International Journal of Infectious Diseases 138 (2024) 110–112

Contents lists available at ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

Short Communication

Assessing the transmission potential of mpox in East Asia during 2022-2023: A focus on Taiwan, China, Japan, and South Korea

Minjin Kim, Eunha Shim*

Department of Mathematics, Soongsil University, 369 Sangdoro, Dongjak-gu, Seoul 06978, Republic of Korea

ARTICLE INFO

Article history:
Received 21 July 2023
Revised 31 October 2023
Accepted 10 November 2023

Keywords:
Mpox
Reproduction number
Taiwan
China
Japan
South Korea

ABSTRACT

Objectives: This study aims to estimate the transmission potential of mpox in East Asia, focusing on the hardest hit nations: Taiwan, China, Japan, and South Korea.
Methods: We utilized six phenomenological dynamic growth models to fit the case incidence during the initial 30 epidemic days. The best-fit model was selected to calculate the reproduction number (R_t). Additionally, we used the latest case data and a Bayesian framework to compute the instantaneous effective R_t by applying the Cori et al. method.
Results: During the early phase, China demonstrated the highest estimated R_t of 2.89 (95% CI: 1.44-3.33); followed by South Korea, 2.18 (95% CI: 0.96-3.57); Japan, 1.73 (95% CI: 0.66-3.94); and Taiwan, 1.36 (95% CI: 0.71-3.30). However, by June 30, 2023, estimated R_t dropped below 1.00 in all countries: China at 0.05 (95% credible interval [CrI]: 0.02-0.10), Japan at 0.32 (95% CrI: 0.15-0.59), South Korea at 0.23 (95% CrI: 0.11-0.42), and Taiwan at 0.41 (95% CrI: 0.31-0.53), indicating the potential decline of the outbreak.
Conclusions: Our analysis shows effective containment by each country. It is crucial to sustain effective management to ensure the ultimate eradication of the outbreak.

Introduction

Mpox, a zoonotic viral disease, primarily transmits to humans through zoonotic interactions and direct skin or mucous membrane contact [1]. Increasingly, sexual transmission is reported, especially within certain demographics [1]. Until 2022, it was largely confined to specific African regions.

However, in early 2022, there was a global surge in its incidence in non-endemic countries, with notable penetration in Europe and North America, and subsequently, Asia. By June 30, 2023, East Asian nations such as Taiwan, China, Japan, and South Korea emerged as significantly impacted, with case counts of 198, 190, 186, and 117, respectively [1–4].

Understanding the magnitude of this mpox surge is crucial for strategic management. The effective reproduction number (R_t) signifies the average number of individuals that an infected person can infect in the presence of any disease control strategy. This study endeavors to determine the R_t in the most impacted East Asian countries, gauging the outbreak's severity and anticipating potential escalations.

* Corresponding author.
E-mail address: alicia@ssu.ac.kr (E. Shim).

Methods

Data

We collected publicly available data from reliable sources for the four countries [1–4]. For precise R_t estimation, symptom onset data is ideal, but only report dates were accessible. Therefore, an empirical distribution detailing the delay from symptom onset to diagnosis was employed to infer the missing onset dates. This led to 300 epidemic curves, producing a mean incidence curve presented based on report dates and symptom onset dates (Supplementary material).

Estimate of reproduction number in the early phase of the disease

During the initial 30 days after the first local case in each country, the R_t was determined (Supplementary Table 1). The R_t estimation utilized a MATLAB (MATrix LABoratory) toolbox, fitting epidemic growth using six phenomenological growth models (Figure 1) [5]. The best-suited model for each country was identified through performance comparison. Parameters and R_t were then estimated by calibrating the top-performing model to the outbreak's early growth phase using the mean serial interval from a previous study on mpox transmission [6].

https://doi.org/10.1016/j.ijid.2023.11.015
1201-9712/

Table 1
The best-fit model for each country and estimates and the corresponding 95% CIs for the effective reproduction number in the early phase of the outbreak and parameters of the model for data from Taiwan, China, Japan, and South Korea when using the best-fit model.

	Taiwan	China	Japan	South Korea
The best-fit model	Generalized logistic growth model	Richards model	Generalized growth model	Generalized logistic growth model
Growth rate, r	0.24 (95% CI: $1.6*10^{-1}$-$4.4*10^{-1}$)	0.17 (95% CI: $1.5*10^{-1}$-$1.9*10^{-1}$)	0.12 (95% CI: $1.0*10^{-3}$-$2.1*10^{-1}$)	0.21 (95% CI: $1.7*10^{-1}$-$2.6*10^{-1}$)
Scaling parameter, a	[a]	3.72 (95% CI: $6.7*10^{-1}$-$1.0*10$)	[a]	[a]
Growth parameter, p	0.68 (95% CI: $1.5*10^{-1}$-1.0)	[a]	0.91 (95% CI: $1.4*10^{-2}$-1.0)	0.95 (95% CI: $6.7*10^{-1}$-1.0)
Final cumulative epidemic size parameter, K_0	62 (95% CI: $2.0*10$-$9.2*10^{10}$)	35 (95% CI: $2.0*10$-$1.5*10^{4}$)	[a]	61 (95% CI: $2.3*10$-$9.4*10^{10}$)
Effective reproduction number, R_t	1.36 (95% CI: $7.1*10^{-1}$-3.3)	2.89 (95% CI: 1.4-3.3)	1.73 (95% CI: $6.6*10^{-1}$-3.9)	2.18 (95% CI: $9.6*10^{-1}$-3.6)

[a] The corresponding parameter is not included in its best-fit model.

Estimate of the effective instantaneous reproduction number

Although phenomenological growth models are commonly used to estimate initial R_t, the Cori et al. methodology is adept at determining the effective R_t, across the pandemic's duration. The estimation incorporates both domestic and imported cases, using the Cori et al. method, defining R_t as the ratio of new local infected cases at time t to the cumulative infectiousness of all infected individuals at time t [7]. Computation employed the *EpiEstim* package (version 4.0.3) in *R* software (The *R* Foundation for Statistical Computing, https://www.r-project.org) [7].

Results

Estimate of reproduction number in the early ascending phase of the epidemic

The Richards model provided the best fit for the initial phase of China's epidemic, while Japan's early outbreak data aligned well with the Generalized growth model (Table 1). Conversely, the Generalized logistic growth model was most appropriate for Taiwan and South Korea during the initial 30 days. Figure 1a visually demonstrates how the selected model corresponds with the average of the simulated epidemic curves, based on the date of symptom onset. The model's fit for each nation is detailed in Supplementary Table 2.

The growth parameter (r), which sets the timescale of the epidemic growth process, was estimated as 0.24 (95% CI: 0.16-0.44), 0.17 (95% CI: 0.15-0.19), 0.12 (95% CI: 0.0010-0.21), and 0.21 (95% CI: 0.17-0.26) for Taiwan, China, Japan, and South Korea respectively (Figure 1 and Table 1). The asymptotic total number of infections in the early epidemic wave, denoted by the final capacity K_0, was projected as 62 for Taiwan, 35 for China, 61 for South Korea (Table 1).

From the best-fit model, the R_t was deduced for each country in the outbreak's early phase. The findings reveal a swift initial spread across all four nations. China had the highest R_t at 2.89 (95% CI: 1.44-3.33), followed by South Korea at 2.18 (95% CI: 0.96-3.57), Japan at 1.73 (95% CI: 0.66-3.94), and Taiwan at 1.36 (95% CI: 0.71-3.30) (Table 1).

Estimate of the instantaneous effective reproduction number from the Cori et al. method

In the early stages of the epidemic, a marked reduction in the effective instantaneous R_t was evident across all four nations, as demonstrated in Figure 1b. In Taiwan, the R_t value fell below 1.00 by mid-March 2023 but saw an uptick in April 2023. By the end of June 2023, the R_t stabilized at 0.41 (95% credible interval [CrI]: 0.31-0.53). For China, the R_t trajectory initially depicted a decline, then exhibited an increase in mid-May 2023, and finally fell below 1.00 in early June. As of June 30, 2023, R_t was estimated 0.05 (95% CrI: 0.02-0.10). Japan's R_t first decreased below 1.00 in August 2022 but later saw a notable resurgence, making its trend the most variable among the countries analyzed. However, after a series of fluctuations, it settled from mid-May 2023, resulting in an R_t of 0.32 (95% CrI: 0.15-0.59) by June 30, 2023. For South Korea, the estimated R_t was below 1.00 in early May 2023. Following minor variations, it was estimated at 0.23 (95% CrI:0.11-0.42) by June 30, 2023. In summary, by June 30, 2023, the R_t values for all the studied countries remained under 1, highlighting the imperative of continuous, effective interventions to manage the epidemic's progression.

Discussion

This research investigated the transmission dynamics of mpox in the most affected East Asian countries: Taiwan, China, Japan, and South Korea. The study revealed that the Generalized logistic growth model effectively estimated early-phase transmission in Taiwan and South Korea. In contrast, the Richards model and Generalized growth model were most suitable for China and Japan, respectively. Our results highlight the rapid initial spread of mpox, underscoring the need for prompt interventions.

Using the Cori et al. method, we derived the effective instantaneous R_t across the epidemic, noting temporal R_t fluctuations. Earlier studies in European countries reported R_t values ranging from 2.32-2.88 [8,9]. Our early-phase estimates were consistent with these figures, but as the epidemic progressed, R_t values decreased, recently falling below 1.00, indicating effective disease control.

Various national measures are underway to control mpox. For instance, South Korea has prioritized vaccinations for high-risk groups and their close contacts since May 8, 2023 [10]. Significant transmission in high-exposure groups, especially among gay and bisexual men, implies these R_t estimates should be interpreted as R_t in this community rather than in the general population. A behavior shift in these groups might lead to case reductions.

Our study has limitations. The imputation of missing onset dates relied on an empirical distribution of reporting delays, with reconstructed epidemic curves. Reporting delays may vary across countries because of differing policies and demographics, affecting outcomes. Furthermore, the public data may lack full accuracy. The presence of undetected cases, either asymptomatic or unreported, could skew R_t estimations. Adjustments considering these undetected cases were made, as seen in Supplementary Material.

In this study, we observed that early R_t values in the analyzed East Asian countries exceeded 1, denoting rapid spread. By June 30, 2023, strategic public health responses reduced R_t values below 1.00 in all countries considered. Persistent and effective management remains essential to mitigate further mpox transmission.

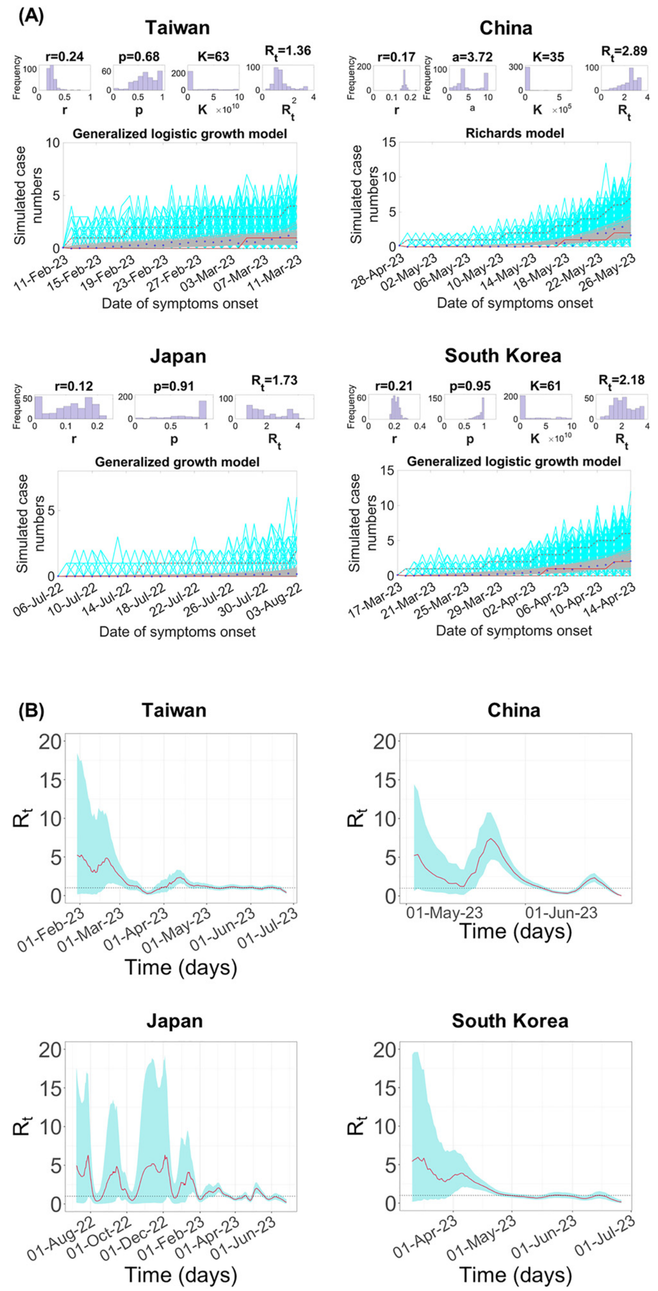

Figure 1. Reproduction number estimation for Taiwan, China, Japan, and South Korea. (a) For each country, in the upper panel, estimates of reproduction number using the best-fit model are provided for the early phase of the epidemic in the four countries. The plots in the lower panel depict the fit of the best-fit model to time-series incidence data during the first 30 days after the first local case was reported in each country. The blue circles indicate the average of the simulated epidemic curves by date of symptom onset, the solid red lines represent the average of the model fits obtained from the 300 bootstrap realizations, and the red dashed lines represent the 95% CI. The cyan lines represent the model fits obtained by bootstrapping. (b) The estimates of effective instantaneous reproduction numbers, determined by the Cori et al. method, are provided. The red line depicts the median value, with the cyan shading highlighting the associated 95% CrI.
CI, confidence interval; CrI, credible interval.
NOTE: Colors should be used in print.

Declaration of competing interest

Authors have no conflict of interest to declare.

Funding

This research was supported by the National Research Foundation of Korea (to MK and ES; NRF-2022M3A9I2017587) and the Basic Science Research Program through the National Research Foundation of Korea funded by the Ministry of Education (to ES; 2021R1A6A1A10044154). The funders of the study had no role in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Ethical approval

This study was conducted in accordance with the Declaration of Helsinki and was exempt from ethical approval because of a waiver that was granted by the Institutional Review Board of Soongsil University (SSU-202309-HR-381-1).

Author Contributions

ES was involved in the study's design, analysis, and interpretation of the study. MK retrieved the data and implemented the study. All authors wrote the first draft of the paper and gave their final approval for the manuscript.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijid.2023.11.015.

References

[1] World Health Organization. Mpox (monkeypox) outbreak: global trends 2022–23, https://worldhealthorg.shinyapps.io/mpx_global/; 2023 [accessed 07 September 2023].
[2] Ministry of Health, Labour and Welfare. Press release on mpox, https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/mpox_press-release.html; 2023 [accessed 21 July 2023].
[3] Korea Disease Control and Prevention Agency. Current Status of mpox (monkeypox) in South Korea, https://www.kdca.go.kr/contents.es?mid=a20108080000; 2023 [accessed 21 July 2023].
[4] Taiwan CDC. Press release on mpox, https://www.cdc.gov.tw/Category/NewsPage/XIyBaj7WM3xs94V4Q8cicg#; 2023 [accessed 17 September 2023].
[5] Chowell G, Bleichrodt A, Dahal S, Tariq A, Roosa K, Hyman JM, et al. A MATLAB toolbox to fit and forecast growth trajectories using phenomenological growth models: Application to epidemic outbreaks. Research Square. 21 April 2023. http://dx.doi.org/10.21203/rs.3.rs-2724940/v2 [accessed 21 July 2023].
[6] Madewell ZJ, Charniga K, Masters NB, Asher J, Fahrenwald L, Still W, et al. Serial interval and incubation period estimates of monkeypox virus infection in 12 jurisdictions, United States, May–August 2022. *Emerg Infect Dis* 2023;**29**:818–21. doi:10.3201/eid2904.221622.
[7] Cori A, Ferguson NM, Fraser C, Cauchemez S. A new framework and software to estimate time-varying reproduction numbers during epidemics. *Am J Epidemiol* 2013;**178**:1505–12. doi:10.1093/aje/kwt133.
[8] Guzzetta G, Mammone A, Ferraro F, Caraglia A, Rapiti A, Marziano V, et al. Early estimates of monkeypox incubation period, generation time, and reproduction number, Italy, May–June 2022. *Emerg Infect Dis* 2022;**28**:2078–81. doi:10.3201/eid2810.221126.
[9] Liu T, Yang S, Luo B, Fan X, Zhuang Y, Gao GF, et al. Anticipating the transmissibility of the 2022 mpox outbreak. *J Med Virol* 2023;**95**:e28683. doi:10.1002/jmv.28683.
[10] Korea Disease Control and Prevention Agency. Expanding vaccinations for high-risk groups of mpox, https://www.kdca.go.kr/board/board.es?mid=a20501010000&bid=0015&list_no=722482&cg_code=&act=view&nPage=1; 2023 [accessed 21 July 2023].