Capturing the COVID-19 Crisis through Public Health and Social Measures Data Science

Cindy Cheng1, Amélie Desvars-Larrive2,3, Bernhard Ebbinghaus4, Thomas Hale5, Alexandra Howes6, Lukas Lehner6, Luca Messerschmidt4,5✉, Angeliki Nika6, Steve Penson6, Anna Petherick5, Hanmeng Xu7, Alexander John Zapf8, Yuxi Zhang5 & Sophia Alison Zweig7

In response to COVID-19, governments worldwide are implementing public health and social measures (PHSM) that substantially impact many areas beyond public health. The new field of PHSM data science collects, structures, and disseminates data on PHSM; here, we report the main achievements, challenges, and focus areas of this novel field of research.

Introduction

In response to the COVID-19 pandemic, governments around the world are enacting a wide range of public health and social measures (PHSM), also known as non-pharmaceutical interventions, including e.g., school closures, movement restrictions, and contact tracing. These measures not only impose unprecedented restrictions on human behaviour, but have also been implemented at an extraordinary scale, duration and variation. For instance, while many governments have collectively implemented thousands of measures related to lockdowns, curfews, or stay-at-home orders recorded in different datasets, other governments have not imposed any at all ("laissez-faire" strategy)1. Meanwhile there has been great variation even among relatively common policies. For example, though most governments implemented lockdown measures which applied to the general population, many governments have introduced their own specifications. Indeed, the Lebanese government limited traffic by allowing citizens with odd or even license plate numbers out on certain days2 while in Panama, citizens were allowed out on certain days depending on their sex3. In short, PHSM have not only shaped the progression of the pandemic but have irrevocably affected how billions of people conduct their lives. Though tracking PHSM is key to our understanding of the pandemic’s drivers and impacts, gathering accurate, timely and complete PHSM data is a monumental task: government responses to COVID-19 are incredibly varied across time and space and their documentation has been both unstructured and dispersed across a broad range of government and news portals.

Without previous work to guide them, starting from March 2020, more than 40 distinct PHSM “trackers” have taken on the challenge of organizing these policies into structured databases that are both understandable to non-experts and available for use in rigorous research. To do so, they have sifted through reams of primary sources, developed structured taxonomies to categorize them, and coordinated tremendous human resources to try to keep pace with the sheer volume of PHSM to collect, categorize, clean, and validate. Though PHSM trackers are largely associated with the underlying data they process, they should be more holistically understood as research groups (from academia or the public or private sectors) that produce both the taxonomies for describing and understanding government responses to COVID-19 as well as the organizational infrastructures for systematically documenting PHSM data in near real-time.

1Hochschule für Politik and the TUM School of Social Sciences and Technology at the Technical University of Munich (TUM), Munich, Germany. 2Unit of Veterinary Public Health and Epidemiology, University of Veterinary Medicine Vienna, Vienna, Austria. 3Complexity Science Hub Vienna, Vienna, Austria. 4Department of Social Policy & Intervention, University of Oxford, Oxford, UK. 5Blavatnik School of Government, University of Oxford, Oxford, United Kingdom. 6ACAPS, Geneva, Switzerland. 7Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA. 8Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA. ✉e-mail: luca.messerschmidt@hfp.tum.de
By granting public access to their data, policy trackers in the new field of PHSM data science provide an essential foundation for our collective ability to answer pressing questions of interest to researchers, policy-makers and the global community alike including: When and under what conditions are some PHSM more or less effective at curbing the spread of the virus? Why do some countries adopt certain PHSM while others do not? What unintended political, economic or social consequences have resulted from PHSM?

While scientifically rigorous research on these and other questions crucially depends on the availability of timely and high-quality PHSM data, the continued provision of this public good is far from guaranteed. As representatives of a consortium of PHSM data trackers, raising awareness of the many achievements and contributions of PHSM data science over the past two years is of secondary importance to making sure the wider research and policy community is aware of the major challenges that trackers face in sustaining their indispensable work. This review of pressing issues in the field of PHSM represents a summary of the discussions conducted between over 40 trackers across two PHSM conferences hosted on these topics. It further includes the results of 16 survey responses of self-reported data collected and project resources from PHSM trackers in our network up until November 2021. For more information on the trackers, see Table 1.

### Major achievements of PHSM trackers

We first provide an overview of what PHSM trackers have achieved over the past two years. In particular, they have been:

- Tracking PHSM data over time (i.e., from the beginning of the pandemic to present day) and space (i.e., worldwide coverage at both national and subnational levels). To date, trackers have collectively coded more than 365,000 policy responses in their databases (Fig. 1). Because what counts as a policy can differ greatly from dataset to dataset, to maximize comparability, we only included policies that could be represented in an event dataset format where each observation is associated with a unique policy event (as opposed to a panel country-day format where a unique policy event may be captured across multiple rows of observations depending on how long the policy event was in place). Further, note that 365,000 + represents the cumulative number of policies documented by trackers independently; the number of unique policies is likely smaller due to duplication across datasets. To minimize the likelihood of double counting policies, we also only included data from trackers that conducted original data collection (for at least 1000 policies) as opposed to republishing data from existing databases.

**Table 1.** List of Trackers Analysed in Fig. 1 and that responded to the survey. Notes: In the geographic scope column, EU+ refers to the European Union plus Norway, and USA refers to the United States of America. In the ‘Categories’ column, NPIs refers to non-pharmaceutical intervention. Since the Oxford Supertracker is a directory of different COVID-19 projects, many of the columns are not applicable to it. *At the time of writing (July 2022). **The US Centers for Disease Control and Prevention (CDC) and WHO EURO’s PHSM dataset (WHO* Euro) are only publicly available through the WHO PHSM database*.

| Dataset | Survey Participation | Geographic Scope | Active | Last update* | Categories |
|---------|----------------------|------------------|--------|--------------|------------|
| ACAPS24 | YES                  | Worldwide        | NO     | 08.12.20     | NPIs, Econ |
| CCCSL** | YES                  | Worldwide        | NO     | 25.01.21     | NPIs       |
| CDC**   | NO                   | Worldwide        | NO     | 28.06.21     | NPIs, Econ |
| CIHI**  | YES                  | Canada           | YES    | 25.07.22     | NPIs, Vaccines |
| CMMP**  | YES                  | Worldwide        | NO     | 01.08.20     | NPIs       |
| CORAP** | NO                   | Worldwide        | NO     | 21.12.21     | NPIs       |
| CoronaNet | YES                | Worldwide        | YES    | 05.07.22     | NPIs, Vaccines |
| COVID-19 EU Policy Watch26 | YES | EU+             | YES    | 05.07.22     | Econ       |
| COVID-19 Food Trade Policy Tracker28 | YES | Worldwide | NO | 01.06.21 | Econ |
| COVID-19 Health System Response Monitor20 | YES | Worldwide | YES | 05.07.22 | NPIs, Econ, Vaccines |
| Covid-19 Law Lab27 | YES | Worldwide | YES | 05.07.22 | NPIs, Vaccines |
| COVID-19 State Policy Project31 | NO | USA          | NO     | 09.08.21     | NPIs       |
| COVID-AMP29 | NO     | Worldwide | YES    | 05.07.22     | NPIs, Vaccines |
| HIT-COVID33 | YES | Worldwide | NO     | 18.05.21     | NPIs       |
| INGSA31 | NO                   | Worldwide        | NO     | 11.01.21     | NPIs       |
| OxCGRT26 | YES                | Worldwide        | YES    | 05.07.22     | NPIs, Econ, Vaccines |
| Oxford Supertracker34 | YES | —             | YES    | —            | —          |
| Response2covid1935 | YES | Worldwide | NO | 04.06.21 | NPIs, Econ |
| TIP36   | NO                   | England          | NO     | 31.12.20     | NPIs       |
| NPI B37 | NO                   | Brazil           | NO     | 19.10.20     | NPIs       |
| UNDP27  | NO                   | Worldwide        | NO     | 31.12.20     | NPIs, Econ |
| WHO Euro38 | NO     | Worldwide | YES    | 05.07.22     | NPIs, Econ, Vaccines |
| WHO PHSM Dataset24 | YES | Worldwide | YES | 05.07.22 | NPIs, Econ, Vaccines |
| Yale State and Local COVID Restriction Database40 | YES | USA       | YES    | 05.07.22 | NPIs, Econ |

By granting public access to their data, policy trackers in the new field of PHSM data science provide an essential foundation for our collective ability to answer pressing questions of interest to researchers, policy-makers and the global community alike including: When and under what conditions are some PHSM more or less effective at curbing the spread of the virus? Why do some countries adopt certain PHSM while others do not? What unintended political, economic or social consequences have resulted from PHSM?
reformatting or repurposing existing PHSM datasets (e.g., the response2covid19 dataset)\(^4\). Finally, note that we focus only on groups that have specifically sought to document COVID-19 PHSM. Though there have been hundreds of other trackers which have gathered related data on COVID-19, including e.g. public opinion surveys\(^5\) or data on SARS-CoV-2 infections\(^6,7\), they are beyond the scope of this commentary. For more information on the trackers covered here, see Table 1.

- Developing novel, structured, and detailed taxonomies customized to capture COVID-19 PHSM. To illustrate how much variation there has been in PHSM data structure and taxonomy, we can consider the coding schemes of the two biggest trackers, the OxCGRT\(^8\) and CoronaNet\(^9\). While the latter tracker organizes COVID-19 policies in a event database that categorizes policies into over 100 sub-categories with detailed text descriptions, the OxCGRT has a panel structure that categorizes policies along 21 broader policy categories.
- Creating original organisational frameworks and infrastructure to process raw data and information into curated PHSM datasets.
- Building significant global networks of data collectors united in the mission to document PHSM. They have accumulated considerable experience and knowledge as part of what is arguably one of the largest efforts ever attempted to collect public health data in real time. Across the trackers that filled out the survey, more than 2,000 people have collected data, mostly as student volunteers motivated by the opportunity to contribute to scientific research.
- Making PHSM data openly accessible and available in (close to) real time as a public good for researchers, the public, and stakeholders to utilize. Public access to PHSM data has played a crucial role in advancing our collective understanding of the countless ways that the pandemic has affected our economies, our communities and our daily lives.
- Fostering international collaboration, coordination, and communication within and between trackers, culminating in two international conference held in 2021. The COVID-19 PHSM Data Coverage Conference, held in February and March 2021, brought together 40 PHSM trackers as well as researchers and PHSM data users to share key tracking lessons, identify challenges, and discuss how to enhance pandemic preparedness. Meanwhile the PHSM Research Outcome Conference, held in October 2021, provided an important forum for scholars to share research findings based on PHSM data.
- Creating the COVID-19 PHSM Network\(^10\), which represents an important collegial advance in facing current and future challenges raised by the novelty and complexity of collecting PHSM data (Fig. 2).

The value of PHSM trackers as essential tools amidst the COVID-19 crisis

PHSM trackers are building a foundation for analysing the impact of COVID-19 government policies and interventions. As such they are building remarkable and readily accessible historical records for future generations of scientists, policy experts, and the public to learn from.
To date, combined with multidisciplinary data (e.g., number of COVID-19 cases, deaths, hospitalisations, mobility, and economic data), PHSM have provided crucial input for researchers to model and understand the spread of COVID-19. In doing so, they provide an important foundation for evidence-based policymaking and scientific research on the pandemic. For example, data from PHSM trackers have been utilized in research to evaluate the impact of PHSM on COVID-19 transmission, mortality, human rights, food prices, health policy and pandemic fatigue. They have also been utilized to describe and explain the cross-country and longitudinal variations in governments’ COVID-19 policy decisions. Importantly, PHSM data can further be used to communicate accurate scientific knowledge to the public, improve data transparency, hold media outlets accountable for misinterpretation, and avoid misinformation around COVID-19 PHSM and their impact as well as their potential consequences.

Major Challenges in Tracking COVID-19 PHSM

PHSM trackers have not been able to come by their achievements easily. From developing data taxonomies to building organizational structures for collecting, cleaning and validating data, PHSM trackers initiated their efforts without the benefit of precedent. At the beginning of the pandemic, trackers also worked without knowledge of each other’s efforts. While a vast improvement over isolation, greater cooperation among trackers entails its own set of challenges. Our review below provides a holistic overview of both the data and organizational challenges facing PHSM trackers individually and as a group. This can be complemented with Shen et al.’s commentary, which provides a more in depth discussion of the various data challenges faced by individual trackers.

Individual challenges. Data taxonomy forms the basis for comprehensible and meaningful use of PHSM data. Each tracker had different strategies for building their taxonomies, and given the peculiarities of how governments implemented COVID-19 PHSM, they generally developed them inductively and inferentially. Trackers have found that the main challenge in doing so is developing a standard taxonomy that can both capture the nuances and peculiarities of a given country’s PHSM rollout while also allowing for cross-country comparisons. Additionally, ensuring that taxonomies remain relevant over time by including periodic updates is also important. This issue affects not only COVID-19 data but also basic demographic data. Indeed, detailed demographic data is often not available to the public and definitions as well as categories for demographic characteristics vary across countries and states. This disarray not only makes data collection highly challenging but also makes it difficult to compare or identify the multitude of e.g., socioeconomic and health consequences of the pandemic, especially with regards to the most vulnerable populations.

To collect, clean, and validate this enormous volume of PHSM data, most trackers rely on the tremendous contribution of volunteers. However, the corresponding recruitment, training, engagement, and organization of volunteers present enormous challenges. Most volunteers are students and their availability thus fluctuates according to the academic calendar. The reliance on unpaid work also raises questions of research ethics and sustainability. According to our survey, only around 10% of data collectors across are paid; the vast majority are volunteers serving a public good.

Many trackers rely on volunteers for data collection not by design, but due to lack of funding. Funding constraints are unfortunately quite severe: many policy trackers have had to stop working because of the lack of...
continued funding, resulting in wide evidentiary gaps. When trackers do receive funding, it is often short-term because of uncertainty about the pandemic’s duration. According to our tracker survey, only 16% of the overall funding needs by trackers are satisfied (Fig. 3b). This has led to a 65% decline in the number of trackers that are actively collecting data (Fig. 3c). Some trackers have attempted to address this problem by harmonising their data into the few databases with more sustainable funding schemes, which underscores the importance of longer-term funding for sustained PHSM data tracking.

Collective challenges. PHSM trackers face challenges not only as individual actors, but also as a collective ecosystem. At the beginning of the pandemic, 40+ PHSM tracking projects launched with little to no knowledge of each other due to their emergency nature. These parallel data collection efforts led to the duplication of data, multiple taxonomy strategies across trackers, gaps in data coverage and variation in data quality. While there is significant data overlap among trackers, many trackers also have unique data coverage in specific domains, such as public health, economic policy, and human rights. Though these differences provide a diversity of perspectives on PHSM data tracking, they can lead to difficulties in data utilization. Working toward a single harmonized source might seem like an obvious solution, and indeed the World Health Organization (WHO) has done important work toward this goal. However, this work also underscores the difficulty in data harmonization when underlying data sources are still in the process of being cleaned and organized. More to the point, we believe that there is great value in continuing to maintain diversity in tracking projects. Doing so allows (i) different datasets to be validated against each other (ii) individual datasets to reflect a variety of research priorities and (iii) stakeholders find the dataset that best fits their needs.

The benefits of diversity must be continuously balanced against the costs of data collection, completeness, and quality. With regards to data completeness, PHSM trackers have done impressive work in documenting how governments around the world have responded to the pandemic at both national and subnational levels; however, data overlaps and gaps persist. In general, across PHSM trackers, data from the “Global North” are

Fig. 3 PHSM Tracker Survey Responses. Table 1 provides information which trackers participated in the survey. Responses from the tracker survey of PHSM Network members to the following questions (a) What are the number of paid versus unpaid data collectors? (b) What are funding needs compared to received funds? (c) Is the tracker still actively coding new policies? (d) What governmental level of policies do trackers gather data for?
overrepresented whereas data from the “Global South” are poor or missing. In the PHSM network, only one tracker has its main team physically based in the Global South. Due to funder interests, most data collection is focused on OECD countries and on national policies, leading to large gaps in data collection for less-developed countries and sub-national levels. While over 50% of the bigger trackers collect sub-national data (Fig. 3d), systematic subnational data collection for non-OECD countries is limited to Brazil, China, India, Russia and Nigeria.

With regards to data quality, trackers have learned that local knowledge and/or language skills are essential to gathering complete and accurate information. Because of this, PHSM data quality for countries in the Global South is also more likely to suffer because many of the major trackers and their funders are based in the Global North.

Altogether, while all trackers are united in their aim to document government responses to the COVID-19, when considering the sheer number of policies it is possible to collect on the one side, with the diversity of understandings of how to define a policy as well as organisational resources to capture them on the other side, there is a great deal of variation in terms of the scope, quality, and structure of PHSM datasets. While providing a definitive guide as to which datasets may be best suited for a given analysis is still premature given the ongoing nature of this commentary and the attendant data collection thereof, Table 1 provides some broad guidance for adjudicating among different datasets with regards to geographic and temporal dimensions at the time of writing of this commentary.

Ultimately, given the colossal volume and speed of government COVID-19 policy making, greater collaboration between researchers in different fields (e.g., epidemiologists, political scientists, data scientists) as well as communication with policy makers is further needed to understand how to best model and analyse PHSM data. Such work would need to start with better integrating PHSM them with other relevant COVID-19 data (e.g., COVID-19 cases, deaths and hospitalizations; economic indicators; environmental indicators). In all likelihood, further work would need to be done to develop novel analytical tools for using PHSM data to assess the drivers and impacts of the pandemic. While some trackers have made more headway than others on this front (e.g., see Our World in Data's COVID-19 dashboard: https://ourworldindata.org/coronavirus; or the PERISCOPE COVID Atlas: https://periscopeproject.eu/covid-atlas), the field as a whole still lacks much needed coordination and resources to forward this work.

To address these challenges, in what follows, we outline key focus areas for PHSM data science and advocate for greater cooperation and communication among and between PHSM trackers.

**Key Focus Areas for Future PHSM Data Tracking**

In sharing and reflecting on the challenges and lessons learned, we argue that greater emphasis on the following key focus areas will greatly improve our ability to track future PHSM:

- Developing a glossary and best practices on PHSM data collection, processing, and management.
- Tracking new PHSM: Governments continue to implement new PHSM as the pandemic progresses (e.g., COVID-19 vaccination policies) and trackers must keep their taxonomies up to date in order to adapt to the changing landscape of COVID-19 PHSM.
- Increasing representation of low- and middle-income countries (LMICs) in the Global South: Given the importance of promoting equity in data coverage, we advocate for increased funding of and collaboration with trackers based in and focused on LMICs and the Global South.
- Collecting health equity data: COVID-19 has highlighted and aggravated existing inequities and human rights abuses across the world, such as racism, poverty, and mistreatment of refugees. There is an urgent need to collect equity and human rights related data, which is exemplified by several PHSM trackers focusing on legal protections, disability justice, and measures of democracy.
- Maintaining independent data collection: Protecting the independence, integrity and freedom to pursue research without pressure from governments or funders is vital to ensuring PHSM data is free from bias and of the highest quality and accuracy.
- Ensuring that data remain openly accessible: Given the severity of the COVID-19 pandemic, the available technology, and the crucial role that PHSM data can play in informing public health policy, making these data open-access advances the common good since they inform policies for the current and future pandemic(s). This is particularly relevant as the burden of the pandemic continues to shift towards lower-income countries with less resources to collect, aggregate, and analyse such data.
- Advocating for greater funding and recognition for volunteers: The availability, quality and timeliness of PHSM data is reliant on the thousands of people who have volunteered their time and energy to contribute to this public good. Their efforts deserve not only more recognition but also financial support to sustain tracking efforts going forward.
- Preparing for future pandemics: Given the lack of coordinated PHSM data collection at the beginning of the COVID-19 pandemic, we advocate that governments, international organizations, and partners incorporate systematic PHSM tracking and analyses as a strategic priority in preparing for the future of this and other pandemic(s). Moreover, the systematic collection of PHSM may be valuable in other areas of research, especially in urgent global issues such as climate change, antimicrobial resistance, and social equity. Our practices can serve as a roadmap both for PHSM data collection as the COVID-19 pandemic evolves and for future public health emergencies.
Next Steps and the Importance of International Collaboration

In addressing the focus areas above, greater communication and collaboration will open doors to further input, feedback, and support in order to reach our common goal of providing real-time, high-quality, and complete PHSM data to inform the COVID-19 pandemic response. The value of such collaboration was demonstrated during the COVID-19 Data Coverage Conference, at which, together with other participating trackers, we launched the PHSM Network and created its underlying mutual framework for building this collaborative ecosystem.

This framework lays an important foundation for future situations in which shared public health challenges call for a collective global response. Thus far, collaboration among individual trackers has significantly increased our shared data collection ability, improved our effectiveness, and helped address the challenges and limitations of PHSM tracking. Given that international cooperation among government leaders in response to the COVID-19 pandemic has been inconsistent at best, we hope that the international cooperation we are fostering within the COVID-19 PHSM Network can also serve as a model for others seeking to work together in responding to this pandemic.

In order to succeed, however, this network will need the input and assistance of an even wider community—policymakers, donors, and other stakeholders—to provide the necessary feedback and financial support to sustain data tracking efforts given the ever-evolving nature of COVID-19 and the corresponding PHSM. The more communication there is among trackers, policymakers, and researchers, the better the quality of the PHSM data we can provide by tailoring the data to their information needs.

The longer the pandemic lasts, both the volume and variation of policies are likely to increase, making the provision of complete and high-quality PHSM data both within and across countries of immeasurable importance. At the same time however, funding and support for PHSM trackers is conversely becoming more limited, threatening the availability, quality, and comprehensiveness of PHSM data. In short, the provision of future PHSM data is not guaranteed. Our ability to provide PHSM data of the desired scope, quality and timeliness to match the importance of PHSM data to forwarding scientifically rigorous research is falling short as trackers stop data collection due to lack of funding. While the authors here are responsible for some of the largest PHSM trackers currently available, many of them have had to discontinue their work due to funding constraints. ACAPS discontinued new data collection in December 2020; CCCSL discontinued new data collection in April 2021; John Hopkins HIT-COVID discontinued new data collection in May 2021. This not only reduces the diversity of approaches to capturing PHSM data but also makes it less likely that future PHSM will be documented at all, a possibility which will only grow bigger as the pandemic stretches out further into the future.

Given the complexities of conducting COVID-19 research, it is easy to take for granted the availability of timely, accurate, and high-quality COVID-19 PHSM data. While hundreds of trackers and thousands of volunteers have laid the foundation for robust research and evidence-based policymaking, PHSM trackers face multiple internal and external challenges in continuing their work. Moreover, to better react to future crises, the infrastructure needs to be developed now to ensure that PHSM data collected to document future emergencies can be integrated with other data and analysed as rigorously and efficiently as possible. Greater international collaboration among PHSM data trackers as well as more investment and financial support from policymakers and donors is necessary to continue broadening our understanding of the current public health crisis as well as informing future pandemic preparedness efforts.

Data availability

All data are available in the main text, Figures and Tables.

Received: 13 June 2022; Accepted: 5 August 2022;
Published online: 26 August 2022

References

1. Da Silva, C. Swedish region declares ‘personal lockdown’ as covid cases soar, https://www.euronews.com/2021/04/14/swedish-region-declares-personal-lockdown-as-country-sees-daily-covid-cases-soar (2021).
2. NewIndianXpress. Lebanon begins new lockdown amid surge in coronavirus cases, https://www.newindianexpress.com/world/2021/jan/07/lebanon-begins-new-lockdown-amid-surge-in-coronavirus-cases-2246870.html (2021).
3. Oppmann, P. Panama will separate men and women in public during coronavirus lockdown,https://edition.cnn.com/2020/04/01/world/panama-coronavirus-sex-intl/index.html (2020).
4. Porcher, S. 'Response2covid19', a dataset of governments' responses to COVID-19 all around the world. Scientific Data 7, 423, https://doi.org/10.1038/s41597-020-00757-y (2020).
5. Brouard, S. et al. 'citizens’ attitudes under covid19', a cross-country panel survey of public opinion in 11 advanced democracies. Scientific Data 9, 108, https://doi.org/10.1038/s41597-022-01249-x (2022).
6. Arneson, D. et al. CovidCounties is an interactive real time tracker of the COVID-19 pandemic at the level of US counties. Scientific Data 7, 405, https://doi.org/10.1038/s41597-020-00731-8 (2020).
7. Napli, A. COVID-19 european regional tracker. Scientific Data 8, 181, https://doi.org/10.1038/s41597-021-00950-7 (2021).
8. Hale, T. et al. A global panel database of pandemic policies (oxford COVID-19 government response tracker. Nature Human Behaviour 5, 529–538, https://doi.org/10.1038/s41562-021-01079-8 (2021).
9. Cheng, C., Barceló, J., Hartnett, A. S., Kubinec, R. & Messerschmidt, L. COVID-19 government response event dataset (CoronaNet v 1.0). Nature Human Behaviour 4, 756–768, https://doi.org/10.1038/s41562-020-0909-7 (2020).
10. COVID-19 PHSM Network: A year of tracking government responses to covid-19: Challenges and lessons learned from the global data collection efforts around the world. https://phsmconference.files.wordpress.com/2021/04/phsm_lessons_learned_final_statement-2.pdf (2021).
11. Golakmen, Y., Baskici, C. & Ercil, Y. Effects of non-pharmaceutical interventions against COVID-19: A cross-country analysis. The International Journal of Health Planning and Management 36, 1178–1188, https://doi.org/10.1002/hpm.3164 (2021).
12. Senthal Prakash, P., Harharan, B., Kalraju, S., Siva, R. & Vivek, D. The impact of various policy factors implemented for controlling the spread of COVID-19. Materials Today: Proceedings https://doi.org/10.1016/j.matpr.2021.01.524 (2021).
Acknowledgements

First and foremost, we are thankful for the contribution of over 2000 volunteers and team members that are working at our trackers (ACAPS, CCCSIL, CoronaNet, HIT COVID, OxCGRT, OxSupertracker). We appreciate the exceptional contribution of more than 40 trackers to the pandemic and especially the participation in “The COVID-19 PHSM (Public Health and Social Measures) Data Coverage Conference” that resulted in the “COVID-19 PHSM Network”. We also gratefully acknowledge the support of Verena Ahne, Stephanie Bourke—that resulted in the “The COVID-19 PHSM (Public Health and Social Measures) Data Coverage Conference” working at our trackers (ACAPS, CCCSIL, CoronaNet, HIT COVID, OxCGRT, OxSupertracker). We appreciate First and foremost, we are thankful for the contribution of over 2000 volunteers and team members that are working at our trackers (ACAPS, CCCSIL, CoronaNet, HIT COVID, OxCGRT, OxSupertracker). We appreciate the exceptional contribution of more than 40 trackers to the pandemic and especially the participation in “The COVID-19 PHSM (Public Health and Social Measures) Data Coverage Conference” that resulted in the “COVID-19 PHSM Network”. We also gratefully acknowledge the support of Verena Ahne, Stephanie Bourke—et al. in helping us with the copy editing, and Alexandra Williams for creating the logo.
Research Alliance Group ‘Crises in a Globalised World’, “CoronaNet in Eurasia: Leveraging the Comparative Moment in COVID-19 Research” (Grant number 832-06 g). Data collection for EU countries in particular has been supported by the European Union’s Horizon 2020 research and innovation program, PERISCOPE: Pan European Response to the Impacts of COVID-19 and future Pandemics and Epidemics, under grant agreement no. 101016233. LM received further support from the German Academic Scholarship Foundation. [AD]: EOSC Co-Creation funding. EOSCsecretariat.eu has received funding from the European Union’s Horizon Programme call H2020-INFRAEOSC-05-2018-2019, grant Agreement number 831644. [BE, LL]: Economic and Social Research Council (ESRC), the Scatcherd European and the Saven European scholarships at the University of Oxford, Mercator Fellow (Ebbinghaus), Deutsche Forschungsgemeinschaft (DFG) [TH, AP, YZ]: Blavatnik Family Foundation, Roche, UK Economic and Social Research Council, UK Research and Innovation Strategic Priorities Fund, UK Cabinet Office. [AH, AN, SP]: ACAPS Core Funding [HX, AZ, SZ]: Johnson & Johnson foundation.

Author contributions
Authors are listed in alphabetical order. Conceptualization: C.C., A.D., B.E., T.H., A.H., L.L., L.M., A.N., S.P., A.P., H.X., A.Z., Y.Z., S.Z. Methodology: C.C., A.D., A.H., L.L., L.M., S.P., A.P., A.Z., Y.Z., S.Z. Investigation: C.C., L.M. Data Curation: C.C., L.M. Writing - Original Draft: C.C. Writing - Review Editing: C.C., A.D., A.H., L.L., L.M., S.P., A.P., A.Z., Y.Z., S.Z. Visualization: L.M. Supervision: C.C., L.M. Project administration: C.C., L.M. Funding acquisition: C.C., L.M.

Funding
Open Access funding enabled and organized by Projekt DEAL.

Competing interests
The authors declare no competing interests. The funders had no role in study design, data collection, analysis, or interpretation, nor in the decision to publish or in the preparation of the manuscript.

Additional information
Correspondence and requests for materials should be addressed to L.M.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher’s note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit http://creativecommons.org/licenses/by/4.0/.

© The Author(s) 2022