Journal of Travel Medicine

International Society of Travel Medicine
Established 1991
Promoting healthy travel worldwide

Journal of Travel Medicine, 2023, 1–3
https://doi.org/10.1093/jtm/taad049
Research Letter

Research Letter

Reproduction number of SARS-CoV-2 Omicron variants, China, December 2022–January 2023

Yuan Bai, PhD[1,2,†], Zengyang Shao, MSc[2,†], Xiao Zhang, MSc[2,†], Ruohan Chen[2,†], Lin Wang, PhD[3], Sheikh Taslim Ali, PhD[1,2], Tianmu Chen, PhD[4], Eric H.Y. Lau, PhD[1], Dong-Yan Jin, PhD[5] and Zhanwei Du, PhD[1,2,*]

[1]WHO Collaborating Centre for Infectious Disease Epidemiology and Control, Li Ka Shing Faculty of Medicine, School of Public Health, The University of Hong Kong, Hong Kong Special Admimistrative Region, China, [2]Laboratory of Data Discovery for Health, Hong Kong Science and Technology Park, Hong Kong Special Administrative Region, China, [3]Department of Genetics, University of Cambridge, Cambridge, CB2 3EH, UK, [4]State Key Laboratory of Molecular Vaccinology and Molecular Diagnostics, School of Public Health, Xiamen University, Xiamen, China and [5]Li Ka Shing Faculty of Medicine, School of Biomedical Sciences, The University of Hong Kong, Hong Kong Special Admimistrative Region, China

*To whom correspondence should be addressed. Email: zwdu@hku.hk
†These authors contributed equally to this manuscript.

Submitted 15 March 2023; Editorial Decision 4 April 2023; Accepted 4 April 2023

China had successfully suppressed multiple waves of SARS-CoV-2 epidemics using the 'dynamic zero-COVID' strategy before November 2022. Due to the substantially reduced pathogenicity of new SARS-CoV-2 Omicron variants (e.g. BF.7 and BA.5.2) in populations with higher vaccine coverage, and the enormous socioeconomic costs incurred by the dynamic zero-COVID strategy, China began to adjust response strategies from 11 November 2022 (including restricting testing coverage, shortening quarantine periods for inbound travellers and suspending secondary contacts tracing).[1] Starting from 7 December 2022,[2] the further relaxation of control measures (including the prohibition of regional mass testing and the implementation of home isolation or quarantine) triggered an unprecedentedly large Omicron wave in China, leading to a sharp increase in fatalities. The abrupt change of COVID control measures and the resulting surge of SARS-CoV-2 infection, hospitalization and death in China have raised great international concerns.[3]

The time-varying reproduction number (R_t), a measure of instantaneous transmissibility of an epidemic, is defined as the average number of secondary infections caused by a typical primary case at time t, after accounting for the population immunity and the impact of control measures. Reliable estimates of R_t are essential to understand how the transmissibility of COVID-19 changes after the relaxation of the public health and social measures. As the population-wide testing of SARS-CoV-2 was abandoned in mainland China from 8 January 2023, surveillance data about the daily number of new infections were lacking since then. To fill this gap, on 25 January 2023, the Chinese Center for Disease Control and Prevention (CDC) published a unique surveillance data estimating the daily hospitalization number of COVID-19 patients in hospitals from December 2022 to January 2023 in China.[4] Informed by these data, we evaluated the R_t for the 32 provincial-level administrative divisions in the study period, together with the number of daily new cases, to nowcast the epidemic growth of COVID-19 Omicron variant in China from December 2022 to January 2023.

We evaluated the time-varying reproduction numbers (R_t) of the COVID-19 Omicron outbreaks in mainland China at the 32 provincial-level administrative divisions (Figure 1, see **'Time-varying Reproduction Number Estimation' in Supplementary Methods**). The prevalence of hospitalizations peaked in early January 2023, with variations across administrative divisions. The peak prevalence of hospitalization (per 100 000 population) ranged from 22 in Tianjin to 390 in Ningxia.

Informed by the hospitalization data, we estimated the daily R_t at the provincial-level administrative divisions. We found that the initial R_t among the 32 study divisions ranges from 3.10 [95% confidence interval (CI): 2.71, 3.49] in Xinjiang Production and Construction Corps to 7.55 (95% CI: 4.48, 10.63) in Jiangsu province. Of these, the reported subvariants in the surveillance system mainly include BA.5.2 (70.2%), predominant in southern regions, and BF.7 (28.3%), predominant in northern regions.[4]

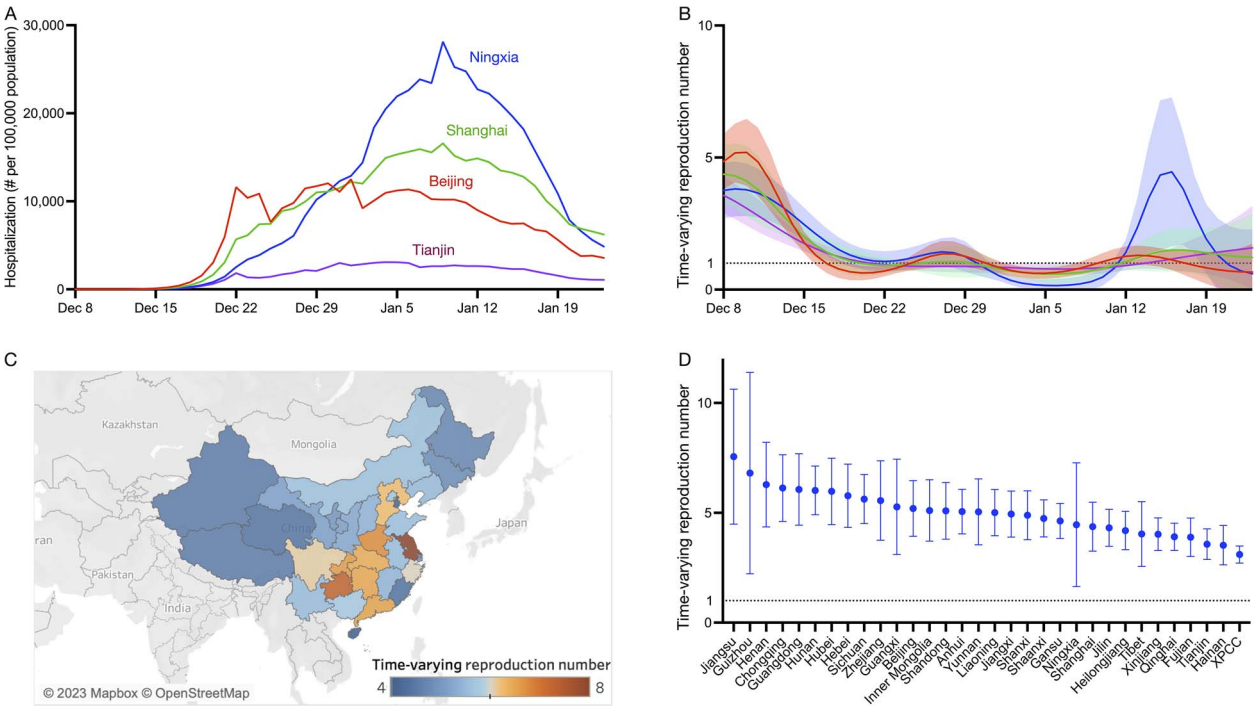

Figure 1. Estimated time-varying reproduction number of regions in mainland China between 8 December 2022 and 23 January 2023. (A) Hospital prevalence (# per 100 000 population) in Beijing, Shanghai, Tianjin and Ningxia between 8 December 2022 and 23 January 2023. (B, C, D) Time-varying reproduction number (R_t) in the provincial-level administrative divisions, estimated from hospitalization data. (B) Lines and shaded areas indicate the mean and 95% CI of R_t over time in Beijing (red) and Shanghai (green). (C) Mean estimates of initial R_t presented by provincial-level administrative divisions. (D) Mean and 95% CI of initial R_t estimates in the study period presented by divisions.

A meta-regression analysis was conducted based on the reported initial R_t estimates for the Omicron variant, which allowed us to explore the potential association between the location and R_t. High heterogeneity was observed among the provincial-level administrative divisions ($I^2 = 0.71$, $P < 0.01$) (Figure S1). The pooled estimate of initial R_t was 4.74 (95% CI: 4.41, 5.07) in 32 provincial-level administrative divisions.

From August 2021, China implemented a 'dynamic zero' COVID strategy until November 2022. This was followed by a rapid transition between partial relaxation on 11 November 2022, and complete opening-up on 7 December 2022. Considering the low vaccination rates among those over 80 years of age and the low population immunity acquired through previous infections, China's elimination of zero-clearance could trigger a wave of Omicron infection under a high transmission scenario that might result in over 90% of the population being infected as of 19 January 2023.[4] We found high heterogeneity of initial reproduction numbers across divisions in mainland China and the pooled estimate is 4.74 (95% CI: 4.41, 5.07).

China has its Spring Festival on 22 January 2023, for which residents and visitors normally make several billion trips throughout China to celebrate the Lunar New Year, starting on 7 January in 2023. However, given the early starting of nationwide loosening, the epidemic impact of the Festival travel might have fueled the transmission in provinces (e.g. Ningxia) (Figure 1A).

The basic reproduction number of the ancestral variant was estimated to be 3.15 (95% CI: 3.04, 3.26) during January 2020 in Chinese provinces,[5] and the initial reproduction number of the Omicron outbreak was estimated to be 3.44 (95% credible interval: 2.82, 4.14) in Beijing in mid-November 2022 based on Weibo and WeChat online polls. When the Omicron wave started in Beijing several weeks earlier than in other parts of mainland China,[6] our pooled estimate in this study is higher than those of earlier COVID-19 waves, denoting the unprecedented COVID-19 outbreak in mainland China given the low population immunity in December 2022.

Globally, in 2021 and 2022, the effective reproduction numbers of the Omicron outbreaks were estimated for South Africa, Denmark, China, England and India.[7] The mean estimates ranged from 2.43 to 5.11, with the pooled estimate being 4.20 (95% CI: 2.05, 6.35).[7] These estimates are close to our pooled estimates in mainland China, suggesting similar transmission efficiency across countries in the initial Omicron outbreaks.

Although the COVID-19 outbreak almost ended in China in late January 2023, the World Health Organization claimed that the COVID-19 pandemic continued to constitute a public health emergency of international concern on 27 January 2023.[8] We will provide an overview of key assumptions in this study. First, our model might be demographically biased by the surveillance system of China CDC,[4] which is based on sentinel hospitals. Criteria of hospital admissions and discharge might have changed when the hospitals reached their capacity, which might have biased the reproduction number estimates. Furthermore, considerable uncertainty remained regarding the lag between hospitalizations and infections. We appeal to the researchers to be careful about their conclusions when using this time-varying reproduction number. We expect that estimates for the time-varying reproduction number will improve as more granular epidemiologic data become available. However, our key qualitative insights are likely robust to these uncertainties.

Our study could inform the relevant governing authorities to make necessary choices regarding the prioritization of conventional and emergency health systems in the next pandemic. Given the transition from the zero-COVID policy to the major relaxation in a short period, China would be expected to prepare in advance by training millions of healthcare workers to care for mild COVID-19 cases and stockpiling antivirals. Compared with earlier COVID-19 waves in China, most people were infected in this outbreak in a short period, and the country has likely leaped from a containment phase to a recovery phase through the abrupt relaxation of control measures. The released surveillance data from Chinese CDC sentinel household surveillance system[4] should provide another opportunity to learn more about the resulting surge and reduce international concerns, after China disbanded its national case reporting system.[9]

Supplementary Data

Supplementary data are available at *JTM* online.

Funding

Financial support was provided by the National Natural Science Foundation of China (grant no. 72104208); General Research Fund (grant no. 17103122), Research Grant Council; Health and Medical Research Fund (grant no. 21200632) and HMRF Research Fellowship Scheme (grant no. 07210147), Food and Health Bureau; Government of the Hong Kong Special Administrative Region; the AIR@InnoHK Programme from Innovation and Technology Commission of the Government of the Hong Kong Special Administrative Region. The funders had no role in the design and conduct of the study; collection, management, analysis and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

Author Contributions

Yuan Bai, Zengyang Shao, Xiao Zhang, Ruohan Chen, Zhanwei Du: conceived the study, designed statistical and modeling methods, conducted analyses, interpreted results, wrote and revised the manuscript; Eric H Y Lau, Dong-Yan Jin, Tianmu Chen, Sheikh Taslim Ali, and Lin Wang: interpreted results and revised the manuscript.

Conflict of interest None declared.

Data availability

All data are collected from open source with detailed description in Supplementary Method.

Code availability

Code used for data analysis is freely available upon request.

References

1. Xinhua. China focus: China releases measures to optimize COVID-19 response. https://english.news.cn/20221111/d4399114a082438eaac32d08a02bf58d/c.html (accessed 19 April 2023).
2. Xinhua. China focus: COVID-19 response further optimized with 10 new measures. https://english.news.cn/20221207/ca014c043bf24728b8dcbc0198565fdf/c.html (accessed 19 April 2023).
3. Cowling B. The impact of ending 'zero COVID' in China. *Nat Med* 2023; **29**:302. https://doi.org/10.1038/d41591-023-00001-1.
4. Chinese Center for Disease Control and Prevention. COVID-19 Clinical and Surveillance Data–Dec 9, 2022 to Jan 23, 2023. China: CDC https://en.chinacdc.cn/news/latest/202301/t20230126_263523.html (accessed 19 April 2023).
5. Tian H, Liu Y, Li Y *et al.* An investigation of transmission control measures during the first 50 days of the COVID-19 epidemic in China. *Science* 2020; **368**:638–42.
6. Leung K, Lau EHY, Wong CKH, Leung GM, Wu JT. Estimating the transmission dynamics of SARS-CoV-2 omicron BF.7 in Beijing after the adjustment of zero-COVID policy in November-December 2022. *Nat Med* 2023; **29**:579–82. https://doi.org/10.1038/s41591-023-02212-y.
7. Du Z, Hong H, Wang S *et al.* Reproduction number of the omicron variant triples that of the Delta variant. *Viruses* 2022; **14**:821. https://doi.org/10.3390/v14040821.
8. Statement on the fourteenth meeting of the International Health Regulations. Emergency committee regarding the coronavirus disease (COVID-19) pandemic. 2005. https://www.who.int/news/item/30-01-2023-statement-on-the-fourteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic (accessed 19 April 2023).
9. National Health Commission of China. Declaration (Dec 25, 2022) *nhc.gov.cn* http://www.nhc.gov.cn/xcs/yqtb/202212/7272431ee60c4f4d953b0c16257c230e.shtml (accessed 26 December 2022).