
- 5 Odone A, Buttigieg S, Ricciardi W, Azzopardi-Muscat N, Staines A. Public health digitalization in Europe. *Eur J Public Health.* 2019;29:28–35.
- 6 Wienert J, Jähnel T, Maa L. What are Digital Public Health Interventions? First Steps Towards a Definition and an Intervention Classification Framework. *JMIR.* 2022. 04/01/2022:31921 (forthcoming/in press).
- 7 Rosalia RA, Wahba K, Milevska-Kostova N. How digital transformation can help achieve value-based healthcare: Balkans as a case in point. *Lancet Reg Health – Eur.* 2021;4. <https://doi.org/10.1016/j.lanepe.2021.100100>.
- 8 Wilson D, Sheikh A, Görgens M, Ward K. *Technology and Universal Health Coverage: Examining the role of digital health.* 2021;11:12.
- 9 Darmann-Finck I, Rothgang H, Zeeb H. Digitalisierung und Gesundheitswissenschaften – White Paper Digital Public Health. *Gesundheitswesen.* 2020;82:620–622.
- 10 Zeeb H, Pigeot I, Schüz B. Leibniz-WissenschaftsCampus Digital Public Health Bremen. Digital Public Health – ein Überblick. *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz.* 2020;63:137–144.
- 11 Jähnel T, Schüz B. Partizipative Entwicklung von Digital-Public-Health-Anwendungen: Spannungsfeld zwischen Nutzer*innenperspektive und Evidenzbasierung. *Bundesgesundheitsblatt - Gesundheitsforschung - Gesundheitsschutz.* 2020;63:153–159.
- 12 van Kessel R, Hrzic R, O’Nuallain E, et al. The digital health paradox: international policy perspectives to address the increased health inequalities for people living with disabilities. *J Med Internet Res.* 2022. doi:10.2196/33819.
- 13 Aiello AE, Renson A, Zivich PN. Social Media– and Internet-Based Disease Surveillance for Public Health. *Annu Rev Public Health.* 2020;41:101–118.
- 14 Shakeri Hossein Abad Z, Kline A, Sultana M, et al. Digital public health surveillance: a systematic scoping review. *Npj Digit Med.* 2021;4:1–13.
- 15 World Health Organization. *Constitution of the World Health Organization.* New York. 1948.
- 16 Rechel B, McKee M. *Facets of Public Health in Europe. European Observatory on Health Systems and Policies Series.* Maidenhead, UK: Open University Press; 2014.
- 17 Sonnier P. *The fourth wave: Digital health - a new era of human progress.* 2017. San Diego, California.
- 18 Wong BLH, Delgrange M, Nathan NL, et al. The Association of Schools of Public Health in the European Region Statement on the Erosion of Public Health Systems. *Public Health Rev.* 2021. <https://doi.org/10.3389/phrs.2021.1604112>. o.
- 19 Fahy N, Williams GA. *COVID-19 Health System Response Monitor Network. Use of digital health tools in Europe: before, during and after COVID-19.* Copenhagen: European Observatory on Health Systems and Policies; 2021. <https://eurohealthobservatory.who.int/publications/i/use-of-digital-health-tools-in-europe-before-during-and-after-covid-19>.
- 20 WHO/Europe. HealthBuddy+. 2020. <https://healthbuddy.plus/index>. Accessed 12 December 2021.
- 21 Budd J, Miller BS, Manning EM, et al. Digital technologies in the public-health response to COVID-19. *Nat Med.* 2020;26:1183–1192.
- 22 Catalan Department of Health. eConsult. 2020. <https://catsalut.gencat.cat/ca/serveis-sanitaris/la-meva-salut/>. Accessed 12 December 2021.
- 23 UK Research and Innovation. Over one million GP consultations using new app. 2020; published online Oct 28. <https://www.ukri.org/our-work/tackling-the-impact-of-covid-19/addressing-technological-challenges/over-one-million-gp-consultations-using-new-app/>. Accessed 14 December 2021.
- 24 Negreiro M. *The rise of digital health technologies during the pandemic.* Brussels: European Parliament; 2021.
- 25 Freeman D, Haselton P, Freeman J, et al. Automated psychological therapy using immersive virtual reality for treatment of fear of heights: a single-blind, parallel-group, randomised controlled trial. *Lancet Psychiatry.* 2018;5:625–632.
- 26 Buntrock C, Ebert DD, Lehr D, et al. Effect of a Web-Based Guided Self-help Intervention for Prevention of Major Depression in Adults With Subthreshold Depression: a Randomized Clinical Trial. *JAMA.* 2016;315:1854–1863.
- 27 inDemand. MENU DO: mobile digital technologies to treat childhood obesity through education, motivation and adherence. 2020 https://www.indemandhealth.eu/wp-content/uploads/2020/11/INDEMANDSTORIES_MENU DO-1.pdf. Accessed 12 December 2021.
- 28 Ming LC, Untong N, Aliudin NA, et al. Mobile health apps on COVID-19 launched in the early days of the pandemic: content analysis and review. *JMIR MHealth UHealth.* 2020;8:e19796.
- 29 Jähnel T, Kernebeck S, Böbel S, et al. Contact-Tracing-Apps als unterstützende Maßnahme bei der Kontaktpersonennachverfolgung von COVID-19. *Gesundheitswesen Bundesverb Ärzte Öffentlichen Gesundheitsdienstes Ger.* 2020;82:664–669.
- 30 Hernández-García I, Giménez-Júlvez T. Assessment of Health Information About COVID-19 Prevention on the Internet: Infodemiological Study. *JMIR Public Health Surveill.* 2020;6:e18717.
- 31 Palermo TM, de la Vega R, Murray C, Law E, Zhou C. A digital health psychological intervention (WebMAP Mobile) for children and adolescents with chronic pain: results of a hybrid effectiveness-implementation stepped-wedge cluster randomized trial. *PAIN.* 2020;161:2763–2774.
- 32 Marvel FA, Spaulding EM, Lee MA, et al. Digital Health Intervention in Acute Myocardial Infarction. *Circ Cardiovasc Qual Outcomes.* 2021;14:e007741.

- 33 Redfern J, Coorey G, Mulley J, et al. A digital health intervention for cardiovascular disease management in primary care (CONNECT) randomized controlled trial. *Npj Digit Med*. 2020;3:1–9.
- 34 Greenhalgh T, Robert G, Macfarlane F, Bate P, Kyriakidou O. Diffusion of innovations in service organizations: systematic review and recommendations. *Milbank Q*. 2004;82:581–629.
- 35 Greenhalgh T, Wherton J, Papoutsi C, et al. Beyond adoption: a new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-Up, spread, and sustainability of health and care technologies. *J Med Internet Res*. 2017;19:e8775.
- 36 Ross J, Stevenson F, Lau R, Murray E. Factors that influence the implementation of e-health: a systematic review of systematic reviews (an update). *Implement Sci*. 2016;11:146.
- 37 Sbayou M, Zacharewicz G, Bouanan Y, Vallespir B. BPMN coordination and devn network architecture for healthcare organizations. *Int J Priv Health Inf Manag*. 2019;7:103–115.
- 38 van Kessel R, Wong BLH, Rubinić I, O’Nuallain E, Czabanowska K. Is Europe prepared to go digital? Making the case for developing digital capacity: an exploratory analysis of Eurostat survey data. *PLOS Digit Health*. 2022. <https://doi.org/10.1371/journal.pdig.0000013>. published online Forthcoming.
- 39 Lefebvre RC, Bornkessel AS. Digital Social Networks and Health. *Circulation*. 2013;127:1829–1836.
- 40 Swiatek B. *Social Networking: the Future of Digital Healthcare*. 10Clouds; 2018. published online April 23; <https://10clouds.com/blog/web/digital-healthcare-social-networking/>. Accessed 8 January 2022.
- 41 Mazzucato M. *Mission Economy: A Moonshot Guide to Changing Capitalism*. 1st edn Allen Lane; 2021.
- 42 Honeyman M, Maguire D, Evans H, Davies A. *Digital technology and health inequalities: a scoping review*. Cardiff: Public Health Wales NHS Trust; 2020.
- 43 Wong BLH, Khurana MP, Smith RD, et al. Harnessing the digital potential of the next generation of health professionals. *Hum Resour Health*. 2021;19:50.
- 44 Wong BLH, Siepmann I, Chen TT, et al. Rebuilding to shape a better future: the role of young professionals in the public health workforce. *Hum Resour Health*. 2021;19:82.
- 45 Wong BLH, Smith RD, Siepmann I, Hasse A, Tandon S. Youth engagement in digital health: a critical perspective towards meaningful youth agency in governance. *MMS Bull*. 2021;157. <https://doi.org/10.6084/m9.figshare.17285477.v1>.
- 46 IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. *IEEE Std*. 1991;610:1–217.
- 47 Lehne M, Sass J, Essenwanger A, Schepers J, Thun S. Why digital medicine depends on interoperability. *Npj Digit Med*. 2019;2:1–5.
- 48 Kolasa K, Kozinski G. How to value digital health interventions? a systematic literature review. *Int J Environ Res Public Health*. 2020;17:2119.
- 49 European Commission. General Data Protection Regulation. 2016 <https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32016R0679>. Accessed 14 December 2021.
- 50 Bincoletto G. Data protection issues in cross-border interoperability of Electronic Health Record systems within the European Union. *Data Policy*. 2020;2:e3.
- 51 Hutchings R, Scobie S, Edwards N. *Fit for the future: what can the NHS learn about digital health care from other European countries?* London: Nuffield Trust; 2021. <https://www.nuffieldtrust.org.uk/files/2021-11/international-digital-policy-review-web.pdf>. Accessed 10 December 2021.
- 52 United nations committee on the rights of the child. General comment on children’s rights in relation to the digital environment. 2021. <https://www.ohchr.org/EN/HRBodies/CRC/Pages/GCChildrensRightsRelationDigitalEnvironment.aspx>. Accessed 19 December 2021.
- 53 Terre des hommes. #CovidUnder19. 2021. <https://www.tdh.ch/en/projects/covidunderr19>. Accessed 19 December 2021.
- 54 Wong BLH, Gray W, Holly L. The future of health governance needs youth voices at the forefront. *The Lancet*. 2021;1–2.
- 55 Wong BLH, Gray W, Georges Stevens EA, et al. *The lancet-financial times commission governing health futures 2030: growing up in a digital world youth statement + call for action*. Geneva, Switzerland: The Lancet and Financial Times Commission on Governing health futures 2030: Growing up in a digital world; 2021. https://els-jbs-prod-cdn.jbs.elsevierhealth.com/pb-assets/Lancet/stories/commissions/governing-health-futures-2030/GHFutures2030_Youth_Statement-1634917151153.pdf.
- 56 Jeyaraman D, Chandan JS. Digital public health: a hopeful strategy to tackle the surge in domestic violence. *Lancet Public Health*. 2020;5:e578.
- 57 Kickbusch I, Piselli D, Agrawal A, et al. The Lancet and Financial Times Commission on governing health futures 2030: growing up in a digital world. *The Lancet*. 2021;398:1727–1776.