Addressing health determinants in a digital age: project report

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Abstract

The aim of this project was to develop a conceptual framework and provide a common understanding of health determinants in a digital age in light of the emergence of digital determinants of health and the digital transformations of social, political, and commercial and economic determinants. A scoping review was conducted in MEDLINE, Embase, Web of Science and Google Scholar. Relevant data were extracted and clustered using a thematic analysis. Priority areas were identified through internal discussions guided by consensus methods. This report offers a comprehensive overview of determinants, encompassing policy decisions, individual behaviours and factors across digital, social, commercial and economic, and political domains that influence health in the digital age. It seeks to deepen understanding of how health outcomes manifest within a digital ecosystem and elucidate strategies for addressing the intricate and evolving networks of health determinants.

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Executive summary

Introduction

The recognition of social determinants of health has linked various factors such as age, education, employment, geographical location and housing to individuals' health status, establishing health as a reflection of everyday life conditions. With rapid digital transformations, however, there is a need for a new framework that incorporates the emerging digital determinants of health.

Objective

This project on which this report is based aimed to develop a conceptual framework and provide a common understanding of health determinants in a digital age, focusing on the emergence of digital determinants of health and the digital transformations affecting social, political, and commercial and economic determinants.

Methods

The project involved a scoping review to inform a draft conceptual framework for digital determinants of health and provide an overview of how health determinants have changed in the digital age. Priority areas were then identified among the list of determinants through internal discussions of all authors and collaborators guided by consensus methods.

Key findings

Conceptual framework development

- One hundred and twenty-seven health determinants were identified and categorized into five parts of society impacted by digitalization: person-specific determinants; community determinants; technology-related determinants; policy determinants; and political, economic, societal and cultural determinants.
- The conceptual framework illustrates the interconnection of these determinants and their impact on health within a digital ecosystem.

Urgency ratings

- Thirty determinants were classified as urgent or very urgent, including Internet access, digital literacy, data and digital capacity, moderation of harmful content, model accuracy, algorithmic validation, and data governance and ethics.
- Key determinants highlighted the need for equitable digital transformations, robust digital public infrastructure, and inclusive health and social care policies.

Conclusion

The report underscores the transformative effect of digitalization on health determinants, emphasizing the need for equitable digital access and literacy. It also highlights the importance of robust data governance policies and the urgent need to address misinformation and harmful content online. Project findings suggest that digital transformations can both positively and negatively affect health, necessitating continuous monitoring and adaptation of policies to address evolving digital divides. The comprehensive overview provided by this report challenges stakeholders to better understand and address health determinants in the digital age. It calls for inclusive and equitable digital health strategies that consider the multifaceted impact of digital transformations on health.

Introduction

The social determinants of health refer to the nonmedical factors that influence health outcomes, encompassing the conditions in which people are born, grow, live, work and age, as well as the wider set of forces and systems shaping these conditions *(1,2)*. One of the best recognized frameworks for understanding the social determinants of health is the Dahlgren and Whitehead model, which organizes the determinants into layers of influence, starting from individual lifestyle factors to broader socioeconomic, cultural and environmental conditions *(1,2)*.

The model demonstrates that health is shaped by a complex interplay of factors at multiple levels. At the core of the model are individual characteristics such as age, sex and genetic factors. Surrounding the core are lifestyle factors that directly affect health, like diet, physical activity and smoking. The next layer includes social and community networks, highlighting the importance of social support and interactions. Beyond this are living and working conditions, including access to education, employment, housing and health-care services. The outermost layer encompasses broader socioeconomic, cultural and environmental conditions, such as economic policies, cultural norms and environmental quality.

This model has profoundly influenced the way public health is approached, shifting the focus from individual behaviours and medical care to a more holistic understanding of health. It emphasizes that health inequalities arise from the inequitable distribution of resources and opportunities, rather than just personal choices or genetic predispositions. This recognition has helped to establish an understanding of health as not merely the absence of disease, but as a reflection of everyday life conditions *(1–4)*.

Complementary frameworks have been developed for specific archetypes of health determinants, such as the political and commercial and economic determinants of health. The political determinants of health refer to the ways in which political decisions and policies influence health outcomes. These determinants, which encompass the distribution of power, resources and opportunities within societies, shape the environments in which people live, work and interact. They include laws, regulations and policies, as well as factors such as political stability, governance, advocacy and political activism *(5–7)*.

The commercial and economic determinants of health refer to the ways in which business practices, corporate policies and economic activities influence health outcomes. These determinants encompass the strategies and actions of private sector entities that affect public and population health, including the production, marketing and distribution of goods and services by businesses that influence the social, economic and environmental conditions affecting health. Examples of these determinants include corporate practices related to marketing, pricing and product availability, the influence of corporations on public policy and regulation, and corporations' labour practices (such as employment conditions, wages and benefits) *(8,9)*.

Health determinants generally are recognized as essential components for maintaining and improving individual and population health. Over time, they have been incorporated into policy-making and governance in high-, middle- and low-income countries *(10)*. A recent review of health determinants frameworks concluded, however, that a new framework is necessary. This new framework should preserve the core components of existing models while addressing newly emerging health challenges, and should incorporate recent knowledge about factors previously not considered relevant, such as those related to digital transformations *(11)* – the digital determinants of health.

The digital determinants of health refer to any factor rooted in, contingent on, or inextricably linked to the digital world that can directly or indirectly influence health or well-being. Digital determinants of health can alter the way in which health care is delivered to improve health, modify an existing relationship between social, political or commercial determinants and health, or create entirely new ways to influence individual or population health *(4,12–14)*.

While the impacts of digitalization on health and social sectors have been studied extensively, research focusing on how the digital world itself is directly and indirectly associated with individual and population health is still emerging *(4,12,13,15,16)*. WHO's Global Digital Health Strategy underscores the need to ground digital foundations within national strategies, establish national digital health agendas and strategies for the health sector, and work with sectors and stakeholders at all levels of governance, from policy, to service delivery, to individual decision-making *(17)*. This highlights the importance of understanding the state of health determinants in a digital age across multiple levels of governance *(18)*.

Accordingly, this report aims to:
- map what health determinants have manifested in the digital ecosystem (that is, the digital determinants of health);

- investigate how existing social, political, and commercial and economic determinants are redefined in a digital context; and

- achieve consensus on which of these digital and digitalized determinants of health should urgently be considered at various governance levels.

Methods

A scoping review with thematic synthesis in accordance with the scoping review framework developed by Arksey & O'Malley and Levac *(19,20)* was conducted according to the Joanna Briggs Institute guidelines for scoping reviews. It contained a combination of systematic and targeted searches and predetermined eligibility criteria *(21,22)*. In contrast to conventional scoping reviews, this review aimed only to create an initial inventory of determinants; this meant that no specific data extraction sheet was developed and no assessment of the quality of the included articles was made, as the aim of the project was not to validate the methodological rigour of the included records to ascertain confidence in the data synthesis, but to collect information about how health determinants have changed in the context of the digital world *(22)*.

Eligibility criteria

To be eligible for inclusion, articles either had to discuss how social, commercial or political determinants of health changed in the digital age or highlight any new determinants that manifested because of digital transformations. Articles that discussed enablers of, or barriers to, digital health implementation were not considered, as these had been mapped in previous research *(23)*; an exception was made for articles that contained information on how certain population groups may experience difficulties engaging with the digital world, or how those difficulties might affect individual health. Only publications in English were considered.

No restrictions were put on study-type eligibility, but for feasibility purposes, the systematic search was limited to include only systematic, scoping, integrative and realist reviews, as wider searches of MEDLINE and Embase (192 710 records) and Web of Science (137 785 records) would return an unfeasible number of sources to screen. Feasibility constraints also meant only publications from 2018 onwards were considered, as a substantial acceleration of digital transformations has occurred since 2018 as a result of the coronavirus disease (COVID-19) pandemic; the societal landscape prior to 2018 may no longer be comparable to the societal landscape after *(13,24–26)*.

Search strategy and data collection

Scientific articles were systematically identified through three scientific databases (MEDLINE, Embase and Web of Science). These databases were chosen to cover both health-specific (MEDLINE and Embase) and interdisciplinary (Web of Science) academic fields and comprise an optimal database combination for health-related literature reviews *(27)*.

While the impacts of digital transformations on other areas, such as political science, sociology and economics, are also captured in the literature bodies of other research fields, the selection of databases in this study was based on the assumption that articles that discuss health determinants specifically tend to be published in health-specific or interdisciplinary journals, which can be identified using these three scientific databases.

Keywords relating to the social *(28,29)*, commercial and economic *(9)*, and political determinants of health were synthesized from previous systematic literature reviews *(30)*. No previous research on the digital determinants of health was available to inform the search string, though previous research on digital health was available to inform the digital-focused keywords *(23)*. The systematic search was supplemented with nonsystematic searches using PubMed and the first 300 hits in Google Scholar *(31)*. These supplementary searches ensured that the most recent academic and grey literature on digital transformations in social, commercial and political determinants, which may not yet be integrated in literature reviews, was also captured. The full query for the scientific databases is shown in Table 1.

An information specialist at the library of Maastricht University, Netherlands (Kingdom of the) validated the search strategy. The screening process was divided between two authors (van Kessel and Seghers) after a calibration process in which both authors discussed the eligibility of a random selection of approximately 10% of total articles from the search strategy. A third author (Anderson) resolved any disagreements between the two reviewers.

Table 1. Overview of the search query per database

Database/ search engine	Query	Hits
MEDLINE, Embase (Ovid)	1 (online or digital or virtual or Internet or AI or "artificial intelligence" or telehealth or telemedicine or ehealth or e-health).ti,ab. 2 Telemedicine/ 3 1 or 2 4 ("social determinant*" or "structural determinant*" or "socioeconomic factor*" or education or income or poverty or employment or housing or gender or ethnicity or race).ti,ab. 5 Employment/ or Housing/ or Poverty/ or Income/ or Education/ or Schools/ or Literacy/ or Socioeconomic Factors/ 6 ("commercial determinant*" or ((commercial or corporate) and determinant* and (health or disease*)) or CDoH).ti,ab. 7 "political determinant*".ti,ab. 8 (democracy or autocracy or "welfare regime" or "welfare state" or "welfare capitalism" or politics or "political tradition" or internationality or globalization).ti,ab. 9 (health or "health service*").ti,ab. 10 8 and 9 11 4 or 5 or 6 or 7 or 10 12 3 and 11 13 ("systematic review" or "scoping review" or "realist review" or "integrative review" or "umbrella review").ti,ab. 14 12 and 13 15 limit 14 to yr="2018 -Current" 16 limit 15 to "remove preprint records"	5 479
Web of Science	TS=(online or digital or virtual or Internet or AI or "artificial intelligence" or telehealth or telemedicine or ehealth or e-health) AND (TS=("social determinant*" or "structural determinant*" or "socioeconomic factor*" or education or income or poverty or employment or housing or gender or ethnicity or race) OR TS=("commercial determinant*" or "corporate determinant*" or "political determinant*")) AND TS=("systematic review" or "scoping review" or "realist review" or "integrative review" or "umbrella review")	5 309
PubMed (nonsystematic)	(digital[Title/Abstract] OR online[Title/Abstract] OR virtual[Title/Abstract] OR internet[Title/Abstract] OR telehealth[Title/Abstract] OR ehealth[Title/Abstract] OR AI[Title/Abstract] OR "Artificial Intelligence"[Title/Abstract]) AND ("social determinants of health"[Title/Abstract] OR SDoH[Title/Abstract] OR "commercial determinants of health"[Title/Abstract] OR CDoH[Title/Abstract] OR "political determinants of health"[Title/Abstract] OR PDoH[Title/Abstract])	823
Google Scholar (nonsystematic)	"AI" "social determinants of health" "digital" "social determinants of health" "AI" "commercial determinants of health" "digital" "commercial determinants of health" "AI" "political determinants of health" "digital" "political determinants of health" "digital determinants of health"	300 300 300 300 300 300 300

AI: artifical intelligence.
CDoH: commercial or corporate determinant of health.

Data synthesis and analysis

Thematic analysis

A thematic analysis was used to extract data relevant to how social, commercial and economic, or political determinants of health changed or digital determinants of health newly manifested in the context of the digital world *(32)*. Information on these determinants was extracted by two authors (van Kessel and Seghers) and clustered post hoc into five parts of society affected by digitalization, using the 1991 model for social determinants of health as the blueprint *(2)*. The data extraction of eligible articles continued until thematic saturation was reached. During this process, three authors iteratively identified subject matter experts through existing research collaborations; the experts were then invited to join the project as authors or contributors, depending on their preference.

All authors and contributors reviewed and enriched the findings of the literature review by identifying additional records between 3 October 2023 and 22 December 2023. They also reviewed and refined the conceptual framework during this time to ensure it was comprehensive and accurately captured how the digital age manifested new and redefined existing health determinants across various parts of society. Finally, an internal discussion applying a consensus method was held to identify priority areas among the mapped health determinants.

Consensus process

A two-round internal consensus process was conducted among the authors and contributors between 8 January 2024 and 23 May 2024 to prioritize the identified determinants for policy action. During the first round (lasting six weeks), each received a list of health determinants compiled through the literature review and expert consultations by logging into Welphi (Welphi, Lisbon, Portugal), a web application designed for consensus processes. Authors and contributors were instructed to evaluate each health determinant using a 5-point Likert scale (1: not urgent; 2: somewhat urgent; 3: fairly urgent; 4: urgent; and 5: very urgent) based on the following statement: "Under the recognition that all health determinants are important to address, how urgent is it for this health determinant to be taken into account?"

The determinants were presented by societal category outlined in the conceptual framework and randomized within each category to reduce the potential effect of order bias and scoring fatigue. To reduce the burden of the consensus process, the second round (lasting four weeks) involved only authors and contributors who fully completed the first round, and they rated only determinants deemed of moderate urgency in the first round. All authors and contributors were invited to validate the description and triangulation of the results after the consensus process concluded. Health determinants were randomized to reduce the potential effect of order bias and scoring fatigue *(33)*.

The consensus analysis included complete and incomplete responses. Outcome measures were percentages and median values as indicators of agreement on the 5-point scales, as well as interquartile ranges (IQRs). Urgency percentage was defined as the combined proportion of ratings at 4 and 5 *(34)*. These combined measures enabled the determinants to be classified under three categories:

- high urgency had a median rating of 4 or 5, an urgency percentage of 80% or higher, and an IQR of 1 or lower;

- moderate urgency had a median rating of 4 or less, an urgency percentage between 50% and 79%, and an IQR of 0 or higher; and

- low urgency was defined as a median rating of less than 4, an urgency percentage of less than 50%, and an IQR of 1 or higher.

A sensitivity analysis using the Mann-Whitney U test *(35)* was performed to explore possible variations in urgency ranking between participants with a primary research background and those whose primary background was not in research. The collected data were exported to R version 4.2.3 for analysis.

Results

The search of MEDLINE, Embase and Web of Science yielded 10 788 records and the nonsystematic searches 2923. Ninety-three records were identified through subject matter. After deduplication, 8595 unique records were screened for eligibility. Ultimately, 204 records (2.4%) were included. The most common reason for exclusion was lack of relevance, with excluded records discussing neither the impact of digital transformations on health nor how existing structures of health determinants were affected by the digital world. Fig. 1 shows a Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) flowchart with the full data extraction process.

In the subset screening of the total sample by the second reviewer (826/8595, 9.6%), a crude interrater agreement score of 93.7% (774/826 observations) between the two reviewers was found. The likelihood of interrater agreement resulting from chance was estimated by computing Cohen κ (0.663), which indicated moderate agreement between the reviewers.

Fig. 1. PRISMA flowchart of full data extraction process
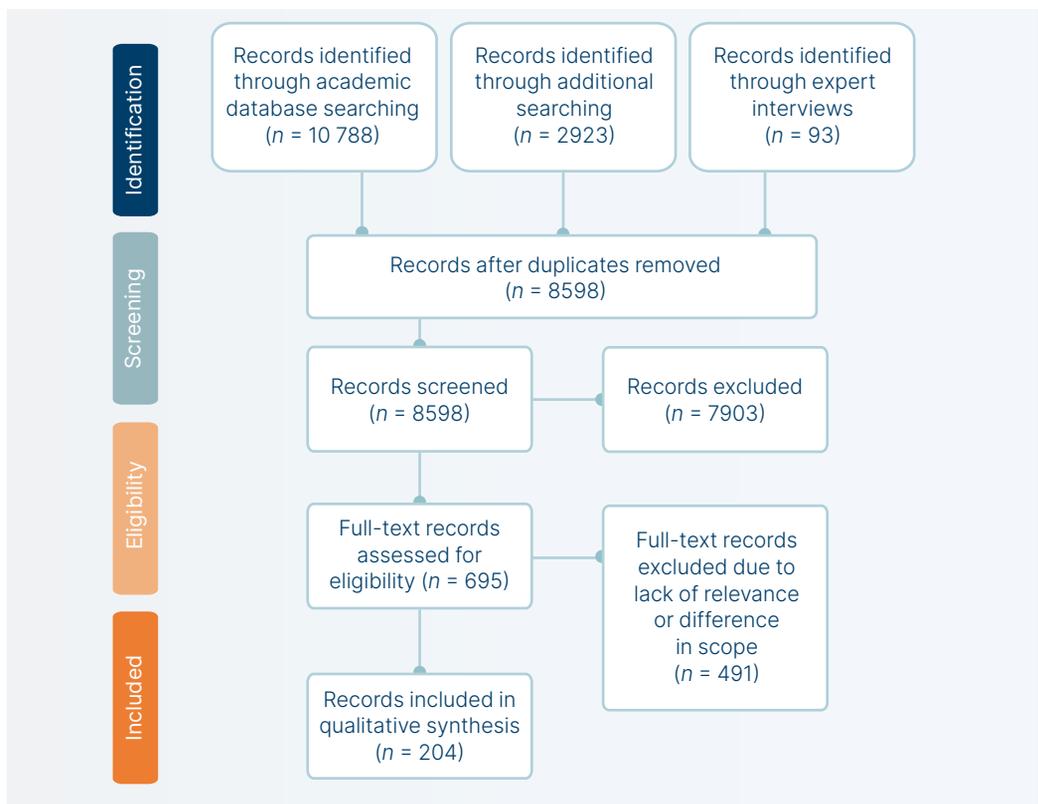
A conceptual framework of health determinants in a digital age

The literature review and expert consultations identified 127 health determinants that manifested or changed in a digital age (for an overview and glossary of the new and updated definitions of the health determinants in a digital age, see van Kessel et al. *(36)*). These health determinants were clustered according to five parts of society affected by digitalization:

- **person-specific determinants**, including personal views, perceptions, behaviours, resources and characteristics;

- **community determinants**, comprising localized determinants that affect health and are found within a village, city or other form of local community;

- **technology-related determinants**, capturing determinants related to digital devices, software and other technologies;

- **policy determinants**, reflecting policies in specific topic areas or themes (such as health care, transport, education and employment); and

- **political, economic, societal and cultural determinants**, encompassing the overarching socioeconomic and political climate, including the cultural settings in one or more countries.

The resulting conceptual framework, shown in Fig. 2, illustrates the relationship between health and the social, commercial and economic, political and digital determinants, and how these determinants have manifested in different parts of a digital ecosystem.

With health being at the core, the first layer stresses that health determinants form a blended spectrum that is heavily interconnected and can jointly affect health directly and indirectly *(13,15,23)*. The second layer shows how individual determinants can be classified as social, commercial and economic, political and digital determinants of health *(1,6,9)*. The outer layer demonstrates how health determinants exist nowadays within a digital ecosystem, meaning they interact with individuals through the physical and digital worlds. This layer also highlights the disruptive and transformative effects of digital transformation on the social, commercial and economic, and political determinants of health that predate the digital age *(4,13)*, while simultaneously manifesting a completely new domain in the digital determinants of health.

Fig. 2. Conceptual framework on the digital determinants of health

Digital ecosystem

The digital ecosystem consists of five societal categories:

1. **person-specific determinants;**
2. **community determinants;**
3. **technology-related determinants;**
4. **policy determinants; and**
5. **political, economic, societal and cultural determinants.**

These societal categories are present across all four health determinants domains.
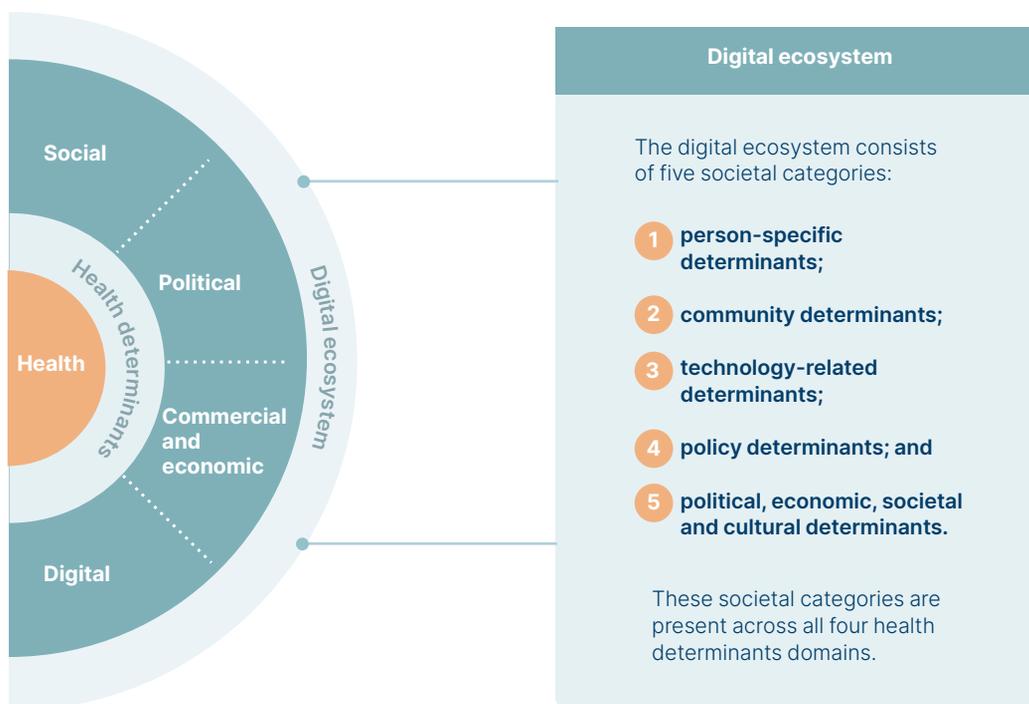
Connecting the determinants

Person-specific determinants

The literature and subject-matter experts emphasized how, in addition to establishing a new set of determinants, digital transformations further interconnect existing commercial, social and political determinants. An individual's Internet access and digital literacy are affected by age, sex, education, employment status, geographical location and health status (social determinants) *(4,13,23,37,38)*, and the person's financial situation (commercial determinants) *(37,39)*. Beyond the individual traits, social and organizational culture, the propensity of communities and health workers to accept and embrace change and social support were also found to affect an individual's Internet access and digital literacy *(23)*, emphasizing that these five levels do not operate in isolation but interact vertically.

Access to education and employment substantially shifted in the context of the digital world *(12,13,40)*. While the new digital model of delivery enabled both to continue throughout the COVID-19 pandemic, skewing the spread of disease, it also meant that education and employment were partially gatekept by the availability of digital devices, resulting in larger discrepancies between digitally connected and disconnected communities *(41)*.

Novel employment opportunities for which people depend on digital devices, such as gig and digital platform work, have emerged in the digital era. This type of work tends predominantly to be carried out by young people and students, with workers in such positions being apt to report high levels of psychological distress and financial insecurity *(42)*. In addition, these forms of employment often are poorly covered by employment policies *(43)*.

Community determinants

The intersection between digital technologies, social enterprise and citizen engagement need to be aligned to develop people-centred digital health solutions *(44)*. It is important that digital technologies use socially and culturally appropriate and sensitive language that matches the language and customs of a target population *(23,45)*. More broadly, digital technologies have profound effects on all areas of modern life, with many changes involving technological substitution rather than infrastructural change. During the COVID-19 pandemic, for instance, employment and educational practices largely shifted to the digital domain as a result of countries' efforts to mitigate the spread of disease, thereby preventing a deeper shutdown of society *(13,40)*. This has disproportionately affected the health and well-being of those with less aptitude for the digital world *(13,46)*.

When this intersection is not sufficiently considered, potential threats of digitalization that can negatively affect the health and well-being of individuals and communities, such as discrimination, breaches of privacy, disinformation and illness caused by medical examination or treatment (such as people from different cultural backgrounds using different terms to describe a condition that may be poorly recognized by the digital health solution) can manifest *(47)*. The effects of digitalization on the micro and meso levels require political awareness and proportionate regulatory responses, although this involves a different layer of determinants *(48)*.

Technology-related determinants

The rise of the digital world has brought with it several positive transformations. For instance, the quality of health care has improved *(23,49)*, novel health-care pathways have manifested *(23,50,51)*, and health care slowly but increasingly is being democratized as patients are empowered to take a more active role *(13,23,38)*. It is also worth noting that the expansion of digital access in resource-constrained settings has enabled the development of novel health-care pathways through which health-care access is expanded *(50–54)*.

Simultaneously, digital transformations have provided novel pathways for nefarious actors to conduct their business at the expense of public health and safety *(55–57)*. Dark commercial patterns (business practices that employ elements of digital choice architecture that subvert consumer decision-making) and health risks have been rooted in the design and implementation of digital solutions, including, but not limited to, problematic Internet use, gaming addiction, online gambling, cyberbullying, hostile communication or peer activity, sexual harassment, nonconsensual messaging and user communities aimed at harmful behaviour (such as self-harm, radicalization, violence and normative body-shaming) *(12,40,55,56,58)*.

Policy determinants

Regulatory factors and strategies form an important component in enabling and empowering citizens and patients in their use of digital technologies *(59,60)*. Transparent pricing of digital health technologies and solutions is also crucial to facilitate a value-based health-care approach and to ensure that prices reflect public funding of medical innovations *(61–63)*. This is especially important in the digital health context, as the innovations present an unprecedented disruption to the health-care field and digital health pricing policies are in their infancy *(64,65)*.

Proactive engagement and planning of health and social policies are necessary to ensure equitable access to digital solutions across population groups *(23,45)*. The capacity and ability of ministries of health to work cross-ministerially on policy-making, standard-setting, planning and implementation of digital solutions and supportive infrastructure is paramount. Stewardship of health nevertheless lies with ministries of health, and the competency to plan, partly regulate and even implement digital health also lies with health ministries in some countries *(66)*.

Political, economic, societal and cultural determinants

The intersection between health data governance and commercialization of health data needs to be closely monitored to ensure that patients' and citizens' data and digital solutions continue primarily to serve their needs rather than those of corporations. For example, health-care innovations that are being developed using patient and health system data could subsequently be sold back to the patient or health system, making them effectively pay twice *(67–69)*. This issue may be amplified in low- and middle-income countries that rely on multinational technology corporations to facilitate their Internet connectivity and the private sector to provide digital (health) solutions.

Developing robust data and digital governance policies requires a profound understanding of the normative and ethical framework that is present within a certain country or region. At the same time, it is important to approach the operationalization of a digital health agenda through a holistic and participatory lens, clearly defining the role of relevant stakeholders and strengthening their capacity; this may be even more important in low-resource settings *(66)*.

Digital transformations of all aspects of society have amplified the effects that deregulation and liberalization have had on the global and geopolitical landscape *(70)*. As a result, old dependencies between geopolitical powerhouses and dependents are reinforced, and novel dependencies are created between digital frontrunners and those with slower uptake of digital solutions *(70)*. This power discrepancy is further fuelled by socioeconomic differences between countries that skew their capability to invest in building a resilient digital infrastructure *(46)*, and the rise and weaponization of disinformation through divisive algorithms *(70)*.

The outcome of these old and new dependencies may give rise to so-called data neocolonialism, in which data are removed from their origin, changed and subsequently used to design products that marginally benefit those at the data source *(71)*. It is important to note that data neocolonialism does not merely refer to country-level discrepancies, but can equally be found within (digitally developed) countries in a form that disadvantages digitally vulnerable members of society *(13,38,72)*.

Consensus methodology

All 54 authors and contributors were invited to participate in the internal discussion guided by consensus methods, of which 35 (64.8%) completed the first round and 32 (59.3%) the second. After the first round, 85 of 127 determinants were removed from the process after consensus was reached, leaving 42 determinants to be re-rated in the second round. Ultimately, 30 determinants (23.6%: 20 digital, six social, zero commercial and economic, and four political) were considered highly urgent by consensus (Fig. 3 and Table 2) (for the complete results of the consensus process, see van Kessel et al. *(36)*).

Fig. 3. Urgency rating of health determinants in the digital age, by health determinants domain
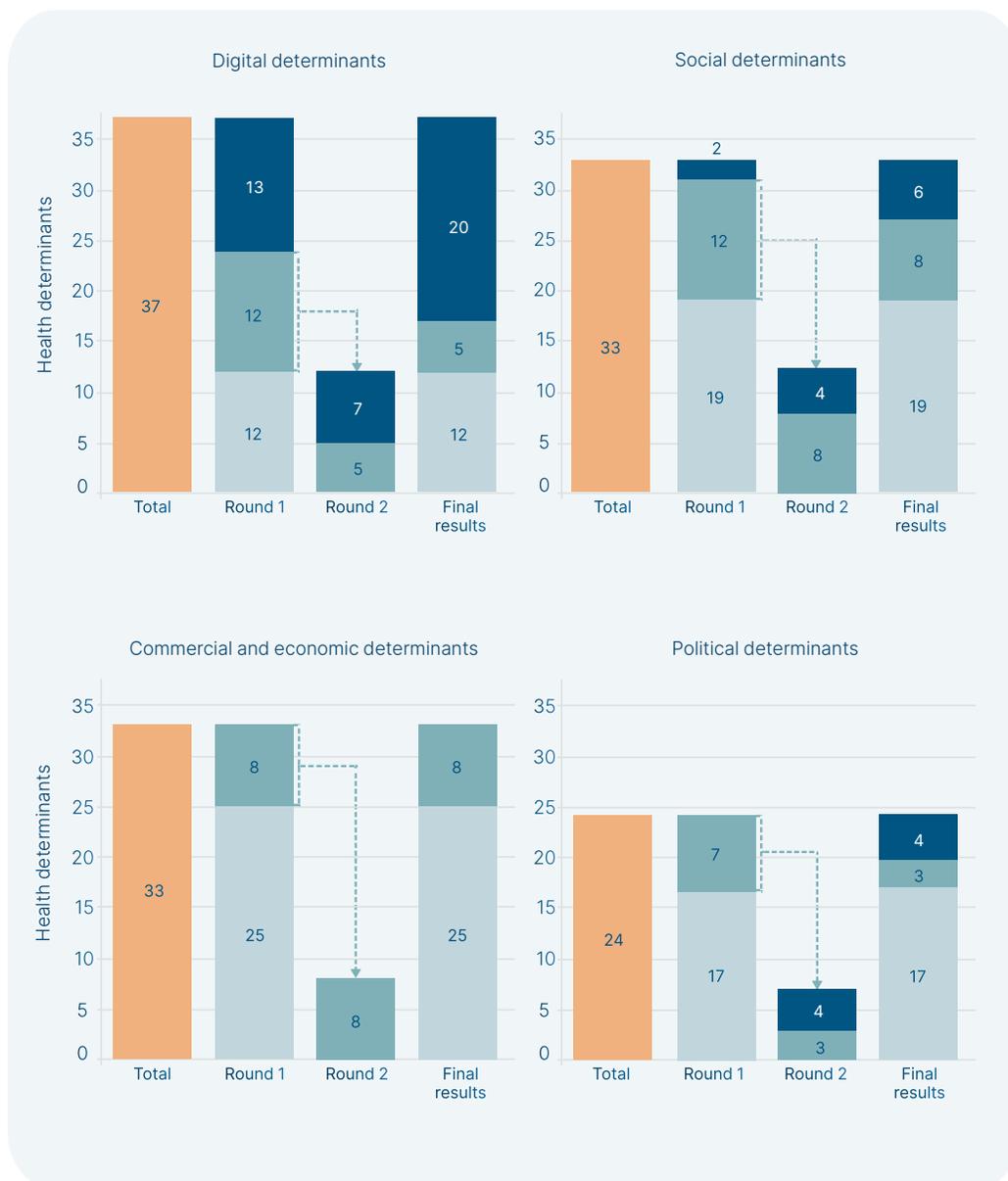
Indicates that only the health determinants rated moderately urgent in round 1 were included in round 2 of the consensus process.

Table 2. High urgency health determinants in a digital age, ranked by consensus

Part of digital ecosystem	Determinant	Median (IQR)	Urgency percentage[a]
Digital domain			
Person-specific determinants	Internet access and connectivity	5 (1)	86.11
	Device and software availability	4 (1)	81.82
	Digital literacy	4 (1)	80.56
Community determinants	Data and digital capacity	4 (1)	80.00
Technology-related determinants	Moderation of harmful content and misinformation	4 (1)	88.57
	Model accuracy and algorithmic validation	5 (1)	80.00
	Data and digital interoperability	5 (1)	91.43
	Explainability	4 (1)	93.75
	Security settings and features	4 (1)	90.62
Policy determinants	AI validation, transparency, explainability, accountability and ethics	5 (1)	91.43
	Privacy and security policy	4 (1)	80.00
	Access and sharing policy	4 (1)	82.86
	Data consent policy	5 (1)	87.50
	Outcomes, utility and value-sharing	4 (1)	84.38
Political, economic, societal and cultural determinants	Digital divides	4 (1)	94.29
	Mis/disinformation policy	4 (1)	80.00
	Data culture	4 (1)	81.25
	Regulatory mandate	4 (0)	90.62
	Data governance and ethics	5 (1)	85.71
	Digital public infrastructure	4 (1)	91.43
Social domain			
Person-specific determinants	Access to health and social services	5 (1)	81.08
	Health/disability status	4 (1)	93.94
Technology-related determinants	Inclusive design	4 (1)	81.25
	Good practice design	4 (0)	87.50
Policy determinants	Health and social care policy	5 (1)	85.71
Political, economic, societal and cultural determinants	Socioeconomic inequalities	4 (0)	90.62

Table 2 contd

Part of digital ecosystem	Determinant	Median (IQR)	Urgency percentage[a]
Political domain			
Community determinants	Ownership of technology	4 (0)	81.25
Political, economic, societal and cultural determinants	Digitalization agenda	4 (0)	84.38
	Accountability and transparency of commercial interests	5 (1)	84.38
	Open and transparent decision-making	4 (1)	93.75

AI: artificial intelligence.
[a] Urgency percentage was defined as the combined proportion of 4 (urgent) and 5 (very urgent) ratings.

Discussion

Summary of findings

This report has identified 127 determinants spanning four domains that can affect health directly or indirectly through the digital world. A relatively even balance of determinants was found across the four domains (37 digital, 33 social, 33 commercial and economic, and 24 political), highlighting the transformative impact of digitalization on all aspects of health. The accompanying conceptual framework (see Fig. 2) stresses that the influence of the four domains of determinants does not occur in isolation, but in combination.

The findings of the consensus process reinforce the importance of ensuring that digital transformations are equitable and sustainable *(38,73)*. The multidisciplinary and international group of authors and contributors reached consensus on the urgent need to address digital divides and ensure sufficient Internet access and digital literacy for individuals, while developing data and digital capacity within communities and building a robust digital public infrastructure in societies.

Overall, younger and healthier groups are better positioned to use digital tools than the rest of the population, but they equally are most likely to be exposed to the adverse effects of digital transformations *(12,39)*. People at highest risk of being digitally excluded, such as older people, people living with disabilities, those with a higher disease burden and migrants, may stand to gain most from the positive digital transformations in health, but are among the best protected from adverse digital effects *(38,60)*. Various solutions have been suggested to mitigate the effects of this digital health paradox, including improving the digital access and literacy of vulnerable populations and putting them at the heart of the digital health design process *(23)*.

Key points
- Empowerment of young people is vital to ensuring the necessary social support for digital technologies to reach all parts of the population.

- Digital technologies need to be designed with the end user in mind, and in collaboration with end users.

Consensus was reached on the urgency of considering access to health and social care services in a digital age at individual and policy levels *(74)*, further highlighting the need to address current digital divides in health-care access and outcomes. The nature of digital divides in an evolving digital landscape can, however, evolve over time.

The heterogenous introduction of basic information technologies such as mobile phones and computers constitutes a digital divide, as basic participation in a digital society and within a health system is directly affected by access and engagement with these technologies *(75,76)*. The subsequent introduction of more advanced digital technologies (such as artificial intelligence (AI), distributed ledger technology and spatial computing) in recent years may incite a second digital divide. A key difference to note between the two kinds of divides is that the second includes elements of the first, resulting in a digital divide that is more complex and heterogenous than its predecessor.

Another factor that may complicate the digital divide over time is that socioeconomic inequalities are projected to increase over the next 30 years *(13,77)*. As such, it will remain crucial to continually monitor, review and adapt policies and practices related to digital (health) technologies.

Key points

- Policies and initiatives aimed at building digital literacy and improving equity of digital access are needed to prevent the digital divide from widening.

- Awareness campaigns on the capabilities, possibilities and risks of emerging technologies are needed to bolster public understanding and uptake.

The handling of misinformation and other forms of harmful content was considered an urgent determinant in the design of digital technologies and policies. The collection of health determinants highlights how this pervasive content can be sustained through the intersection of digital, commercial and economic, and political determinants at multiple levels of governance *(55–57)*. For example, dark commercial patterns are rooted in the design and implementation of commercial digital solutions, playing an important role in various forms of problematic Internet use *(12,40,55,56,58)*. Similarly, even though targeted advertising to minors is illegal, digital marketing can still reach children through households sharing a single device and children being exposed to marketing strategies aimed at the adults in the household *(8,12,13)*.

> ### Key points
>
> - Awareness of the association between commercial and digital determinants of health and problematic Internet use needs to be raised.
>
> - Adequate safeguards need to be developed to mitigate the risk of exposing young people to harmful online content.

Data governance and ethics were rated as urgent priorities, particularly data access and sharing, data privacy and security, data consent policy, and value and outcome sharing. The health sector is in a unique position when it comes to digitalization and an individual's data rights, as health data have always been considered sensitive *(78,79)*. Data relating to people with diminished autonomy (such as minors and people living with certain disabilities) require an additional duty of care. Responsible data approaches must therefore adhere to higher standards and security measures *(80,81)*.

The (re)use of health data forms an important cornerstone for scientific advancements in the public health and medical fields and is the crux of population health management. To enable more comprehensive and sophisticated population health insights to emerge from these data, national legal frameworks should allow the benefits of secondary use of sensitive data to be realized *(82)*, building on existing principles for equitable health data governance *(80,83)*. To achieve this, policy-makers in and around the health sector need to be sensitized, empowered and incentivized to understand the most cutting-edge advancements in privacy- and security-preserving technologies *(55)*.

As new research infrastructures emerge in the digital era, novel approaches to analysing health data also arise. These simultaneously can safeguard health data and produce meaningful population health insights. Examples include approaches from the Population Health Information Research Infrastructure and the Data Analysis and Real World Interrogation Network.

> ### Key points
>
> - Initiatives that minimize the risks of health data misuse in a digital age are required.
>
> - Policies that target the societal risk of the non-use of health data are needed to improve the quality of health-care services and public and population health.

Developing robust data and digital governance policies requires a profound understanding of underlying normative and ethical frameworks, which can differ substantially between countries and global regions *(84–88)*. Data governance in Europe and North America, for example, is heavily influenced by the Kantian principles of ensuring that people retain a measure of control over their data and that individuals' data cannot be used for secondary purposes without their explicit consent *(86)*. This governance approach primarily aims to safeguard the privacy and safety of the individual *(87,88)*. In contrast, data governance approaches found in parts of Asia are profoundly influenced by Confucian principles *(84,85)*. While this paradigm stresses the importance of respecting individual autonomy, it also regards the interests of the family and the community as more influential than those of the individual *(84)*. This approach to data governance seeks to promote collectivism while respecting the integrity of the individual.

That said, data governance policies reflecting local norms and values may not necessarily govern the health data of the local population, especially in cases where digital (health) providers deliver services at global level. In this case, the data collected by the digital (health) technology are brought to the country in which the servers for the technology are located, meaning the data governance policies of the country hosting the server can be applied rather than those of the country of residence of the data subjects.

Key points

- Geographical, cultural and ethical differences must be accounted for, particularly for international data-sharing and/or technology suppliers.

- The right of data subjects to benefit from the innovations their data helped develop needs to be better ensured to mitigate extractive and neocolonial data practices.

Finally, consensus was reached on the urgency of AI validation, transparency, explainability, accountability and ethics at design and policy levels. The widespread emergence of AI over the past few years has highlighted the potential benefits it can bring *(89–97)*, as well as the risks if its capabilities are deployed for interests other than the public good *(13,90,98–105)*.

It is particularly important to recognize that the impacts of AI venture into the commercial and political domains, each with possible repercussions for individual and population health and well-being. AI can interact with political determinants by influencing election campaigns, affecting government decision-making, and impacting on surveillance and national security *(13,90)*. On the commercial front, AI can influence market analysis, personalize marketing strategies, optimize supply chains and generally affect financial decision-making, labour markets and product development *(13,90,100,101)*. These benefits and risks are unevenly spread among different segments of the global population *(105–107)*, resulting in potential exacerbation of existing inequalities. This calls for a governance framework that skews risks while allowing sufficient room for the benefits of AI to materialize and public trust in AI to grow *(90,108–110)*.

While AI is embedded within the digital determinants of health as a sector-specific policy, it is unlikely that a single set of AI policies will be universally fit for purpose *(111)*, given how vastly differently AI affects various sectors. With different archetypes of AI being introduced in society, it is imperative that discipline- and archetype-specific policies are put in place to complement baseline policy that targets the field of AI holistically (such as the AI Act in the European Union, for instance) *(112)*. This baseline policy framework can form an important cornerstone for building more discipline-specific regulation, as it can target ubiquitous risks of AI by, for example, creating a risk framework under which unacceptable risk to citizens can be militated and guidelines for high- or low-risk AI applications can be presented.

> **Key points**
>
> ● There is an urgent need for archetype- or discipline-specific AI policies that build upon generalist risk frameworks.
>
> ● Further development of transparency and accountability mechanisms related to AI are needed.

Strengths and limitations

While the conceptual framework (see Fig. 2) is primarily intended for decision-makers to help them identify the broad range of pathways that can affect individual and population health, it is also valuable in raising awareness among non-health experts (such as technology developers and decision-makers outside the health domain) on how their decisions can affect (positively or negatively) individual and population health. The conceptual framework bridges the gap between articles that focus either on the beneficial or harmful aspects of digital transformations. It therefore complements existing frameworks looking at pathways that enable the implementation of digital health applications using a whole-of-society lens *(23,113)*, and informs targeted action to mitigate or prevent the burdens of the harmful effects of the digitalization of society *(12,56,114,115)*.

The conceptual framework also combines two competing interpretations of the position of the digital determinants of health within the landscape of health determinants. Recognizing that some social, commercial, and economic and political determinants have changed in the digital age supports the idea that the effects of the digital world can be observed in how traditional determinants of health have adapted to digitalization *(14,73,116,117)*. Simultaneously, the framework recognizes that certain health determinants did not exist before the digital age, supporting the development of a separate category for digital determinants of health *(14,118–120)*.

Some limitations need to be considered. First, the findings of this review should be interpreted as a high-level literature overview, therefore potentially missing more intricate or localized factors related to health determinants in a digital age. Secondly, selection bias is possible, as only three academic databases and Google Scholar were used, and the search strategy was not exhaustive. Thirdly, the quality of the included sources was not assessed, which should be considered when interpreting the results. However, as the aim of the project was not to validate methodological rigour to ascertain confidence in the data synthesis, but rather to collect information about how the landscape of health determinants has shifted in the digital age, the absence of a quality assessment does not undermine its validity. In fact, the information collected did not solely rely on scientific articles, as the international and multidisciplinary author and collaborator team also ensured that the collected information was comprehensive, accurate and unbiased across global regions, strengthening confidence in the potential broad applicability of the findings to various countries and cultural settings.

Lastly, it is acknowledged that the review makes broad conclusions about health determinants in a digital age and the priority areas therein, which may not be directly transferable to localized contexts.

Future research

This report provides a descriptive and cross-sectional overview of digital and digitalized determinants of health that can be used to inform future research into the interlinkages between digital, social, commercial and political factors to further disentangle their multifaceted effects on health. Additionally, the concept of health determinants in a digital age – especially the digital determinants of health – will likely further develop into patterns that are not predictable as of now, meaning the digital determinants of health presented in this report may need to be redefined as time passes, more research has been conducted and emerging technologies are able to ingrain themselves into health and social systems. This report can serve as a starting point for future research to monitor the developments of health determinants in a digital age over time.

Future research should also explore the relative contribution of sociological and philosophical aspects of the proliferation of the digital age and the implications for health. Some work around the negative components of this has already been conducted through the concept of Onlife (a type of life in which the online world is indistinguishably absorbed into the lifeworld) *(121)*, which points to the risks of being unable to distinguish between the physical and digital worlds. This has been connected to the rise of radicalization movements, such as the one that led to the Christchurch massacre in March 2019 in New Zealand *(40,122)*, and has been highlighted as a potential risk to children and their brain development *(123)*.

Even though the concept of radicalization precedes the existence of the digital age, it can take on new digitalized forms that prey on people's inability to distinguish the physical from

the digital world. In today's context, it targets mainly young people and adolescents who spent their formative years in both the physical and digital worlds. Potential upsides generated by the digital age, such as improvements in health-care quality and accessibility *(23,49)*, increased social cohesion *(124)* and the development of new learning pathways to enhance conventional education *(125)*, are also well established.

Future work should focus on further exploring and raising awareness of the effects of commercial determinants in a digital age. While none of the mapped commercial determinants were considered urgent in this project, they can play a prominent role in the manifestation of some determinants that were considered urgent (such as dark commercial patterns in the propagation of harmful online content) *(100,101)*.

Conclusion

Ultimately, health is created in people's everyday lives, and life is an increasing blend of physical and digital experiences *(3,4)*. This report has provided a multilevel overview of contemporary factors, ranging from policy decisions to individual behaviours, across four major sets of determinants that can be found in people's everyday lives and which affect their health. It presents a challenge to better understand how health can be impacted in the digital age, and how determinants can interact to facilitate the development, sustenance and betterment of the digital environment.

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