

Preparing for pandemics needs a dose of public health and a booster of “complex thought” (Errare humanum est, perseverare diabolicum)

Elisabeth Paul¹  | Garrett W. Brown²  | David Bell³  | Valéry Ridde⁴  | Joachim Sturmberg⁵ 

¹Research Center on Health Policies & Systems – International Health, School of Public Health, Université Libre de Bruxelles, Brussels, Belgium

²Global Health Theme, University of Leeds, Leeds, UK

³Independent Public Health Consultant, Lake Jackson, Texas, USA

⁴Institut de Recherche Pour le développement (IRD), INSERM, CEPED, Université Paris Cité, Paris, France

⁵College of Health, Medicine and Wellbeing, University of Newcastle, Newcastle, New South Wales, Australia

Correspondence

Elisabeth Paul, Research Center on Health Policies & Systems – International Health, School of Public Health, Université Libre de Bruxelles, Campus Erasme, Route de Lennik 808, CP 591, 1070 Brussels, Belgium.
Email: elisabeth.paul@ulb.be

Abstract

The COVID-19 pandemic has triggered unprecedented governmental responses worldwide, revealing weaknesses in health systems and public health policies due to lack of “complex thought” required to manage complex adaptive systems. Understanding COVID-19 response strategies' multiple effects is particularly important now that pandemic preparedness and response (PPR) is on top of the global health political agenda. Here, we adopt a complex adaptive systems approach to critically analyze the literature and draw lessons from the COVID-19 response to inform future PPR strategies. We observe that in many contexts, strategies implemented in response to COVID-19 were poorly effective, inefficient, and inequitable. We explain the limitations of these prevailing measures and propose approaches and strategies to manage pandemics arising from a “systems thinking” perspective. PPR demands the adoption of an evolving, evidenced-informed, and context-specific strategy based on comprehensive approaches reflecting the complexities of health crises. This means moving away from single-focused health security paradigms to consider the full range of health problems facing populations and adopting a package of interventions chosen via participatory and deliberative processes that are context-specific and sensitive, as well as evidence-driven, to ensure a fair balance between various pillars of pandemic responses: health promotion, non-pharmaceutical interventions, prophylaxis, vaccines, and treatments.

It is no longer a matter of obeying a principle of order (excluding disorder), of clarity (excluding obscurity), of distinction (excluding adherences, participations and communications), of disjunction (excluding subject, antinomy, complexity), that is to say a principle which ties science to logical simplification. On the contrary, starting from a principle of complexity, it is a matter of linking what was disjointed.

Edgar Morin—The Challenge of Complexity (Morin, 2022)

1 | LEARNING FROM COVID-19 ERRORS

The COVID-19 pandemic has triggered unprecedented governmental responses worldwide, revealing weaknesses in health systems (Paul et al., 2020, 2022) and policies not previously used at scale or recommended for epidemic response (World Health Organization, 2019). Understanding their impact is particularly important now as the pandemic preparedness and response (PPR) agenda is enshrining such responses through the World Health Organization (WHO)

This is an open access article under the terms of the [Creative Commons Attribution-NonCommercial-NoDerivs](https://creativecommons.org/licenses/by-nc-nd/4.0/) License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

© 2024 The Author(s). *Global Policy* published by Durham University and John Wiley & Sons Ltd.

pandemic treaty currently negotiated, including measures like the amendments to the International Health Regulations, the 100-Day to Vaccine Program, WHO Medical Countermeasures Platform, WHO emerging threat initiative and financial instruments such as the World Bank Pandemic Fund (The Pandemic Fund, 2024; World Health Organization, 2023). Even if not necessarily proportionate to needs (Bell et al., 2024), the PPR agenda seeks to mobilize an estimated US\$31.1 billion a year globally, including US\$10.5 billion in additional international finance and US\$26.4 billion of investment at country level (World Health Organization and World Bank, 2022). Further PPR financing and new response priorities have been outlined at the United Nations in September 2023 (United Nations, 2023). Yet, much of the discourse remains wedded to “biomedical and technocratic reductionism” paradigms (Holst & van de Pas, 2023) which sideline more holistic “complex thought” approaches to promoting health, system strengthening, multisectoral preparedness, and health security.

Like other pandemics, COVID-19 is a complex zoonotic disease whose outcome depends not only on the characteristics and dynamics of the virus but also on a number of environmental factors (e.g., climate, seasonality), population density and age structure, social determinants (e.g., socioeconomic deprivation, racial inequalities), individual comorbidities (Paul et al., 2022; Paul, Brown, Dechamps, et al., 2021), and underlying health system capacities (Kapitsinis, 2021). However, despite theoretical knowledge on taking account of context, decision-makers still struggle to do so (Craig et al., 2018). Issues with interdependent characteristics like the COVID-19 pandemic are best understood as complex adaptive systems: their behaviors and outcomes arise from the interactions of many different factors. The real impact of any one factor—as Alexander von Humboldt pointed out in the late 1790s—can only be fully understood in the context of the system-as-a-whole. Indeed, the characteristics and properties of a system are not present in any one of its parts. Notably, focusing on improving system parts in isolation will likely fail to improve the function of the whole (Sturmborg, 2020). Examples of broader—and negative—health impacts from COVID-19 response measures abound in the literature. They affect all regions of the world depending on their epidemiological profile and health system resilience—from a reduction in cancer diagnosis and treatment in the US (Negoita et al., 2024; Nogueira et al., 2024) to important declines in outpatient consultations in low- and middle-income countries which are expected to cause high excess mortality (Ahmed et al., 2022). Hence, public health principles must adopt context-sensitive approaches to managing pandemics like COVID-19, including communication strategies, since trust in public authorities and acceptance of public health responses

vary greatly between contexts (Ba et al., 2022; Bollyky et al., 2022). Moreover, successful management must be adaptive. Namely, it must shift depending on the evolution of the epidemic locally as well as globally, be reflective of local health system capacities and capabilities, population characteristics, and the degree of acquired immunity. Vaccine acceptance is particularly context-sensitive (Steinert et al., 2022; Unfried & Priebe, 2024; Vermeulen, 2024) and also evolves with time (Schmelz & Bowles, 2022), hence the need to regularly update vaccine policies and related communication. Overall, responses must have an appropriate mix of strategies balancing effectiveness and cost and respect the principles of proportionality, efficiency, and equity (Paul et al., 2022; Paul, Brown, Bell, et al., 2024; Schmets et al., 2016). However, in many countries, contextualized adaptive response policies have been lacking, resulting in top-level prescribed “one-size-fits-all” approaches divorced from the evolution of the pandemic in particular local contexts. Worryingly, a recent global review of COVID-19 national preparedness and response plans in 86 countries showed that most plans lacked transparency about whether, which, and how additional stakeholders were involved, denoting lack of public participation in PPR (Aguilera et al., 2024).

2 | MATERIALS AND METHODS

In this article, we adopt a complex system lens to draw several strategic lessons based on the COVID-19 response experiences to inform governments' planning for future health crises. This analysis is based on a combination of our professional experience and of a targeted (unsystematic) review of the extensive literature published on COVID-19, but also on public health, primary healthcare, policymaking, and complexity sciences. We conclude that “systems thinking” approaches will naturally lead to more effective, efficient, and equitable strategies to manage future pandemics.

3 | RESULTS

3.1 | Non-pharmaceutical interventions have indirect effects—they are negative

At the beginning of the COVID-19 pandemic, most countries imposed non-pharmaceutical interventions (NPIs) while awaiting COVID-19 vaccines (see below). NPIs cover a vast array of often juxtaposed individual measures like mask mandates, limits to mass gatherings, and workplace and travel restrictions. These imposed huge socio-economic costs and often lacked appropriate evidence regarding their effectiveness and adverse

consequences (Bain et al., 2022; Enria et al., 2021; Hirt et al., 2022; Schippers et al., 2022).

While “circuit breaker” lockdowns are understandable at the very beginning of the COVID-19 outbreak, lasting indiscriminate blanket lockdowns must be seen as questionable considering their expected collateral damage (World Health Organization, 2019). Indeed, lockdowns had variable impacts, with no demonstrated effect on excess mortality (Agrawal et al., 2021; Gupta et al., 2021; Karlinsky & Kobak, 2021). However, they had major impacts on physical and mental health, and the disruptions of health services have caused negative long-term health impacts, especially on children (Green et al., 2022). Furthermore, they disproportionately harmed the most vulnerable, for example, promoting child marriage and child labor (Cousins, 2020; International Labour Organization et al., 2020) and exacerbating inequities (Chakrabarti et al., 2021; Engzell et al., 2021; Racine et al., 2021; Woolford et al., 2021). In particular, in most contexts, school closures have had minimal impact on spreading SARS-CoV-2 in society, but already show lasting harm to children's mental and social well-being, education and future health prospects (Christakis et al., 2020; Munro et al., 2023; Zimmerman & Anderson, 2021), and economic disruptions impacted especially low- and middle-income countries with underdeveloped social safety nets (Egger et al., 2021), an outcome “very predictable” using “complex thought.” Likewise, emergency measures have at times violated citizen's fundamental human rights (European Union Agency for Fundamental Rights, 2021; Loewenson et al., 2020). With 3 years' hindsight, a Scottish COVID-19 response evaluation shows that they were disproportionate, insufficiently evidence-based, and inefficient (Croft, 2023).

For future pandemics, it is essential to use health impact assessment methodologies to weigh, in advance, the expected benefits, harms and costs of response measures over the medium term (Green et al., 2022). This could have been done taking note of the early emerging evidence that SARS-CoV-2 was spreading asymptotically (Bendavid et al., 2021) and that many uninfected people had strong pre-existing cross-coronavirus immune responses (Grifoni et al., 2020).

3.2 | One-size does not fit all

Most countries adopted the false premise that 100% of their population was highly vulnerable to SARS-CoV-2. The subsequent use and reuse of population-wide NPIs indicates a failure to recognize COVID-19 as a complex heterogeneous disease. In fact, COVID-19 is a syndemic—that is, a synergy of epidemics that “co-occur in time and place, interact with each other to produce complex sequelae, and share common underlying societal drivers” (Swinburn et al., 2019). The

COVID-19 syndemic is global and exposed the consequences of interacting factors including malnutrition, socioeconomic deprivation, racial discrimination, and environmental/climate drivers. Thus, COVID-19 has had very different characterizations and outcomes depending on the context in which it occurred (Ngepah, 2021; Van Damme et al., 2020). People likely to develop a severe form of COVID-19 are well known: the elderly, the overweight, people with comorbidities, and the economically deprived (Bennett et al., 2021; Karmakar et al., 2021; Kompaniyets et al., 2021; O'Hearn et al., 2021; Williamson et al., 2020). Each cohort has specific risks and needs that cannot be addressed through universal measures.

Heterogeneity in disease impact based on socioeconomic, behavioral factors, and comorbidities is not specific to COVID-19 but characterizes most communicable (Fallah et al., 2016; Worrall et al., 2005) and non-communicable diseases (Fioranelli et al., 2018; Hamad et al., 2020; He et al., 2023; Mendenhall et al., 2017; Rosengren et al., 2019; Vaccarella et al., 2023), as well as health outcomes (Dwyer-Lindgren et al., 2023). This calls for health systems redesigns—and PPR policies—that move away from disease-specific to more holistic approaches to health and health care (Barnett et al., 2012; Sturmberg et al., 2020).

3.3 | Complex problems have no simple solutions

The “one-size-fits-all” approach to COVID-19 focused on finding a single, universal cure. Although antiviral (Wan et al., 2023) and antibody treatments (Misset et al., 2023) have eventually been developed, the initial focus on repurposed drugs for COVID-19 was unable to quickly identify an effective drug against COVID-19, except for dexamethasone in the severely respiratory compromised (The Recovery Collaborative Group, 2020). Importantly, all clinical trials occurred in hospital settings; they were unable to differentiate between the various stages of disease evolution and severity, and potential benefits in the early stages of the disease. While the early efforts to repurpose known medications are understandable, a more important focus must be on improving general immune competency, supplemented by the emergence of disease-specific antivirals. Disease complications are immunologically mediated and potentially preventable with a focus on each patient's disease severity and comorbidities, especially those affected by diabetes and malnutrition (Du Laing et al., 2021; Gibbons et al., 2022; Logette et al., 2021; Matin et al., 2021; Rawson et al., 2020).

The “vaccine-only” exit strategy adopted by many governments was always jeopardized by many unknowns (Paul, Brown, Kalk, & Ridde, 2021). In particular, the authoritarian way in which mass vaccination

has been imposed in many settings has been criticized as possibly causing more harm than good (Bardosh et al., 2022) and can no longer be justified (Vogel, 2023). It is now unquestioned that COVID-19 vaccine effectiveness wanes over time, especially with the development of new variants (Chemaitelly et al., 2021; Goldberg et al., 2021; Harvey et al., 2021; Jang et al., 2023; Kim et al., 2022; Menegale et al., 2023; Nordström et al., 2022), and that they offer little protection against virus transmission (Madewell et al., 2022; Riemersma et al., 2022; Sinha & Konetzka, 2022). Therefore, relying on vaccination alone to reach a hypothetical “herd immunity” threshold is untenable (Aschwanden, 2021), all the more since it remains unclear whether the risk–benefit balance is in favor of vaccinating children and youngsters (Bardosh et al., 2024; Krug et al., 2022; Munro et al., 2024) and whether they provide significant all-cause mortality benefit (Adhikari et al., 2024; Agrawal et al., 2021; Benn et al., 2023; Fürst et al., 2024). Furthermore, COVID-19 response measures should take account of innate and acquired immunity (Kalk et al., 2022). Vaccine-induced and natural immunity can be complementary in reaching some level of community immunity (Altarawneh et al., 2023), though vaccinating people once they have acquired natural immunity adds very little additional benefit (León et al., 2022). Given emerging evidence of the advantage of naturally acquired vs. vaccine-induced immunity (Dietler et al., 2023), the application of principles of efficiency, equity, and sustainability call for vaccinating only those who need it most, especially in resource-constrained contexts (Bell et al., 2023; Bell & Paul, 2022). For instance, as early as October 2022, the COVID-19 Platform Operational Research Group for West and Central Africa called for reconsidering “the application of so-called universal vaccination” in that region for being “currently inappropriate ... in the present context, given the demographic and epidemiological specificities of the population (...), the cost of vaccination for health systems (...), the low level of risk compared with other disease burdens, and the poor effectiveness of vaccines to contribute to herd immunity” (Msellati et al., 2022).

Considering this, one measure that remains contrary to evidence is vaccine passports as imposed in several high-income countries. Beyond incentivizing people to get vaccinated (Gbenonsi et al., 2022; Vermeulen et al., 2023)—yet with little effect on vulnerable people who are out of the formal health system (Agarwal et al., 2021; Bhanu et al., 2021; Ridde Valéry et al., 2023)—they make little sense from a public health perspective.

More than a century of experience with vaccination against viral diseases shows that vaccination as a prevention strategy is generally effective for stable viruses such as measles, but less so against

frequently mutating ones, such as influenza or SARS-CoV-2 (Morens et al., 2023). For such viruses, “mass vaccination can only be expected to delay rather than prevent new infections, in which case the obligation to contribute to herd immunity is much weaker, and coercive policies less justifiable” (Bullen et al., 2023). The relative failures of the mass COVID-19 vaccination strategy—and rapid evolution of evidence base regarding the limitations of vaccines (Paul, Brown, Ridde, & Sturmberg, 2024)—offer insights for the design of more targeted and comprehensive PPR policies, while taking into account the cumulative harms of non-pharmaceutical interventions.

3.4 | We are human, we don't like uncertainty, and we tend to latch onto “simple solutions”

Mencken summarized human fallibilities and its consequences succinctly—“For every complex problem, there is an answer that is clear, simple and wrong” (Sturmberg & Topolski, 2014). In response, our aim here is not to pretend to have all the answers. Our goal is merely not to be “boxed in by models” (Pawson, 2021) and to highlight the “known knowns” and “known unknowns” in the spirit of open discussion, with an eye on equity (Sturmberg et al., 2021). Unfortunately, this deliberative approach does not represent much of the COVID-19 and PPR lexicon and policy practice, which has tended to reflect Mencken's warning. In addition to being one-size-fits-all, pandemic countermeasures have also been implemented in a command-and-control way, relying on fear and punitive disincentives, often bypassing local communities at highest risk while increasing stress disorders that weaken immune responsiveness (Loewenson et al., 2020). A fundamental public policy fault has been a lack of tailored policies to fit local needs. These must be owned by those affected, with actionable accountability chains for implementation (Howlett & Mukherjee, 2018). Moreover, vulnerable populations (which will be different in each context) require humane engagement with greater interaction with local community leaders, rather than through government mandates, penalties, and/or production line services in stadium-sized centers (Leask et al., 2021; Marmot, 2017).

More generally, people need policy coherence and they need to understand policy goals, particularly if we want them to own a policy (Paul et al., 2022). At the beginning of the COVID-19 pandemic in March 2020, the alleged aim of many governments was to “flatten the curve” (or “save the NHS” in the UK). However, beyond March 2020, the public health objective(s) pursued through COVID-19 response measures were not clear, with NPIs continuing to be imposed

and re-imposed—sometimes even widened. Unlike in March 2020, these policies were pursued despite evidence suggesting that reaching hospital capacity within many countries was unlikely. The opacity of COVID-19 response goals was particularly difficult to grasp within implicit (in some European countries) and explicit (in some Australian states and in New Zealand) zero-COVID-19 strategies, given that SARS-CoV-2 is an ubiquitous zoonosis and highly genetically unstable (He et al., 2021).

Lastly, policy decisions need to be examined for their wider impact (Sturmberg et al., 2021). The mental health effects of the constant apocalyptic portrayal of COVID-19 in the media, especially on the young, are going to have lasting effects.

4 | DISCUSSION

We also may err; however, we dare to call for a critical shift in the way we consider pandemic preparedness—we need to apply “complex thought” that allows us to “connect” the emerging “knowns and unknowns” in pandemic response approaches. In other words, we make a plea for inserting public health into pandemic preparedness and response, which requires taking context into account and balancing cost and benefit, principles of public health that have seemingly waned post-COVID-19. Given the current momentum around the pandemic preparedness and response initiatives, we plead for a major evolution—and in many ways a return to public health—in the way PPR strategies are conceived and implemented at the global level. Our knowledge and experience with COVID-19, and the effects of our interventions, demand the adoption of an evolving, evidenced-informed and context-specific strategy based on more comprehensive approaches which reflect the complexities of a health crisis (Paul et al., 2022). This means moving away from single-focused health security paradigms to consider the full range of health problems facing populations (Galea, 2021). This also means adopting more than the single blueprint approach, favoring a package of interventions chosen via participatory and deliberative processes that are context-specific and sensitive, as well as evidence-driven, to ensure a fair balance between various pillars of pandemic responses: health promotion, NPIs, prophylaxis, vaccines, and treatments (Paul, Brown, Dechamps, et al., 2021). Policies must be associated with a clear set of attainable population health objectives, not merely those that are politically expedient. They must be communicated in a culturally and linguistically appropriate way to the public, preferably through local community leaders. For these objectives to take hold long-term, they must respect the principles of equity, proportionality, trust between all stakeholders in the

health system, communication, policy dialog, and democracy (Paul et al., 2022). Transversally, this also requires sufficiently funded healthcare systems with universal access to well-resourced primary healthcare (Kapitsinis, 2021). How can these lofty principles be operationalized? We plead for adoption of a community-based pandemic approach (Loewenson et al., 2021), relying on primary healthcare providers and community stakeholders to increase health literacy among the at-risk populations, to monitor their health status and to treat patients early according to their clinical diagnosis, and their values and preferences (Sackett et al., 1996).

Vaccination should be targeted to those who have a clear positive benefit–risk balance (particularly the elderly, since four-fifths of COVID-19 deaths occurred in people above 60 (Wong et al., 2023), predominantly in those with comorbidities who have not been previously infected (Paul, Brown, Ridde, & Sturmberg, 2024)). As a complementary strategy, health promotion campaigns must aim to reduce the burden of comorbidities and malnutrition. Primary healthcare provision should be strengthened to augment patient-centered early treatments. More generally, following years of under-investment in public health services, we call for an ambitious reinvestment and redesign of health systems for the better (Sturmberg et al., 2020; Sturmberg & Martin, 2020) (Sturmberg, 2018), and a reorientation of these systems to strengthen underlying health and prevention in line with the Ottawa Charter (World Health Organization, 1986) and principles of health promotion effectiveness (McQueen & Jones, 2007). This should increase their effectiveness, efficiency, equity, resilience (“Rebuilding resilient health systems for Europe: The Lancet Regional Health – Europe,” 2021) and preparedness to future threats (World Health Organization, 2021). These are, in a word, “non-erroneous” approaches of crises intervention respecting the long-proven principles of patient-centeredness and the centrality of primary health care (Starfield et al., 2005; World Health Organization and United Nations Children's Fund [UNICEF], 2018).

CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Elisabeth Paul  <https://orcid.org/0000-0002-3928-4093>
Garrett W. Brown  <https://orcid.org/0000-0002-6557-5353>

David Bell  <https://orcid.org/0000-0002-7010-6340>
 Valéry Ridde  <https://orcid.org/0000-0001-9299-8266>
 Joachim Sturmberg  <https://orcid.org/0000-0002-2219-6281>

REFERENCES

- Adhikari, B., Bednash, J.S., Horowitz, J.C., Rubinstein, M.P. & Vlasova, A.N. (2024) Brief research report: impact of vaccination on antibody responses and mortality from severe COVID-19. *Frontiers in Immunology*, 15, 1325243. Available from: <https://doi.org/10.3389/fimmu.2024.1325243>
- Agarwal, R., Dugas, M., Ramaprasad, J., Luo, J., Li, G. & Gao, G.G. (2021) Socioeconomic privilege and political ideology are associated with racial disparity in COVID-19 vaccination. *Proceedings of the National Academy of Sciences of the United States of America*, 118, e2107873118. Available from: <https://doi.org/10.1073/pnas.2107873118>
- Agrawal, V., Cantor, J., Sood, N. & Whaley, C.M. (2021) *The impact of the COVID-19 pandemic and policy responses on excess mortality* (working paper no. 28930), working paper series. National Bureau of Economic Research.
- Aguilera, B., Donya, R.S., Vélez, C.M., Kapiro, L., Abelson, J., Nouvet, E. et al. (2024) Stakeholder participation in the COVID-19 pandemic preparedness and response plans: a synthesis of findings from 70 countries. *Health Policy*, 142, 105013. Available from: <https://doi.org/10.1016/j.healthpol.2024.105013>
- Ahmed, T., Robertson, T., Vergeer, P., Hansen, P.M., Peters, M.A., Ofosu, A.A. et al. (2022) Healthcare utilization and maternal and child mortality during the COVID-19 pandemic in 18 low- and middle-income countries: an interrupted time-series analysis with mathematical modeling of administrative data. *PLoS Medicine*, 19, e1004070. Available from: <https://doi.org/10.1371/journal.pmed.1004070>
- Altarawneh, H.N., Chemaitelly, H., Ayoub, H.H., Tang, P., Hasan, M.R., Yassine, H.M. et al. (2023) Effects of previous infection, vaccination, and hybrid immunity against symptomatic Alpha, Beta, and Delta SARS-CoV-2 infections: an observational study. *eBioMedicine*, 95, 104734. Available from: <https://doi.org/10.1016/j.ebiom.2023.104734>
- Aschwanden, C. (2021) Five reasons why COVID herd immunity is probably impossible. *Nature*, 591, 520–522. Available from: <https://doi.org/10.1038/d41586-021-00728-2>
- Ba, M.F., Ridde, V., Diallo, A.I., Tine, J.A.D., Kane, B., Gaye, I. et al. (2022) Acceptability of contact management and care of simple cases of COVID-19 at home: a cross-sectional study in Senegal. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 116, 1214–1222. Available from: <https://doi.org/10.1093/trstmh/trac094>
- Bain, L.E., Berner-Rodoreda, A., McMahon, S.A., Sarker, M., Tanser, F., Bärnighausen, T. et al. (2022) One lesson of COVID-19: conduct more health policy trials. *Proceedings of the National Academy of Sciences of the United States of America*, 119, e2119887119. Available from: <https://doi.org/10.1073/pnas.2119887119>
- Bardosh, K., de Figueiredo, A., Gur-Arie, R., Jamrozik, E., Doidge, J., Lemmens, T. et al. (2022) The unintended consequences of COVID-19 vaccine policy: why mandates, passports and restrictions may cause more harm than good. *BMJ Global Health*, 7, e008684. Available from: <https://doi.org/10.1136/bmjgh-2022-008684>
- Bardosh, K., Krug, A., Jamrozik, E., Lemmens, T., Keshavjee, S., Prasad, V. et al. (2024) COVID-19 vaccine boosters for young adults: a risk benefit assessment and ethical analysis of mandate policies at universities. *Journal of Medical Ethics*, 50, 126–138. Available from: <https://doi.org/10.1136/jme-2022-108449>
- Barnett, K., Mercer, S.W., Norbury, M., Watt, G., Wyke, S. & Guthrie, B. (2012) Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. *Lancet*, 380, 37–43. Available from: [https://doi.org/10.1016/S0140-6736\(12\)60240-2](https://doi.org/10.1016/S0140-6736(12)60240-2)
- Bell, D., Brown, G.W., Oyibo, W.A., Ouédraogo, S., Tacheva, B., Barbaud, E. et al. (2023) COVAX – time to reconsider the strategy and its target. *Health Policy Open*, 4, 100096. Available from: <https://doi.org/10.1016/j.hpopen.2023.100096>
- Bell, D., Brown, G.W., von Agris, J. & Tacheva, B. (2024) Urgent pandemic messaging of WHO, World Bank, and G20 is inconsistent with their evidence base. *Global Policy*, 1–19. Available from: <https://doi.org/10.1111/1758-5899.13390>
- Bell, D. & Paul, E. (2022) Vaccine equity or health equity? *Journal of Global Health Economics and Policy*, 2, e2022005. Accessed 16 September 2024.
- Bendavid, E., Mulaney, B., Sood, N., Shah, S., Bromley-Dulfano, R., Lai, C. et al. (2021) COVID-19 antibody seroprevalence in Santa Clara County, California. *International Journal of Epidemiology*, 50, 410–419. Available from: <https://doi.org/10.1093/ije/dyab010>
- Benn, C.S., Schaltz-Buchholzer, F., Nielsen, S., Netea, M.G. & Aaby, P. (2023) Randomized clinical trials of COVID-19 vaccines: do adenovirus-vector vaccines have beneficial non-specific effects? *iScience*, 26(5), 106733. Available from: <https://doi.org/10.1016/j.isci.2023.106733>
- Bennett, T.D., Moffitt, R.A., Hajagos, J.G., Amor, B., Anand, A., Bissell, M.M. et al. (2021) Clinical characterization and prediction of clinical severity of SARS-CoV-2 infection among US adults using data from the US national COVID cohort collaborative. *JAMA Network Open*, 4, e2116901. Available from: <https://doi.org/10.1001/jamanetworkopen.2021.16901>
- Bhanu, C., Gopal, D.P., Walters, K. & Chaudhry, U.A.R. (2021) Vaccination uptake amongst older adults from minority ethnic backgrounds: a systematic review. *PLoS Medicine*, 18, e1003826. Available from: <https://doi.org/10.1371/journal.pmed.1003826>
- Bollyky, T.J., Angelino, O., Wigley, S. & Dieleman, J.L. (2022) Trust made the difference for democracies in COVID-19. *Lancet*, 400, 657. Available from: [https://doi.org/10.1016/S0140-6736\(22\)01532-X](https://doi.org/10.1016/S0140-6736(22)01532-X)
- Bullen, M., Heriot, G.S. & Jamrozik, E. (2023) Herd immunity, vaccination and moral obligation. *Journal of Medical Ethics*, 49, 636–641. Available from: <https://doi.org/10.1136/jme-2022-108485>
- Chakrabarti, S., Hamlet, L.C., Kaminsky, J. & Subramanian, S.V. (2021) Association of human mobility restrictions and race/ethnicity-based, sex-based, and income-based factors with inequities in well-being during the COVID-19 pandemic in the United States. *JAMA Network Open*, 4, e217373. Available from: <https://doi.org/10.1001/jamanetworkopen.2021.7373>
- Chemaitelly, H., Tang, P., Hasan, M.R., AlMukdad, S., Yassine, H.M., Benslimane, F.M. et al. (2021) Waning of BNT162b2 vaccine protection against SARS-CoV-2 infection in Qatar. *The New England Journal of Medicine*, 385, e83. Available from: <https://doi.org/10.1056/NEJMoa2114114>
- Christakis, D.A., Van Cleve, W. & Zimmerman, F.J. (2020) Estimation of US children's educational attainment and years of life lost associated with primary school closures during the coronavirus disease 2019 pandemic. *JAMA Network Open*, 3, e2028786. Available from: <https://doi.org/10.1001/jamanetworkopen.2020.28786>
- Cousins, S. (2020) 2.5 million more child marriages due to COVID-19 pandemic. *Lancet*, 396, 1059. Available from: [https://doi.org/10.1016/S0140-6736\(20\)32112-7](https://doi.org/10.1016/S0140-6736(20)32112-7)
- Craig, P., Di Ruggiero, E., Frohlich, K., Mykhalovskiy, E. & White, M. (2018) *Taking account of context in population health intervention research: guidance for producers, users and funders of research* (NIHR Evaluation, Trials and Studies Coordinating

- Centre). On behalf of the Canadian Institutes of Health Research (CIHR)–National Institute for Health Research (NIHR), Southampton.
- Croft, A. (2023) *Report for the Scottish COVID-19 inquiry (No. GMC number: 3013254)*. Accessed 15 September 2024. Available at: <https://www.covid19inquiry.scot/sites/default/files/2023-07/Dr-Croft-epidemiology-report.pdf>
- Dietler, D., Kahn, F., Inghammar, M. & Björk, J. (2023) Waning protection after vaccination and prior infection against COVID-19-related mortality over 18 months. *Clinical Microbiology and Infection*, 29, 1573–1580. Available from: <https://doi.org/10.1016/j.cmi.2023.08.007>
- Du Laing, G., Petrovic, M., Lachat, C., De Boevre, M., Klingenberg, G.J., Sun, Q. et al. (2021) Course and survival of COVID-19 patients with comorbidities in relation to the trace element status at hospital admission. *Nutrients*, 13(10), 3304. Available from: <https://doi.org/10.3390/nu13103304>
- Dwyer-Lindgren, L., Kendrick, P., Kelly, Y.O., Baumann, M.M., Compton, K., Blacker, B.F. et al. (2023) Cause-specific mortality by county, race, and ethnicity in the USA, 2000–19: a systematic analysis of health disparities. *Lancet*, 402, 1065–1082. Available from: [https://doi.org/10.1016/S0140-6736\(23\)01088-7](https://doi.org/10.1016/S0140-6736(23)01088-7)
- Egger, D., Edward, M., Warren, S.S., Ashish, S., Elliott, C., Dean, K. et al. (2021) Falling living standards during the COVID-19 crisis: quantitative evidence from nine developing countries. *Science Advances*, 7, eabe0997. Available from: <https://doi.org/10.1126/sciadv.abe0997>
- Engzell, P., Frey, A. & Verhagen, M.D. (2021) Learning loss due to school closures during the COVID-19 pandemic. *Proceedings of the National Academy of Sciences of the United States of America*, 118, e2022376118. Available from: <https://doi.org/10.1073/pnas.2022376118>
- Enria, D., Feng, Z., Fretheim, A., Ihekweazu, C., Ottersen, T., Schuchat, A. et al. (2021) Strengthening the evidence base for decisions on public health and social measures. *Bulletin of the World Health Organization*, 99, 610–610A. Available from: <https://doi.org/10.2471/BLT.21.287054>
- European Union Agency for Fundamental Rights. (2021) *Fundamental rights report – 2021*. Accessed 15 September 2024. Available from: https://fra.europa.eu/sites/default/files/fra_uploads/fra-2021-fundamental-rights-report-2021_en.pdf
- Fallah, M.P., Skrip, L.A., Gertler, S., Yamin, D. & Galvani, A.P. (2016) Quantifying poverty as a driver of Ebola transmission. *PLoS Neglected Tropical Diseases*, 9, e0004260. Available from: <https://doi.org/10.1371/journal.pntd.0004260>
- Fioranelli, M., Bottaccioli, A.G., Bottaccioli, F., Bianchi, M., Rovesti, M. & Rocca, M.G. (2018) Stress and inflammation in coronary artery disease: a review Psychoneuroendocrinology-immunology-based. *Frontiers in Immunology*, 9, 2031. Available from: <https://doi.org/10.3389/fimmu.2018.02031>
- Fürst, T., Bazalová, A., Fryčák, T. & Janošek, J. (2024) Does the healthy vaccinee bias rule them all? Association of COVID-19 vaccination status and all-cause mortality from an analysis of data from 2.2 million individual health records. *International Journal of Infectious Diseases*, 142, 106976. Available from: <https://doi.org/10.1016/j.ijid.2024.02.019>
- Galea, S. (2021) Reckoning with COVID-19 exceptionalism. *JAMA Health Forum*, 2, e214854. Available from: <https://doi.org/10.1001/jamahealthforum.2021.4854>
- Gbenonsi, G.Y., Labat, A., Oleffe, A., Jidovstev, B., Servais, O., Vermeulen, N. et al. (2022) Factors associated with COVID-19 vaccination among individuals with vaccine hesitancy in French-speaking Belgium. *JAMA Network Open*, 5, e2234433. Available from: <https://doi.org/10.1001/jamanetworkopen.2022.34433>
- Gibbons, J.B., Norton, E.C., McCullough, J.S., Meltzer, D.O., Lavigne, J., Fiedler, V.C. et al. (2022) Association between vitamin D supplementation and COVID-19 infection and mortality. *Scientific Reports*, 12, 19397. Available from: <https://doi.org/10.1038/s41598-022-24053-4>
- Goldberg, Y., Mandel, M., Bar-On, Y.M., Bodenheimer, O., Freedman, L., Haas, E.J. et al. (2021) Waning immunity after the BNT162b2 vaccine in Israel. *The New England Journal of Medicine*, 385, e85. Available from: <https://doi.org/10.1056/NEJMoa2114228>
- Green, L., Ashton, K., Bellis, M., Clements, T. & Douglas, M. (2022) Predicted and observed impacts of COVID-19 lockdowns: two health impact assessments in Scotland and Wales. *Health Promotion International*, 37, daac134. Available from: <https://doi.org/10.1093/heapro/daac134>
- Grifoni, A., Weiskopf, D., Ramirez, S.I., Mateus, J., Dan, J.M., Moderbacher, C.R. et al. (2020) Targets of T cell responses to SARS-CoV-2 coronavirus in humans with COVID-19 disease and unexposed individuals. *Cell*, 181, 1489–1501.e15. Available from: <https://doi.org/10.1016/j.cell.2020.05.015>
- Gupta, S., Georgiou, A., Sen, S., Simon, K. & Karaca-Mandic, P. (2021) US trends in COVID-19-associated hospitalization and mortality rates before and after reopening economies. *JAMA Health Forum*, 2, e211262. Available from: <https://doi.org/10.1001/jamahealthforum.2021.1262>
- Hamad, R., Penko, J., Kazi, D.S., Coxson, P., Guzman, D., Wei, P.C. et al. (2020) Association of low socioeconomic status with premature coronary heart disease in US adults. *JAMA Cardiology*, 5, 899–908. Available from: <https://doi.org/10.1001/jamacardio.2020.1458>
- Harvey, W.T., Carabelli, A.M., Jackson, B., Gupta, R.K., Thomson, E.C., Harrison, E.M. et al. (2021) SARS-CoV-2 variants, spike mutations and immune escape. *Nature Reviews Microbiology*, 19, 409–424. Available from: <https://doi.org/10.1038/s41579-021-00573-0>
- He, J., Bundy, J.D., Geng, S., Tian, L., He, H., Li, X. et al. (2023) Social, behavioral, and metabolic risk factors and racial disparities in cardiovascular disease mortality in U.S. adults: an observational study. *Annals of Internal Medicine*, 176, 1200–1208. Available from: <https://doi.org/10.7326/M23-0507>
- He, S., Han, J. & Lichtfouse, E. (2021) Backward transmission of COVID-19 from humans to animals may propagate reinfections and induce vaccine failure. *Environmental Chemistry Letters*, 19, 763–768. Available from: <https://doi.org/10.1007/s10311-020-01140-4>
- Hirt, J., Janiaud, P. & Hemkens, L.G. (2022) Randomized trials on non-pharmaceutical interventions for COVID-19: a scoping review. *BMJ Evidence-Based Medicine*, 27, 334–344. Available from: <https://doi.org/10.1136/bmjebm-2021-111825>
- Holst, J. & van de Pas, R. (2023) The biomedical securitization of global health. *Globalization and Health*, 19, 15. Available from: <https://doi.org/10.1186/s12992-023-00915-y>
- Howlett, M. & Mukherjee, I. (2018) Introduction: the importance of policy design: effective processes, tools and outcomes. In: *Routledge handbook of policy design*. New York; London: Routledge, Taylor and Francis Group.
- International Labour Organization, United Nations, Children's Fund. (2020) *COVID-19 and child labour: a time of crisis, a time to act*. New York: ILO and UNICEF.
- Jang, E.J., Choe, Y.J., Kim, R.K., Lee, S., Park, S.K. & Park, Y.-J. (2023) Estimated effectiveness of prior SARS-CoV-2 BA.1 or BA.2 infection and booster vaccination against omicron BA.5 subvariant infection. *JAMA Network Open*, 6, e232578. Available from: <https://doi.org/10.1001/jamanetworkopen.2023.2578>
- Kalk, A., Sturmberg, J., Van Damme, W., Brown, G., Ridde, V., Zizi, M. et al. (2022) Surfing Corona waves? Instead of breaking them: rethinking the role of natural immunity in COVID-19 policy. *F1000Research*, 11, 337. Available from: <https://doi.org/10.12688/f1000research.110593.1>
- Kapitsinis, N. (2021) The underlying factors of excess mortality in 2020: a cross-country analysis of pre-pandemic healthcare conditions and strategies to cope with Covid-19. *BMC Health Services Research*, 21, 1197. Available from: <https://doi.org/10.1186/s12913-021-07169-7>

- Karlinsky, A. & Kobak, D. (2021) Tracking excess mortality across countries during the COVID-19 pandemic with the world mortality dataset. *eLife*, 10, e69336. Available from: <https://doi.org/10.7554/eLife.69336>
- Karmakar, M., Lantz, P.M. & Tipirneni, R. (2021) Association of social and demographic factors with COVID-19 incidence and death rates in the US. *JAMA Network Open*, 4, e2036462. Available from: <https://doi.org/10.1001/jamanetworkopen.2020.36462>
- Kim, S.S., Chung, J.R., Talbot, H.K., Grijalva, C.G., Wernli, K.J., Kiniry, E. et al. (2022) Effectiveness of two and three mRNA COVID-19 vaccine doses against Omicron- and Delta-related outpatient illness among adults, October 2021–February 2022. *Influenza and Other Respiratory Viruses*, 16, 975–985. Available from: <https://doi.org/10.1111/irv.13029>
- Kompaniyets, L., Pennington, A.F., Goodman, A.B., Rosenblum, H.G., Belay, B., Ko, J.Y. et al. (2021) Underlying medical conditions and severe illness among 540,667 adults hospitalized with COVID-19, March 2020–March 2021. *Preventing Chronic Disease*, 18, E66. Available from: <https://doi.org/10.5888/pcd18.210123>
- Krug, A., Stevenson, J. & Høeg, T.B. (2022) BNT162b2 vaccine-associated Myo/pericarditis in adolescents: a stratified risk-benefit analysis. *European Journal of Clinical Investigation*, 52, e13759. Available from: <https://doi.org/10.1111/eci.13759>
- Leask, J., Seale, H., Williams, J.H., Kaufman, J., Wiley, K., Mahimbo, A. et al. (2021) Policy considerations for mandatory COVID-19 vaccination from the Collaboration on Social Science and Immunisation. *Medical Journal of Australia*, 215, 499–503. Available from: <https://doi.org/10.5694/mja2.51269>
- León, T.M., Dorabawila, V., Nelson, L., Lutterloh, E., Bauer, U.E., Backenson, B. et al. (2022) COVID-19 cases and hospitalizations by COVID-19 vaccination status and previous Covid-19 diagnosis – California and New York, May–November 2021. *MMWR. Morbidity and Mortality Weekly Report*, 71, 125–131.
- Loewenson, R., Accoe, K., Bajpai, N., Buse, K., Deivanayagam, T.A., London, L. et al. (2020) Reclaiming comprehensive public health. *BMJ Global Health*, 5, e003886. Available from: <https://doi.org/10.1136/bmjgh-2020-003886>
- Loewenson, R., Colvin, C.J., Szabzon, F., Das, S., Khanna, R., Coelho, V.S.P. et al. (2021) Beyond command and control: a rapid review of meaningful community-engaged responses to COVID-19. *Global Public Health*, 16, 1439–1453. Available from: <https://doi.org/10.1080/17441692.2021.1900316>
- Logette, E., Lorin, C., Favreau, C., Oshurko, E., Coggan, J.S., Casalegno, F. et al. (2021) A machine-generated view of the role of blood glucose levels in the severity of COVID-19. *Frontiers in Public Health*, 9, 1068. Available from: <https://doi.org/10.3389/fpubh.2021.695139>
- Madewell, Z.J., Yang, Y., Longini, I.M., Jr., Halloran, M.E. & Dean, N.E. (2022) Household secondary attack rates of SARS-CoV-2 by variant and vaccination status: an updated systematic review and meta-analysis. *JAMA Network Open*, 5, e229317. Available from: <https://doi.org/10.1001/jamanetworkopen.2022.9317>
- Marmot, M. (2017) The health gap: the challenge of an unequal world: the argument. *International Journal of Epidemiology*, 46, 1312–1318. Available from: <https://doi.org/10.1093/ije/dyx163>
- Matin, S., Fouladi, N., Pahlevan, Y., Asghariazar, V., Molaei, S., Afzoun Khiavi, H. et al. (2021) The sufficient vitamin D and albumin level have a protective effect on COVID-19 infection. *Archives of Microbiology*, 203, 5153–5162. Available from: <https://doi.org/10.1007/s00203-021-02482-5>
- McQueen, D.V. & Jones, C.M. (2007) *Global perspectives on health promotion effectiveness*, International Union for Health Promotion and Education. New York, NY, USA: Springer.
- Mendenhall, E., Kohrt, B.A., Norris, S.A., Ndetei, D. & Prabhakaran, D. (2017) Non-communicable disease syndemics: poverty, depression, and diabetes among low-income populations. *Lancet*, 389, 951–963. Available from: [https://doi.org/10.1016/S0140-6736\(17\)30402-6](https://doi.org/10.1016/S0140-6736(17)30402-6)
- Menegale, F., Manica, M., Zardini, A., Guzzetta, G., Marziano, V., d'Andrea, V. et al. (2023) Evaluation of waning of SARS-CoV-2 vaccine-induced immunity: a systematic review and meta-analysis. *JAMA Network Open*, 6, e2310650. Available from: <https://doi.org/10.1001/jamanetworkopen.2023.10650>
- Misset, B., Piagnerelli, M., Hoste, E., Dardenne, N., Grimaldi, D., Michaux, I. et al. (2023) Convalescent plasma for Covid-19-induced ARDS in mechanically ventilated patients. *The New England Journal of Medicine*, 389, 1590–1600. Available from: <https://doi.org/10.1056/NEJMoa2209502>
- Morens, D.M., Taubenberger, J.K. & Fauci, A.S. (2023) Rethinking next-generation vaccines for coronaviruses, influenzaviruses, and other respiratory viruses. *Cell Host & Microbe*, 31, 146–157. Available from: <https://doi.org/10.1016/j.chom.2022.11.016>
- Morin, E. (2022) *The challenge of complexity: essays by Edgar Morin*, Heath-Carpentier, Amy (editor). Ed. Liverpool, UK: Liverpool University Press.
- Msellati, P., Sow, K., Desclaux, A., Cottrell, G., Diallo, M., Le Hesran, J.-Y. et al. (2022) Reconsidering the COVID-19 vaccine strategy in West and Central Africa. *Lancet*, 400, 1304. Available from: [https://doi.org/10.1016/S0140-6736\(22\)01896-7](https://doi.org/10.1016/S0140-6736(22)01896-7)
- Munro, A., Buonsenso, D., González-Dambrauskas, S., Hughes, R.C., Bhopal, S.S., Vásquez-Hoyos, P. et al. (2023) In-person schooling is essential even during periods of high transmission of COVID-19. *BMJ Evidence-based Medicine*, 28, 175–179. Available from: <https://doi.org/10.1136/bmjebm-2023-112277>
- Munro, A.P.S., Jones, C.E. & Faust, S.N. (2024) Vaccination against COVID-19 – risks and benefits in children. *European Journal of Pediatrics*, 183, 1107–1112. Available from: <https://doi.org/10.1007/s00431-023-05380-8>
- Negoita, S., Chen, H.-S., Sanchez, P.V., Sherman, R.L., Henley, S.J., Siegel, R.L. et al. (2024) Annual report to the nation on the status of cancer, part 2: early assessment of the COVID-19 pandemic's impact on cancer diagnosis. *Cancer*, 130, 117–127. Available from: <https://doi.org/10.1002/cncr.35026>
- Ngepah, N. (2021) Socio-economic determinants of global COVID-19 mortalities: policy lessons for current and future pandemics. *Health Policy and Planning*, 36, 418–434. Available from: <https://doi.org/10.1093/heapol/czaa161>
- Nogueira, L.M., Schafer, E.J., Fan, Q., Wagle, N.S., Zhao, J., Shi, K.S. et al. (2024) Assessment of changes in cancer treatment during the first year of the COVID-19 pandemic in the US. *JAMA Oncology*, 10, 109–114. Available from: <https://doi.org/10.1001/jamaoncol.2023.4513>
- Nordström, P., Ballin, M. & Nordström, A. (2022) Risk of infection, hospitalisation, and death up to 9 months after a second dose of COVID-19 vaccine: a retrospective, total population cohort study in Sweden. *Lancet*, 399, 814–823. Available from: [https://doi.org/10.1016/S0140-6736\(22\)00089-7](https://doi.org/10.1016/S0140-6736(22)00089-7)
- O'Hearn, M., Liu, J., Cudhea, F., Micha, R. & Mozaffarian, D. (2021) Coronavirus disease 2019 hospitalizations attributable to cardiometabolic conditions in the United States: a comparative risk assessment analysis. *Journal of the American Heart Association*, 10, e019259. Available from: <https://doi.org/10.1161/JAHA.120.019259>
- Paul, E., Brown, G.W., Bell, D., von Agris, J.M. & Ridde, V. (2024) Royal Society report: what would a comprehensive evaluation suggest about non-pharmaceutical interventions during COVID-19? *Critical Public Health*, 34, 1–10. Available from: <https://doi.org/10.1080/09581596.2024.2349894>
- Paul, E., Brown, G.W., Dechamps, M., Kalk, A., Laterre, P.-F., Rentier, B. et al. (2021) COVID-19: an 'extraterrestrial' disease? *International Journal of Infectious Diseases*, 110, 155–159. Available from: <https://doi.org/10.1016/j.ijid.2021.07.051>

- Paul, E., Brown, G.W., Kalk, A. & Ridde, V. (2021) Playing vaccine roulette: why the current strategy of staking everything on Covid-19 vaccines is a high-stakes wager. *Vaccine*, 39, 4921–4924.
- Paul, E., Brown, G.W., Kalk, A., Van Damme, W., Ridde, V. & Sturmberg, J. (2022) “When my information changes, I alter my conclusions.” What can we learn from the failures to adaptively respond to the SARS-CoV-2 pandemic and the under preparedness of health systems to manage COVID-19? *International Journal of Health Policy and Management*, 11, 1241–1245. Available from: <https://doi.org/10.34172/ijhpm.2020.240>
- Paul, E., Brown, G.W. & Ridde, V. (2020) COVID-19: time for paradigm shift in the nexus between local, national and global health. *BMJ Global Health*, 5, e002622. Available from: <https://doi.org/10.1136/bmjgh-2020-002622>
- Paul, E., Brown, G.W., Ridde, V. & Sturmberg, J.P. (2024) Who is “anti-science”? *Public Health in Practice*, 7, 100493. Available from: <https://doi.org/10.1016/j.puhp.2024.100493>
- Pawson, R. (2021) The coronavirus response: boxed in by models. *Evaluation*, 27, 149–167. Available from: <https://doi.org/10.1177/1356389020968579>
- Racine, N., McArthur, B.A., Cooke, J.E., Eirich, R., Zhu, J. & Madigan, S. (2021) Global prevalence of depressive and anxiety symptoms in children and adolescents during COVID-19: a meta-analysis. *JAMA Pediatrics*, 175, 1142–1150. Available from: <https://doi.org/10.1001/jamapediatrics.2021.2482>
- Rawson, T.M., Moore, L.S.P., Zhu, N., Ranganathan, N., Skolimowska, K., Gilchrist, M. et al. (2020) Bacterial and fungal coinfection in individuals with coronavirus: a rapid review to support COVID-19 antimicrobial prescribing. *Clinical Infectious Diseases*, 71, 2459–2468. Available from: <https://doi.org/10.1093/cid/ciaa530>
- Rebuilding resilient health systems for Europe: The Lancet Regional Health-Europe, 2021. *The Lancet Regional Health-Europe* 9, 100238. <https://doi.org/10.1016/j.lanepe.2021.100238>
- Ridde, V., André, G., Bouchaud, O. & Bonnet, E. (2023) COVID-19 vaccination at a hospital in Paris: spatial analyses and inverse equity hypothesis. *medRxiv*. <https://doi.org/10.1101/2023.05.05.23289561>
- Riemersma, K.K., Haddock, L.A., III, Wilson, N.A., Minor, N., Eickhoff, J., Grogan, B.E. et al. (2022) Shedding of infectious SARS-CoV-2 despite vaccination. *PLoS Pathogens*, 18, e1010876. Available from: <https://doi.org/10.1371/journal.ppat.1010876>
- Rosengren, A., Smyth, A., Rangarajan, S., Ramasundarahettige, C., Bangdiwala, S.I., AlHabib, K.F. et al. (2019) Socioeconomic status and risk of cardiovascular disease in 20 low-income, middle-income, and high-income countries: the prospective urban rural epidemiologic (PURE) study. *The Lancet Global Health*, 7, e748–e760. Available from: [https://doi.org/10.1016/S2214-109X\(19\)30045-2](https://doi.org/10.1016/S2214-109X(19)30045-2)
- Sackett, D.L., Rosenberg, W.M.C., Gray, J.A.M., Haynes, R.B. & Richardson, W.S. (1996) Evidence based medicine: what it is and what it isn't. *BMJ*, 312, 71–72. Available from: <https://doi.org/10.1136/bmj.312.7023.71>
- Schippers, M.C., Ioannidis, J.P.A. & Joffe, A.R. (2022) Aggressive measures, rising inequalities, and mass formation during the COVID-19 crisis: an overview and proposed way forward. *Frontiers in Public Health*, 10, 950965. Available from: <https://doi.org/10.3389/fpubh.2022.950965>
- Schmelz, K. & Bowles, S. (2022) Opposition to voluntary and mandated COVID-19 vaccination as a dynamic process: evidence and policy implications of changing beliefs. *Proceedings of the National Academy of Sciences of the United States of America*, 119, e2118721119. Available from: <https://doi.org/10.1073/pnas.2118721119>
- Schmets, G., Rajan, D. & Kadandale, S. (2016) *Strategizing national health in the 21st century: a handbook*. Geneva: World Health Organization.
- Sinha, S. & Konetzka, R.T. (2022) Association of COVID-19 vaccination rates of staff and COVID-19 illness and death among residents and staff in US nursing homes. *JAMA Network Open*, 5, e2249002. Available from: <https://doi.org/10.1001/jamanetworkopen.2022.49002>
- Starfield, B., Shi, L. & Macinko, J. (2005) Contribution of primary care to health systems and health. *The Milbank Quarterly*, 83, 457–502. Available from: <https://doi.org/10.1111/j.1468-0009.2005.00409.x>
- Steinert, J.I., Sternberg, H., Prince, H., Fasolo, B., Galizzi, M.M., Büthe, T. et al. (2022) COVID-19 vaccine hesitancy in eight European countries: prevalence, determinants, and heterogeneity. *Science Advances*, 8, eabm9825. Available from: <https://doi.org/10.1126/sciadv.abm9825>
- Sturmberg, J., Paul, E., Van Damme, W., Ridde, V., Brown, G.W. & Kalk, A. (2021) The danger of the single storyline. Obfuscating the complexities of managing SARS-CoV-2/COVID-19. *Journal of Evaluation in Clinical Practice*, 28, 1173–1186. Available from: <https://doi.org/10.1111/jep.13640>
- Sturmberg, J. & Topolski, S. (2014) For every complex problem, there is an answer that is clear, simple and wrong. *Journal of Evaluation in Clinical Practice*, 20, 1017–1025. Available from: <https://doi.org/10.1111/jep.12156>
- Sturmberg, J.P. (2018) *Health system redesign. How to make health care person-centered, equitable, and sustainable*. Cham: Springer.
- Sturmberg, J.P. (2020) Approaching complexity—start with awareness. *Journal of Evaluation in Clinical Practice*, 26, 1030–1033. Available from: <https://doi.org/10.1111/jep.13355>
- Sturmberg, J.P. & Martin, C.M. (2020) COVID-19 – how a pandemic reveals that everything is connected to everything else. *Journal of Evaluation in Clinical Practice*, 26, 1361–1367. Available from: <https://doi.org/10.1111/jep.13419>
- Sturmberg, J.P., Tsasis, P. & Hoemeke, L. (2020) COVID-19 – an opportunity to redesign health policy thinking. *International Journal of Health Policy and Management*, 11, 409–413. Available from: <https://doi.org/10.34172/ijhpm.2020.132>
- Swinburn, B.A., Kraak, V.I., Allender, S., Atkins, V.J., Baker, P.I., Bogard, J.R. et al. (2019) The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *Lancet*, 393, 791–846. Available from: [https://doi.org/10.1016/S0140-6736\(18\)32822-8](https://doi.org/10.1016/S0140-6736(18)32822-8)
- The Pandemic Fund. (2024) *The pandemic fund for a resilient world*. Available from: <https://www.thepandemicfund.org/>
- The Recovery Collaborative Group. (2020) Dexamethasone in hospitalized patients with Covid-19 – preliminary report. *The New England Journal of Medicine*, 383, 2030–2040. Available from: <https://doi.org/10.1056/NEJMoa2021436>
- Unfried, K. & Priebe, J. (2024) Vaccine hesitancy and trust in sub-Saharan Africa. *Scientific Reports*, 14, 10860. Available from: <https://doi.org/10.1038/s41598-024-61205-0>
- United Nations General Assembly A/78/L.2. (2023) Seventy-eighth session Agenda item 125 Draft resolution submitted by the President of the General Assembly: Political declaration of the General Assembly high-level meeting on pandemic prevention, preparedness and response 25 September 2023. Accessed 16 September 2024. Available at: <https://digitallibrary.un.org/record/4022577?ln=en&v=pdf>
- Vaccarella, S., Georges, D., Bray, F., Ginsburg, O., Charvat, H., Martikainen, P. et al. (2023) Socioeconomic inequalities in cancer mortality between and within countries in Europe: a population-based study. *The Lancet Regional Health-Europe*, 25, 100551. Available from: <https://doi.org/10.1016/j.lanepe.2022.100551>
- Van Damme, W., Dahake, R., Delamou, A., Ingelbeen, B., Wouters, E., Vanham, G. et al. (2020) The COVID-19 pandemic: diverse

- contexts; different epidemics—how and why? *BMJ Global Health*, 5, e003098. Available from: <https://doi.org/10.1136/bmjgh-2020-003098>
- Vermeulen, N. (2024) Neuroticism predicts national vaccination rates across 56 countries. *Current Psychology*, 43, 113–118. Available from: <https://doi.org/10.1007/s12144-023-04234-8>
- Vermeulen, N., Guyomarch, M., Jidovtseff, B., Oleffe, A., Labat, A. & Paul, E. (2023) Expectations and disappointments relative to COVID-19 passes: results from a voluntary mixed-methods study in French-speaking Belgium. *IJID Regions*, 6, 146–151. Available from: <https://doi.org/10.1016/j.ijregi.2023.01.010>
- Vogel, G. (2023) Do COVID-19 vaccine mandates still make sense? *Science*, 379, 1072–1073. Available from: <https://doi.org/10.1126/science.adh7971>
- Wan, E.Y.F., Yan, V.K.C., Mok, A.H.Y., Wang, B., Xu, W., Cheng, F.W.T. et al. (2023) Effectiveness of molnupiravir and nirmatrelvir-ritonavir in hospitalized patients with COVID-19: a target trial emulation study. *Annals of Internal Medicine*, 176, 505–514. Available from: <https://doi.org/10.7326/M22-3057>
- Williamson, E.J., Walker, A.J., Bhaskaran, K., Bacon, S., Bates, C., Morton, C.E. et al. (2020) Factors associated with COVID-19-related death using OpenSAFELY. *Nature*, 584, 430–436. Available from: <https://doi.org/10.1038/s41586-020-2521-4>
- Wong, M.K., Brooks, D.J., Ikejezie, J., Gacic-Dobo, M., Dumolard, L., Nedelec, Y. et al. (2023) COVID-19 mortality and progress toward vaccinating older adults – World Health Organization, worldwide, 2020–2022. *MMWR. Morbidity and Mortality Weekly Report*, 72, 113–118. Available from: <https://doi.org/10.15585/mmwr.mm7205a1>
- Woolford, S.J., Sidell, M., Li, X., Else, V., Young, D.R., Resnicow, K. et al. (2021) Changes in body mass index among children and adolescents during the COVID-19 pandemic. *Journal of the American Medical Association*, 326, 1434–1436. Available from: <https://doi.org/10.1001/jama.2021.15036>
- World Health Organization. (1986) *Ottawa charter for health promotion* (No. WHO/HPR/HEP/95.91). Ottawa, ON: World Health Organization.
- World Health Organization. (2021) *Health systems for health security: a framework for developing capacities for international health regulations, and components in health systems and other sectors that work in synergy to meet the demands imposed by health emergencies*. Geneva: World Health Organization.
- World Health Organization. (2023) *INB process*. Available from: <https://inb.who.int/home/inb-process>
- World Health Organization, Global Influenza Programme (GIP). (2019) *Non-pharmaceutical public health measures for mitigating the risk and impact of epidemic and pandemic influenza*. Geneva, Switzerland: World Health Organization.
- World Health Organization, United Nations Children's Fund (UNICEF). (2018) *Declaration of Astana. Global conference on primary health care*. Astana, Kazakhstan: World Health Organization, United Nations Children's Fund (UNICEF).
- World Health Organization, World Bank. (2022) *Analysis of pandemic preparedness and response (PPR) architecture, financing needs, gaps and mechanisms (prepared for the G20 Joint Finance & Health Task Force)*. Geneva and Washington, D.C.: World Health Organization and World Bank, G20 Indonesia 2022.
- Worrall, E., Basu, S. & Hanson, K. (2005) Is malaria a disease of poverty? A review of the literature. *Tropical Medicine & International Health*, 10, 1047–1059. Available from: <https://doi.org/10.1111/j.1365-3156.2005.01476.x>
- Zimmerman, F.J. & Anderson, N.W. (2021) Association of the timing of school closings and behavioral changes with the evolution of the coronavirus disease 2019 pandemic in the US. *JAMA Pediatrics*, 175, 501–509. Available from: <https://doi.org/10.1001/jamapediatrics.2020.6371>

AUTHOR BIOGRAPHIES

Elisabeth Paul owns a PhD in Management Science. She has combined an academic and consultancy career in the fields of global health policies, health financing, health systems strengthening, foreign aid effectiveness management, and public finance management. She has mostly worked in Western Africa and at the global health institutional level. She teaches various courses related to health policies and health systems analysis.

Garrett W. Brown is Chair of Global Health Policy at the University of Leeds. His research focuses on global health governance, health financing, health system strengthening, health equity, and pandemic preparedness and response. His research includes work with governments in Africa, the UK Cabinet Office and DHSC, WHO, G7, and G20.

David Bell is a public health physician with a PhD in population health and background in internal medicine, modeling, and epidemiology of infectious disease. He was Director of Global Health Technologies at the Global Good Fund, Programme Head for Malaria at FIND, and coordinated malaria diagnostics strategy at the WHO.

Valéry Ridde is Director of Research (Senior Research Fellow) at CEPED (University Paris Cité and the French Research Institute for Development (IRD)). He was Associate Professor at the School of Public Health at the University of Montreal, Canada. His research work focuses on universal health coverage, health service financing, public health policies, and knowledge transfer.

Joachim Sturmberg is a general practitioner whose practice has been grounded in “complex thought.” His systems and complexity thinking informed work has resulted in numerous contributions to the clinical, organizational, and philosophical literature on health, health care, and health system. He is Foundation President of the International Society for Systems and Complexity Sciences for Health.

How to cite this article: Paul, E., Brown, G.W., Bell, D., Ridde, V. & Sturmberg, J. (2024) Preparing for pandemics needs a dose of public health and a booster of “complex thought” (Errare humanum est, perseverare diabolicum). *Global Policy*, 00, 1–10. Available from: <https://doi.org/10.1111/1758-5899.13449>