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Estimating the transmission dynamics of SARS-CoV-2 Omicron BF.7 in Beijing after adjustment of the zero-COVID policy in November–December 2022

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We tracked the effective reproduction number (R_t) of the predominant severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) variant Omicron BF.7 in Beijing in November–December 2022 by fitting a transmission dynamic model parameterized with real-time mobility data to (i) the daily number of new symptomatic cases on 1–11 November (when China's zero-COVID interventions were still strictly enforced) and (ii) the proportion of individuals who participated in online polls on 10–22 December and self-reported to have been test-positive since 1 November. After China's announcement of 20 measures to transition from zero-COVID, we estimated that R_t increased to 3.44 (95% credible interval (CrI): 2.82–4.14) on 18 November and the infection incidence peaked on 11 December. We estimated that the cumulative infection attack rate (IAR; that is, proportion of the population infected since 1 November) in Beijing was 75.7% (95% CrI: 60.7–84.4) on 22 December 2022 and 92.3% (95% CrI: 91.4–93.1) on 31 January 2023. Surveillance programs should be rapidly set up to monitor the evolving epidemiology and evolution of SARS-CoV-2 across China.

After implementing the 'zero-COVID' policy for more than two years, China has recently begun to adjust its coronavirus disease 2019 (COVID-19) response strategies, notably by announcing the 20 measures on 1 November and further the 10 measures on 7 December 2022 (refs. [1,2]). Although increasing vaccination coverage among the elderly and protection of high-risk groups were emphasized, the 20 measures included restricting testing coverage, cutting quarantine period for close contacts or inbound travelers and suspending the tracing of secondary contacts[1]. The 10 measures further prohibited region-wide mass testing, and home isolation or quarantine was allowed[2]. Since then, Omicron infections have spread rapidly in major cities in China, including Beijing, where the predominant SARS-CoV-2 variant, Omicron BF.7, has put great pressure on the healthcare system since early December[3,4].

Regular mass testing and intensive contact tracing were suspended in late November, and nucleic acid testing has been conducted on a voluntary basis thereafter[5]. As such, the daily number of confirmed cases reported by Beijing Municipal Health Commission (http://wjw.beijing.gov.cn/) was no longer an accurate reflection of the epidemic, making

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it difficult to assess the transmission dynamics. Here, we tracked the effective reproduction number of Omicron BF.7 in Beijing in November–December 2022 (refs. [6,7]) using our previous epidemic nowcast framework, which combined real-time mobility data and case data in the disease transmission models[8].

Effective reproduction number (R_t) of Omicron in Beijing

We categorized the COVID-19 response adjustments in Beijing into three stages:

i. Stage 1 (1–11 November): Zero-COVID strategy was strictly implemented with regular mass testing, intensive contact tracing and lockdown of residential buildings or communities once polymerase chain reaction (PCR)-positive infections and their close contacts were traced.
ii. Stage 2 (12–25 November): Although mass testing and contact tracing were maintained after the announcement of 20 measures on 11 November, lockdown was limited to the residential buildings or only the floors or units where people with PCR-positive infections lived.
iii. Stage 3 (after 25 November): The requirements of regular mass testing, intensive contact tracing and lockdown were gradually relaxed and finally suspended on 30 November. Nucleic acid testing is conducted on a voluntary basis after the announcement of 10 measures on 7 December.

We parameterized the disease transmission model with the daily number of passengers from Beijing Mass Transit Railway (MTR) and Beijing Subway, which collectively manage 22 of 27 rapid transit lines in Beijing (Fig. 1). We fitted the model to two data streams to estimate the effective reproduction number R_t: (i) the daily number of symptomatic cases reported to Beijing Municipal Health Commission between 1 and 11 November (Stage 1), when the testing and reporting behavior were relatively stable and (ii) the proportion of participants who self-reported to have ever tested positive by PCR or rapid antigen test (RAT) since 1 November, based on Weibo and WeChat online polls conducted via convenience sampling between 10 and 22 December (Fig. 1 and Extended Data Table 1). See Methods for details.

Within one week of the announcement of 20 measures, R_t increased from 1.04 (95% CrI: 0.84–1.29) on 11 November to 3.44 (95% CrI: 2.82–4.14) on 18 November (Fig. 2). In response to the increasing number of cases, public health and social measures (PHSMs) were implemented: residents were urged to stay home over the weekend of 19–20 November; 95% of staff were advised to work from home during the week of 21–25 November and kindergartens and primary and secondary schools were closed on 21 November. Consequently, mobility decreased, and R_t dropped to 0.99 (95% CrI: 0.83–1.16) on 27 November.

The surge of infections saturated the capacity of PCR testing and quarantine facility in late November. The requirement of regular mass testing, intensive contact tracing and lockdown were gradually relaxed and finally suspended with the announcement of 10 measures. PHSMs were relaxed and consequently R_t increased to 2.43 (95% CrI: 2.11–2.52) on 7 December (Fig. 2), which was substantially higher than R_t of 1.9 under similar PHSMs in the early stage of Hong Kong's Omicron wave in February–March 2022[9].

Omicron infections spread rapidly again starting from early December, and many symptomatic individuals and their close contacts self-isolated[10]. Within one week after the announcement of 10 measures, Beijing's mobility dropped to low levels, and we estimated that R_t dropped below 1 on 11 December and to 0.72 (95% CrI: 0.30–0.93) on 14 December. The mobility level started to increase in the week of 17–23 December, and R_t increased to 1.09 (95% CrI: 0.39–1.96) on 19 December. We estimated that R_t dropped below 1 again on 21 December due to depletion of the susceptible population (Fig. 2).

Daily incidence and cumulative infection attack rate

We estimated the daily incidence and cumulative infection attack rate from the fitted model accordingly (Fig. 2). On 30 November, when regular mass testing was suspended, we estimated the daily number of infections was 94,272 (95% CrI: 52,270–160,042) in Beijing. The daily incidence increased rapidly since then and peaked on 11 December, with an estimated daily number of infections of 1.03 million (95% CrI: 0.61–1.49; that is, 4.7% of the population).

We estimated that the cumulative IAR was 43.1% (95% CrI: 25.6–60.9) on 14 December. The daily incidence slightly decreased between 11 and 16 December but started to increase again on 17 December coincident with increased mobility. We estimated that the cumulative IAR reached 75.7% (95% CrI: 60.7–84.4) on 22 December. Assuming that the mobility and population mixing level would remain at the same levels after 22 December, we estimated the cumulative IAR would reach 92.3% (95% CrI: 91.4–93.1) on 31 January 2023 (Extended Data Fig. 1).

In the base-case scenario above, we assumed each participant of the online polls underwent multiple RATs and the ascertainment probability of previous infection was 1 after 11 November (Fig. 2). As such, the actual IAR was likely to be slightly higher than our base-case estimates. As a sensitivity analysis, we included the ascertainment probability in the inference framework (Extended Data Fig. 2). The resulting estimate of ascertainment probability was 81.5% (95% CrI: 78.9–84.2). The corresponding estimated R_t was slightly higher (for example, 3.92 (95% CrI: 3.19–4.73) versus 3.44 (95% CrI: 2.82–4.14) on 18 November and 3.05 (95% CrI: 2.63–3.24) versus 2.43 (95% CrI: 2.11–2.52) on 7 December). The estimated cumulative IAR was higher accordingly, reaching 55.1% (95% CrI: 34.3–73.5) on 14 December and 88.5% (95% CrI: 80.1–93.0) on 22 December. Assuming that the mobility and population mixing level would remain at the same levels after 22 December, we estimated the cumulative IAR would reach 96.2% (95% CrI: 96.1–96.3) on 31 January 2023.

Discussion

Our study tracked R_t of the Omicron BF.7 variant in Beijing by fitting an epidemic transmission model parameterized with mobility data to early-stage case count and recent survey data on cumulative incidence[8]. When mass testing and confirmation of all cases become impossible during the surge of infections, it is important to continuously monitor infection prevalence in the community through various surveillance programs, such as REACT-type studies in the United Kingdom and Hong Kong[11,12], wastewater surveillance[13] and serological surveillance[14]. Given the rollout of the second booster vaccines, data from such surveillance studies could also inform the assessment of vaccine effectiveness in real time[12,14].

By 22 December, we estimated that the Omicron epidemic had peaked in Beijing and 76% of the Beijing residents had been infected (Fig. 2). Assuming no changes in PHSMs or population behavior, we anticipated that the number of infections would start dropping toward the end of December and the pressure on the healthcare system would be alleviated in January 2023 (Extended Data Fig. 1). However, vaccination should be ramped up in the coming months in anticipation of new waves that might arise due to importation of different Omicron variants from increased population movement between Beijing and other provinces during the Spring Festival in January 2023.

Our study has several limitations. First, passenger statistics of Beijing MTR and Beijing Subway were the only real-time mobility data we found. These passengers only account for about 95% of Beijing's subway volume and might not be representative of the population using other transportation means. Second, the subway mobility data might not be the best proxy for changes in contacts and hence R_t. During the week of 8–14 December, most of the population stayed home or self-quarantined and only made contact with their household members[15]. Thus, it is difficult to accurately estimate the rapid

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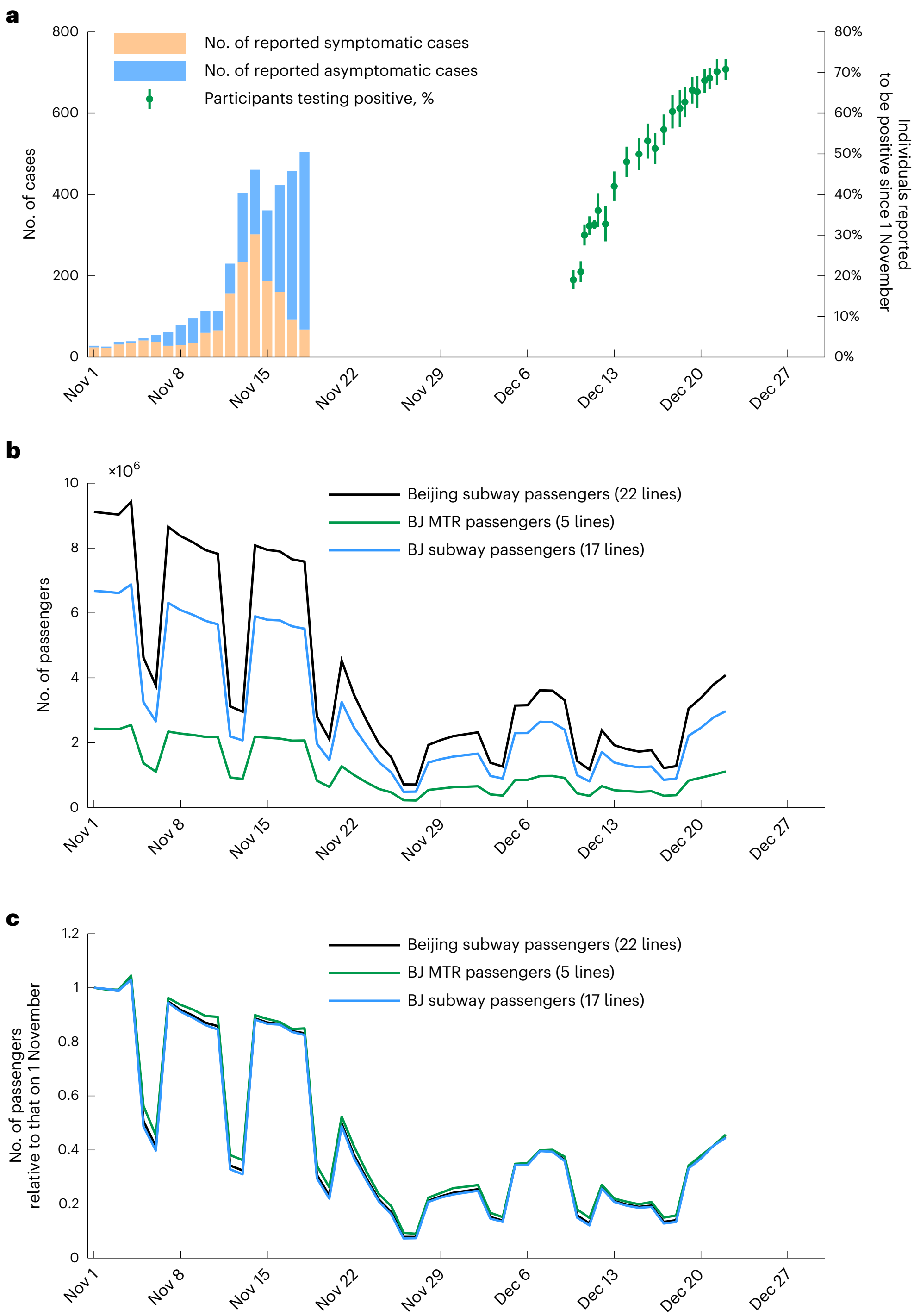

Fig. 1 | Data used in the inference. a, The daily number of reported symptomatic cases between 1 and 18 November (orange), the daily number of reported asymptomatic cases between 1 and 18 November (blue) and the proportion of participants of Weibo or WeChat polls who reported to have ever tested positive (PCR or RAT) between 10 and 22 December (green). The details of Weibo or WeChat polls are provided in Extended Data Table 1. The dots and bars in green indicate the mean and 95% confidence interval (CI) of the binomial proportions of the positive participants in the polls. **b**, The daily number of passengers of Beijing (BJ) subway lines managed by Beijing MTR (five lines, https://www.mtr.bj.cn/) and Beijing Subway (17 lines, https://www.bjsubway.com/). **c**, The daily number of subway passengers relative to that on 1 November. The daily number of passengers are provided in Extended Data Table 2.

changes in population mixing and PHSM effectiveness. Third, our estimation relied on IARs inferred from the results of Weibo and WeChat online polls. As most active Weibo or WeChat users are between 18 and 60 years old, the poll results might not be representative of all age groups. Self-reported infection status or test results can also introduce bias, and the ascertainment probability of infection was uncertain. Future refinements of our framework should include more reliable data to estimate IARs, such as age-specific seroprevalence data[14]

Given that COVID-19 response strategies have been adjusted nationwide, the number of new infections is expected to surge across China. The epidemics in other major cities and counties might be similar to that of Beijing with multiple incidence peaks, especially when

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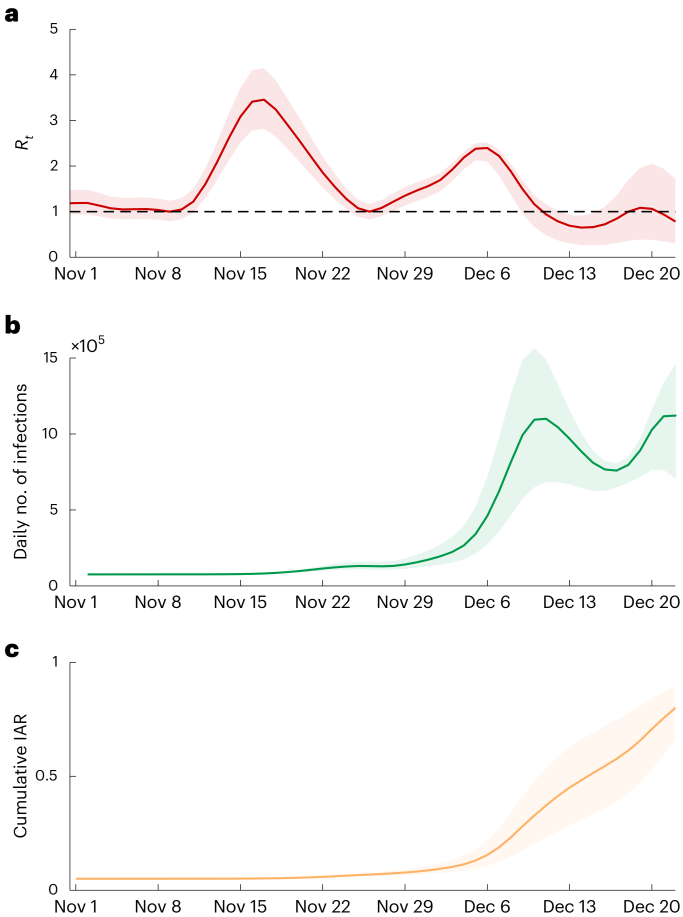

Fig. 2 | Estimated effective *Rt*, daily incidence and cumulative IAR in Beijing. **a**, Estimated R_t between 1 November and 22 December. Lines indicate the maximum a posteriori probability (MAP) estimates and shades indicate 95% CrI. **b**, Estimated daily number of infections between 1 November and 22 December. Lines indicate MAP estimates and shades indicate 95% CrI. **c**, Estimated cumulative infection attack rates between 1 November and 22 December. Lines indicate MAP estimates and shades indicate 95% CrI.

population mixing starts to increase after the first peak which is further exacerbated by the upcoming mass population movement during the annual Spring Festival. Surveillance programs should be rapidly set up to monitor the spread and evolution of SARS-CoV-2 infections; further work should be done to track the transmissibility, incidence and IAR of the epidemics.

Online content

Any methods, additional references, Nature Portfolio reporting summaries, source data, extended data, supplementary information, acknowledgements, peer review information; details of author contributions and competing interests; and statements of data and code availability are available at https://doi.org/10.1038/s41591-023-02212-y.

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Methods

Data

Ethics statement. The study was based on anonymized data that are publicly available. No ethical approval was required for use of the data.

Mobility data from Beijing Subway and Beijing MTR. Beijing Mass Transit Railway Operation Corporation Limited (https://www.bjsubway.com/, Beijing Subway) and Beijing MTR Corporation Limited (https://www.mtr.bj.cn/, Beijing MTR) operate 22 major lines out of 27 rapid transit lines in Beijing, which serve about 95% of the subway passengers daily. Both Beijing Subway and Beijing MTR publish the recorded daily number of trips regularly (https://weibo.com/bjsubway and https://weibo.com/bjmtr) and we obtained the data between 1 November and 22 December 2022, from their Weibo accounts (Extended Data Table 2).

Data from online polls conducted via Sina Weibo or Tencent WeChat. Since the announcement of 10 measures on 7 December 2022, verified Weibo and WeChat users have conducted online polls to track the proportion of participants who self-reported to be ever positive by PCR or RAT since 1 November, in view of the rapid increase of Omicron infections around them.

Sina Weibo has a verification policy to confirm the identity of a personal user or organization, similar to Twitter's account verification (https://kefu.weibo.com/faqdetail?id=37). On Weibo, verified users can create Weibo online polls (https://kefu.weibo.com/faqdetail?id=20533). Similar to Twitter polls, the default duration of Weibo polls is 1 day and the poll results are instantly displayed. Also, the poll creators are able to stratify the poll results by provinces inferred from the IP addresses where the participants voted.

Similarly, verified Tencent WeChat users can register as a public account, which enables them to interact with subscribers and provide them with services. WeChat online polls can be conducted in public accounts with results stratified by provinces inferred from IP addresses (https://kf.qq.com/faq/161221FN7fi6161221NRBJzq.html).

In this study, we included data from 22 cross-sectional online polls conducted on Weibo or WeChat by verified users whose polls were read more than 100,000 times nationwide within the day posted (Extended Data Table 1). Results of these polls were publicly available, and there were two to four options in most of the polls; for example:

i. Two-option polls (such as https://weibo.com/chinaetfs, 11 December)
   a. Option 1: I have tested positive in this wave (recovered or not yet recovered)
   b. Option 2: I have not tested positive in this wave
ii. Three-option polls (such as https://weibo.com/u/2987102112, December 10–14)
   a. Option 1: I have tested positive and recovered in this wave
   b. Option 2: I have tested positive but not yet recovered in this wave
   c. Option 3: I have not tested positive in this wave
iii. Four-option polls (such as https://weibo.com/u/7126731879, 10 December)
   a. Option 1: I have not tested positive
   b. Option 2: I have tested positive and recovered
   c. Option 3: I have tested positive but not yet recovered
   d. Option 4: I have tested positive twice

Transmission model

We used our previous age-structured Susceptible-Exposed-Infectious-Removed (SEIR) model to simulate the transmission of Omicron in Beijing[16]:

$$\begin{aligned}
\frac{dS_a(t)}{dt} &= -S_a(t)\sum_{b=1}^{m}\sum_{i=1}^{k}\beta_{ab}(t)I_{b,i}(t)\\
\frac{dE_a(t)}{dt} &= -\gamma_E E_a(t) + S_a(t)\sum_{b=1}^{m}\sum_{i=1}^{k}\beta_{ab}(t)I_{b,i}(t)\\
\frac{dI_{a,1}(t)}{dt} &= -\gamma_I I_{a,1}(t) + \gamma_E E_a(t)\\
\frac{dI_{a,2}(t)}{dt} &= -\gamma_I I_{a,2}(t) + \gamma_I I_{a,1}(t)\\
&\dots\\
\frac{dI_{a,k}(t)}{dt} &= -\gamma_I I_{a,k}(t) + \gamma_I I_{a,k-1}(t)\\
\frac{dR_a(t)}{dt} &= \gamma_I I_{a,k}(t)\\
N_a &= S_a(t) + E_a(t) + \sum_{i=1}^{k} I_{a,i}(t) + R_a(t),
\end{aligned}$$

where m was the number of age groups in the population; k=4 was the number of infectious states of the model; $S_a(t)$, $E_a(t)$ and $R_a(t)$ were the number of susceptible, exposed and removed individuals in age group a at time t; $I_{a,i}(t)$ was the number of individuals in the i-th infectious state of age group a at time t; N_a was the total number of people in age group a; $1/\gamma_E$ was the duration from exposure to become infectious; and k/γ_I was the duration of being infectious. The mean generation time was calculated as $T_{GT} = 1/\gamma_E + \frac{k+1}{2\gamma_I}$, following the formulation of Svensson[17].

Following our previous framework to parameterize SARS-CoV-2 transmission models with mobility data[8], we formulated the average rate at which an individual in age group a made infectious contacts with age group b at time t (that is, $\beta_{ab}(t)$ as

$$\beta_{ab}(t) = c_{ab}\gamma(t)\left(1 - e^{-g(t)}\right)$$

where c_{ab} was the contact rates between age group a and age group b from Mistry et al[18] and $g(t)$ was the normalized number of passengers of subway lines managed by Beijing Subway and Beijing MTR on day t (such that $g(t)$=1 on 1 November 2022). $\gamma(t)$ was the scaling factor for the mobility data proxy $g(t)$. Given the changes in PHSMs during the weeks of 12–25 November, we assumed $\gamma(t)$ was γ_1 between 1 and 11 November, increased linearly between 12 and 25 November from γ_1 to γ_2, and remained at γ_2 after 25 November. γ_1 and γ_2 were estimated in the parameter inference (Extended Data Tables 3, 4).

The time-varying next generation matrix for this SEIR model was:

$$NGM(t) = T_g\begin{bmatrix} \frac{\beta_{11}(t)S_1(t)}{N_1(t)} & \cdots & \frac{\beta_{1m}(t)S_1(t)}{N_1(t)}\\ \vdots & \ddots & \vdots\\ \frac{\beta_{m1}(t)S_m(t)}{N_m(t)} & \cdots & \frac{\beta_{mm}(t)S_m(t)}{N_m(t)}\end{bmatrix}$$

where T_g was the mean generation time.

The effective reproduction number R_t corresponded to the dominant eigenvalue of $NGM(t)$[19,20]. The incidence rate of infection and reported onsets at time t were calculated as follows:

$$A_{infection}(t) = \sum_a S_a(t)\pi_a(t)$$

$$A_{onset}(t) = p_{report}\int_0^t f_{incubation}(t-u)\left(\sum_a A_{a,infection}(u)\right)du,$$

where p_{report} was the proportion of infections ascertained and reported as symptomatic cases by Beijing Municipal Health Commission (http://wjw.beijing.gov.cn/). Similarly, the cumulative IAR at time t was calculated as follows:

$$IAR(t) = \int_0^v A_{infection}(u)du.$$

We assumed that the epidemic was seeded by M local infections on 1 November 2022.

Inference

The set of parameters that were subject to statistical inference, which we denoted by θ, included: (i) the seed size M, (ii) the scaling factors γ_1 and γ_2 and (iii) the ascertainment proportion p_{report} between 1 and 11 November (Extended Data Table 3). We estimated θ from (i) the daily number of symptomatic cases reported to Beijing Municipal Health Commission between 1 November and 11 (Fig. 1) and (ii) the proportion of participants who reported to be positive by PCR or RAT since 1 November in Weibo or WeChat online polls conducted between 10 and 22 December (Extended Data Table 1).

The likelihood function $L(\theta)$ is a product of the two components $L_1(\theta)$ and $L_2(\theta)$. $L_1(\theta)$ was formulated as below:

$$L_1(\theta) = \prod_t \left(\frac{A_{onset}(t)!}{n_{case}(t)!\,(A_{onset}(t) - n_{case}(t))!} p_{report}^{n_{case}(t)} (1 - p_{report})^{A_{onset}(t) - n_{case}(t)} \right),$$

where $n_{case}(t)$ was the daily number of symptomatic cases confirmed and reported by Beijing Municipal Health Commission between 1 and 11 November and $A_{onset}(t)$ was daily number of infections from the model convoluted by the incubation period distribution, assuming no onset-to-confirmation delay under mass testing and intensive contact tracing between 1 and 11 November. Similarly, assuming each participant of the online polls underwent multiple RATs and the ascertainment probability of infection was 100% after 1 November, $L_2(\theta)$ was formulated as:

$$L_2(\theta) = \prod_i \left(\frac{n_{pol,i}!}{n_{pos,i}!\,(n_{pol,i} - n_{pos,i})!} IAR(t_{pol,i})^{n_{pos,i}} (1 - IAR(t_{pol,i}))^{n_{pol,i} - n_{pos,i}} \right),$$

where $t_{pol,i}$ was the time or date when Weibo or WeChat online poll i was carried out, $n_{pol,i}$ was the number of participants of Weibo or WeChat online poll i and $n_{pos,i}$ was the number of participants of Weibo or WeChat online poll i who reported to have ever tested positive by PCR or RAT since 1 November.

However, the sensitivity of RAT ranges between 70% and 80% for Omicron and thus the ascertainment probability of infection could be less than 100% after 1 November[21]. In a sensitivity analysis, we assumed that the ascertainment probability of infection ($p_{ascertain}$) was not 100%, and estimated $p_{ascertain}$ and other parameters with the updated $L_2(\theta)$ as:

$$L_2(\theta) = \prod_i \left(\frac{n_{pol,i}!}{n_{pos,i}!(n_{pol,i} - n_{pos,i})!} (p_{ascertain} IAR(t_{pol,i}))^{n_{pos,i}} (1 - p_{ascertain} IAR(t_{pol,i}))^{n_{pol,i} - n_{pos,i}} \right),$$

$L(\theta)$ was formulated as follows:

$$L(\theta) = L_1(\theta) \times L_2(\theta).$$

Reporting summary

Further information on research design is available in the Nature Portfolio Reporting Summary linked to this article.

Data availability

We collated all data from publicly available data sources. All data included in the analyses are available in the main text or supplementary materials.

Code availability

All MATLAB codes are available at https://github.com/kathyleung/2022_12_24_Beijing_Rt_Omicron.

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Author contributions

All authors designed the study, developed the model, analyzed data, interpreted the results and wrote the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

Extended data is available for this paper at https://doi.org/10.1038/s41591-023-02212-y.

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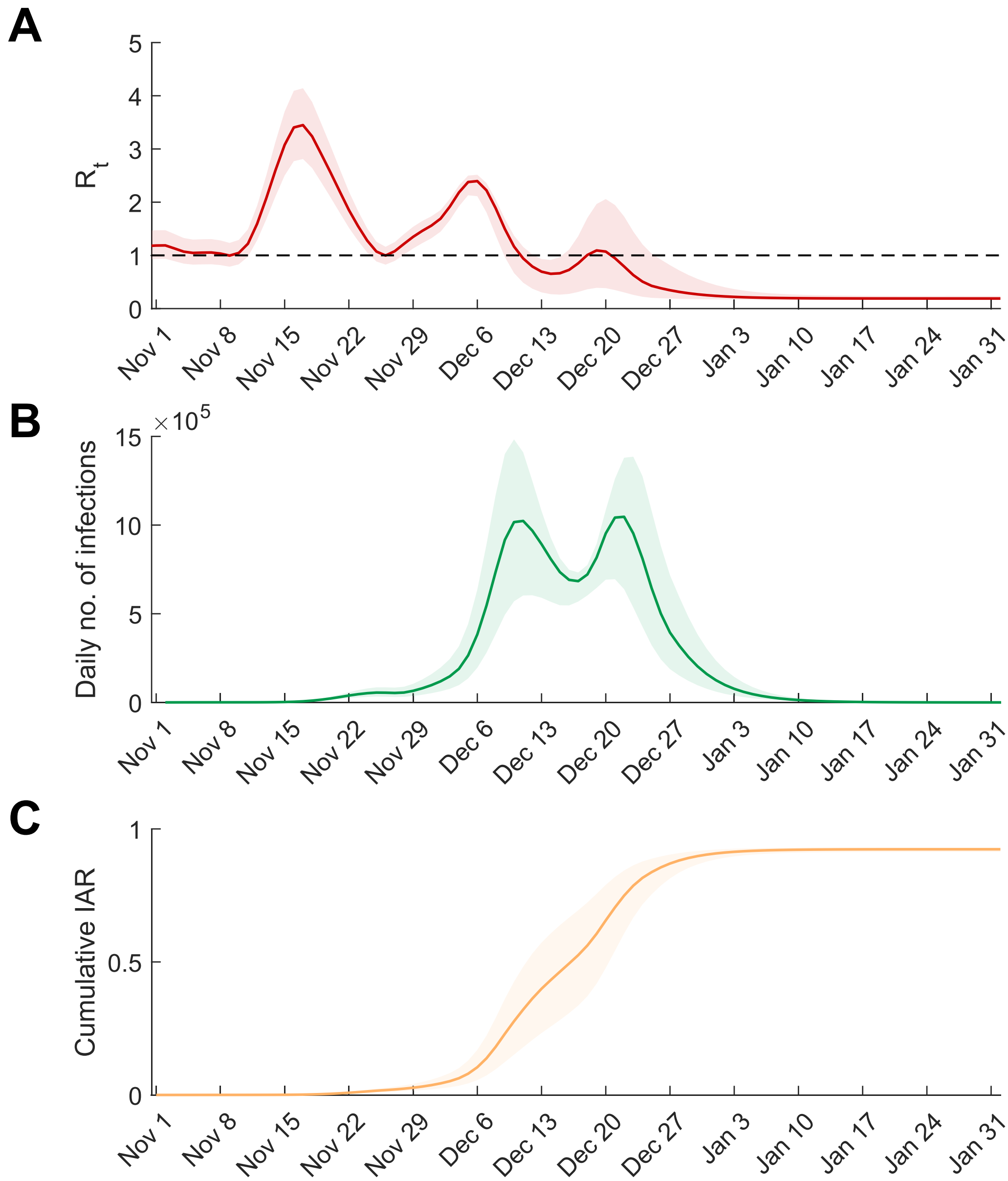

Extended Data Fig. 1 | Estimated R_t, daily incidence and cumulative infection attack rate in Beijing. a, Estimated R_t between 1 November, 2022, and January 31, 2023, assuming that the mobility and population mixing level would remain at the same levels of December 22 between December 23, 2022 and January 31, 2023. Lines indicate the *maximum a posteriori probability (MAP)* estimates and shades indicate the 95% credible interval (95% CrI). **b**, Estimated daily number of infections between 1 November, 2022 and January 31, 2023. Lines indicate the *maximum a posteriori probability (MAP)* estimates and shades indicate the 95% credible interval (95% CrI). **c**, Estimated cumulative infection attack rates between 1 November, 2022 and January 31, 2023. Lines indicate the *maximum a posteriori probability (MAP)* estimates and shades indicate the 95% credible interval (95% CrI).

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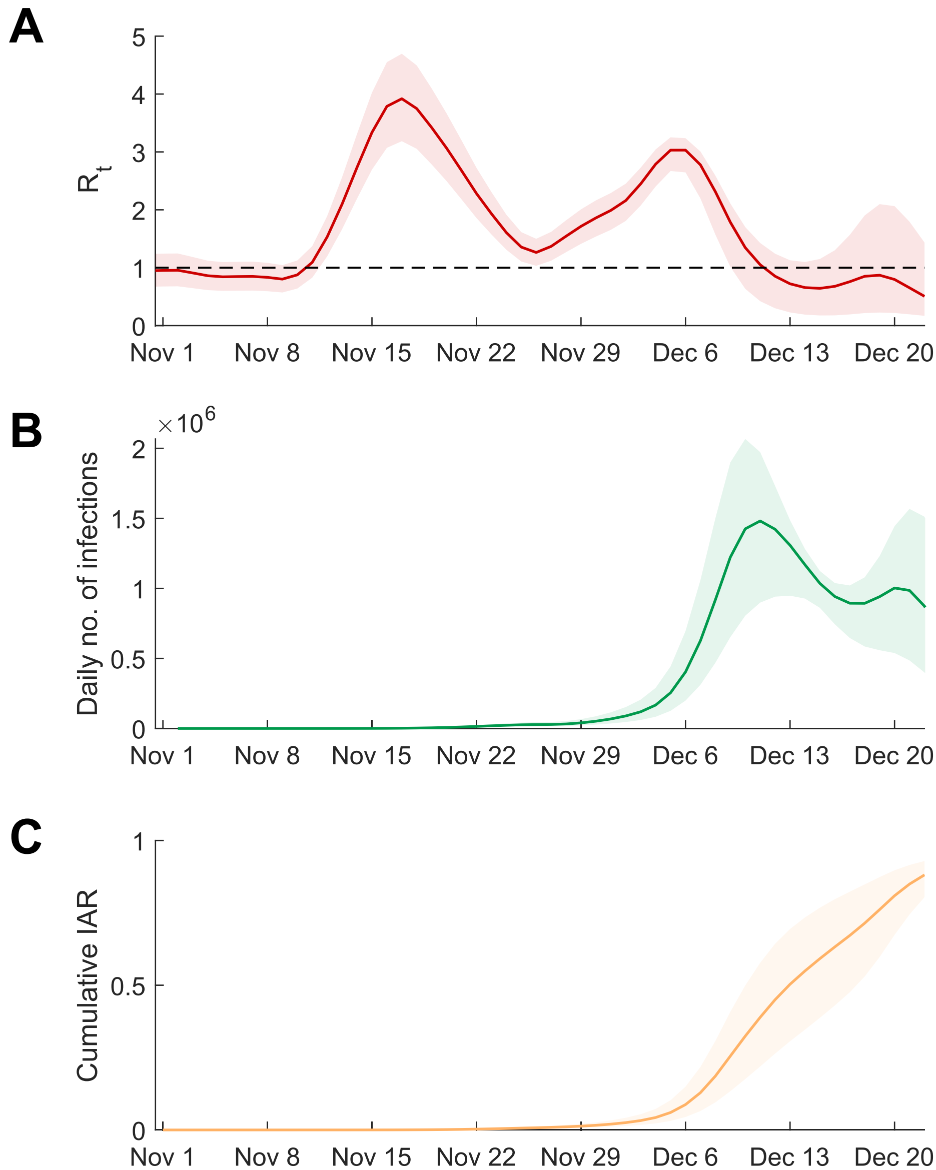

Extended Data Fig. 2 | Estimated R_t daily incidence and cumulative infection attack rate in Beijing when the ascertainment probability after 1 November was estimated in the inference. a, Estimated R_t between 1 November and 22 December. Lines indicate the *maximum a posteriori probability (MAP)* estimates and shades indicate the 95% credible interval (95% CrI). **b**, Estimated daily number of infections between 1 November and 22 December. Lines indicate the *maximum a posteriori probability (MAP)* estimates and shades indicate the 95% credible interval (95% CrI). **c**, Estimated cumulative infection attack rates between 1 November and 22 December. Lines indicate the *maximum a posteriori probability (MAP)* estimates and shades indicate the 95% credible interval (95% CrI).

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Extended Data Table 1 | The daily proportion of participants in Beijing who reported to have tested positive by PCR or RAT since 1 November in Weibo or WeChat online polls

Date	Proportion of participants who reported to be positive	No. of participants who reported to be positive	No. of participants	Source of Weibo/WeChat online polls
Dec 10	0.190	211	1110	https://weibo.com/u/2987102112
Dec 10	0.210	214	1021	https://weibo.com/u/7126731879
Dec 11	0.300	373	1243	https://weibo.com/u/2987102112
Dec 11	0.320	524	1622	https://weibo.com/chinaetfs
Dec 11	0.330	2296	7043	https://weibo.com/chinaetfs
Dec 12	0.360	199	552	https://weibo.com/u/2987102112
Dec 12	0.320	150	458	https://weibo.com/u/7126731879
Dec 13	0.420	311	740	https://weibo.com/u/2987102112
Dec 14	0.480	345	718	https://weibo.com/u/2987102112
Dec 15	0.499	331	663	https://weibo.com/u/2987102112
Dec 16	0.531	285	536	https://weibo.com/u/2987102112
Dec 16	0.513	348	678	https://mp.weixin.qq.com/s/PJuDlOcTon-WaWTRLIdXMw
Dec 17	0.560	389	695	https://weibo.com/u/2987102112
Dec 18	0.605	342	566	https://weibo.com/u/2987102112
Dec 18	0.612	281	459	https://mp.weixin.qq.com/s/PJuDlOcTon-WaWTRLIdXMw
Dec 19	0.628	430	685	https://weibo.com/u/2987102112
Dec 19	0.657	555	845	https://mp.weixin.qq.com/s/PJuDlOcTon-WaWTRLIdXMw
Dec 20	0.653	391	599	https://weibo.com/u/2987102112
Dec 20	0.681	656	964	https://mp.weixin.qq.com/s/PJuDlOcTon-WaWTRLIdXMw
Dec 21	0.686	857	1249	https://weibo.com/u/2987102112
Dec 21	0.703	583	830	https://mp.weixin.qq.com/s/6jSGzWt_kyd6K880gnQ6wA
Dec 22	0.708	861	1216	https://weibo.com/u/2987102112

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Extended Data Table 2 | The daily number of passengers of Beijing Subway including five lines managed by Beijing MTR Corporation Limited and 17 lines managed by Beijing Mass Transit Railway Operation Corporation Limited ('0000)*

Date	Passengers of 5 lines managed by Beijing MTR Corporation Limited	Passengers of 17 lines managed by Beijing Mass Transit Railway Operation Corporation Limited
11/1/2022	243.5	668.14
11/2/2022	241.9	665.35
11/3/2022	241.8	661.44
11/4/2022	254.5	688.01
11/5/2022	137	325.2
11/6/2022	110.5	265.85
11/7/2022	234.3	631.04
11/8/2022	228.1	608.73
11/9/2022	223.8	594.07
11/10/2022	218.1	575.84
11/11/2022	217.3	564.99
11/12/2022	92.8	219.41
11/13/2022	88.3	207.25
11/14/2022	218.8	589.57
11/15/2022	215.4	579.04
11/16/2022	212.7	577.11
11/17/2022	206.3	558.94
11/18/2022	206.9	551.43
11/19/2022	83.1	197.43
11/20/2022	63.8	147.13
11/21/2022	127.4	325.61
11/22/2022	100.5	246.89
11/23/2022	77.8	191.41
11/24/2022	57.6	140.05
11/25/2022	46.9	108.3
11/26/2022	22.8	48.77
11/27/2022	21.9	49.33
11/28/2022	54.4	138.99
11/29/2022	58.7	149.52
11/30/2022	63	157.22
12/1/2022	64.3	161.86
12/2/2022	65.8	166.36
12/3/2022	40.8	97.72
12/4/2022	36.9	89.69
12/5/2022	84.9	229.71
12/6/2022	85.6	230
12/7/2022	97.1	264.6
12/8/2022	97.6	262.9
12/9/2022	91.4	239.95
12/10/2022	43.9	100.15
12/11/2022	36.2	80.83
12/12/2022	66.1	171.78
12/13/2022	53.6	138.92
12/14/2022	50.8	129.62
12/15/2022	48.5	124.21
12/16/2022	50.5	126.64
12/17/2022	36.5	85.66
12/18/2022	38.4	89.35
12/19/2022	83.3	221.57
12/20/2022	92.3	246.03
12/21/2022	101.2	277.56
12/22/2022	111.2	297.2

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Extended Data Table 3 | Parameters fitted in the transmission model

Parameter	Description	Estimate (95% CrI)
γ_1	The scaling factor for translating the mobility data proxy into the contact matrix between November 1 and 11 (see methods)	0.0285 (0.0269 – 0.0304)
γ_2	The scaling factor for translating the mobility data proxy into the contact matrix after November 25 (see methods)	0.0951 (0.0942 – 0.0960)
M	The number of local infections on November 1 that might generate community transmission when the simulation was started	1562 (906 – 2292)
p_{report}	The proportion of infections ascertained as symptomatic cases by Beijing Municipal Health Commission	8.70% (6.84 – 11.65)

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Extended Data Table 4 | Fixed parameters in the transmission model

Parameter	Description, assumption, and source	Value
$1/\gamma_E$	Duration from exposure to becoming infectious	Assumed to be 1 day
T_{GT}	Mean generation time [1]	4.6 days Assumed to be normal distributed with the coefficient of variation of 0.05 when the posterior distributions of R_t and IARs were generated
VE_S	Vaccine effectiveness in reducing susceptibility	Assumed to be 0 since most of the vaccinations were given >8 months ago and most of the vaccines were inactivated virus vaccines
VE_I	Vaccine effectiveness in reducing infectiousness	Assumed to be 0
$f_{incubation}$	Probability density function of incubation period [2,3]	Gamma distribution Mean: 3.5 days SD: 2.6 days

nature portfolio

Corresponding author(s): Kathy Leung

Last updated by author(s): Dec 28, 2022

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Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	We collated all data from publicly available data sources. All data included in the analyses are available in the main text or the supplementary materials. All MATLAB codes are available at https://github.com/kathyleung/2022_12_24_Beijing_Rt_Omicron.
Data analysis	The data analysis was performed using MATLAB R2022b.

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We collated all data from publicly available data sources. All data included in the analyses are available in the main text or the supplementary materials.

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Policy information about studies involving human research participants and Sex and Gender in Research.

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Population characteristics	Not applicable. No human research participant was involved.
Recruitment	Not applicable. No human research participant was involved.
Ethics oversight	Not applicable. No human research participant was involved.

Note that full information on the approval of the study protocol must also be provided in the manuscript.

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Data exclusions	No data has been excluded. The study is an observational study and the analysis was based on observed data that are publicly available.
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Randomization	Observational study, no randomization
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☒	☐	Eukaryotic cell lines
☒	☐	Palaeontology and archaeology
☒	☐	Animals and other organisms
☒	☐	Clinical data
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Methods

n/a	Involved in the study	
☒	☐	ChIP-seq
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