Original Article

Distribution and Growth Rate of COVID-19 Outbreak in Tamil Nadu: A Log-linear Regression Approach

Adhin Bhaskar[1], Chinnaiyan Ponnuraja[2], Ramalingam Srinivasan[3], Srinivasan Padmanaban[1]

[1]Scientist B, [2]Scientist E, [3]Senior Technical Officer, Department of Statistics, National Institute for Research in Tuberculosis, Chennai, Tamil Nadu, India

Abstract

Background: Most of the countries are affected with the pandemic outbreak of the coronavirus infection. Understanding the severity and distribution in various regions will help in planning the controlling measures. **Objectives:** The objective was to assess the distribution and growth rate of COVID-19 infection in Tamil Nadu, India. **Methods:** The data on the number of infections of COVID-19 have been obtained from the media reports released by the Government of Tamil Nadu. The data contain information on the incidence of the disease for the first 41 days of the outbreak started on March 7, 2020. Log-linear model has been used to estimate the progression of the COVID-19 infection in Tamil Nadu. Separate models were employed to model the growth rate and decay rate of the disease. Spatial Poisson regression was used to identify the high-risk areas in the state. **Results**: The models estimated the doubling time for the number of cases in growth phase as 3.96 (95% confidence interval [CI]: 2.70, 9.42) days and halving time in the decay phase as 12.08 (95% CI: 6.79, 54.78) days. The estimated median reproduction numbers were 1.88 (min = 1.09, max = 2.51) and 0.76 (min = 0.56, max = 0.99) in the growth and decay phases, respectively. The spatial Poisson regression identified 11 districts as high risk. **Conclusion:** The results indicate that the outbreak is showing decay in the number of infections of the disease which highlights the effectiveness of controlling measures.

Key words: COVID-19 outbreak, decay rate, growth rate, Tamil Nadu

Introduction

The first COVID-19 positive case in Tamil Nadu was diagnosed on March 7, 2020, and the number of infection crossed thousand by April 12, 2020. Tamil Nadu is one of the states severely affected with the pandemic outbreak. This study is assessing the distribution and growth rate of COVID-19 infection in Tamil Nadu state, India

Materials and Methods

Log-linear model has been used to find the growth rate of COVID-19 outbreak in Tamil Nadu. The log-linear model can model the exponential growth or decay of the incidence of a disease over time by modeling the log of the count of infections as a linear function of time. The model can be written as:

$$\ln(y) = b + rt$$

where y is the count of cases, t is the time variable which is often days from the start of the outbreak, r is the growth rate, and b is the intercept. The log-linear model for infectious disease outbreak is implemented in R software (R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/) through the package incidence.[1] The model has been fitted to assess the growth rate as well as decay rate of the pandemic. Using the fitted model, the distribution of R_0, the basic reproduction number is also studied. The basic reproduction number is essentially an estimate of the average number of healthy people infected by a sick person.[2] Spatial Poisson regression model was used to

Address for correspondence: Dr. Adhin Bhaskar, Department of Statistics, National Institute for Research in Tuberculosis, #1, Mayor Sathiyamoorthy Road, Chetpet, Chennai - 600 031, Tamil Nadu, India.
E-mail: adhinb6001@gmail.com

Access this article online

Quick Response Code:

Website: www.ijph.in

DOI: 10.4103/ijph.IJPH_502_20

Submitted: 27-Apr-2020 **Revised:** 06-May-2020
Accepted: 11-May-2020 **Published:** 02-Jun-2020

How to cite this article: Bhaskar A, Ponnuraja C, Srinivasan R, Padmanaban S. Distribution and growth rate of COVID-19 outbreak in Tamil Nadu: A log-linear regression approach. Indian J Public Health 2020;64:S188-91.

estimate the population-adjusted relative risk (ARR) in each district as the crude estimates may give biased results.

Data

The data on the number of COVID-19 cases have been obtained from the media reports released at stopcorona.tn.gov.in by the Government of Tamil Nadu. The data on the infection were collected from the day of first COVID-19 positive diagnosis, March 7, 2020 to April 16, 2020. The data contained information of 1267 patients affected with COVID-19. Apart from the information on the number of COVID-19 cases, available information on gender, age, travel history, and district was also obtained from the media reports released by the state government. The published reports did not contain any personal identifying information of the patients.

Results

In Tamil Nadu, 1267 people were notified COVID-19 positive in 41 days through various sources such as travel and contact with the infected people. The outbreak was spread across 34 districts of the state, of which Chennai was the most affected district with 17.60% (n = 223) cases, followed by Coimbatore (10.03%, n = 127) and Tiruppur (6.56%, n = 83). The age of the first 180 patients was available, and the average age at onset of the infection was 43.34 (standard deviation [SD] = 13.57) years ranging from 10 to 76 years. The state witnessed an escalation in the number of COVID-19 infection by the end of March with more than fifty new positive cases every day.

As the calculated incidence did not account the population size in each district, spatial Poisson regression was used to calculate the ARR in each district. The ARR was calculated after adjusting the total population size in each district. Based on the estimates, the districts were classified as low-risk areas (ARR <1) and high-risk areas (ARR >1). The model identified 11 high-risk (hotspot) districts in Tamil Nadu, and they are Chennai (ARR = 3.54), Coimbatore (ARR = 2.49), Karur (ARR = 2.43), Tiruppur (ARR = 2.21), Theni (ARR = 2.18), Erode (ARR = 2.03), Dindigul (ARR = 1.96), Namakkal (ARR = 1.87), Nagapattinam (ARR = 1.50), Chengalpattu (1.31), and Trichy (ARR = 1.002).

The traveling history of the first 621 COVID-19 positive cases was released in the media bulletin, and 27 (4.35%) were observed to have traveling history to other countries and 537 (86.47%) had traveled to Delhi. There were 55 (8.86%) patients without any history of traveling. In addition, two patients had traveling history to Thiruvananthapuram (Kerala) and Andaman. The number of positive cases reached 969 by March 11, 2020, in which 747 (77.09%) were male and 222 (22.91%) were female. Although the number of infected females was less, Figure 1a shows that there was an escalation in the number of females with infection at later time points. The figure also shows that there was a sharp decline in the number of male positive cases.

The highest number of COVID-19 cases was observed on April 1, 2020, with 110 new positive cases. There was a slow decay in the number of the cases from April 2, 2020 onward. However, 102 and 106 new cases were diagnosed on April 3, 2020 and April 12, 2020, respectively. Apart from considering the observed peak in the incidence curve, the bootstrap method was also used to estimate the peak in the curve. The generated 100 bootstrap data sets also estimated the highest number of COVID-19 cases on April 1, 2020. The peak splits the curve into two parts as growth phase and decay phase. The distribution of the peak of the number of COVID-19 cases is presented in Figure 1b.

Two log-linear models have been fitted to model the growth phase before the peak and decay phase after the peak [Figure 1b]. The estimated growth rate before the peak was 0.18 (95% confidence interval [CI]: 0.09, 0.26) and the decay rate was −0.05 (95% CI: −0.10, −0.01). The growth and decay rates imply that the doubling time for the number of cases in growth phase is 3.96 (95% CI: 2.70, 9.42) days and halving time in the decay phase is 12.08 (95% CI: 6.79, 54.78) days. The decay phase is started after 26 days of the outbreak. However, the results show that the decay phase is having a slower pace.

The fitted log-linear models were also used to estimate the reproduction number, R_0 for the growth phase as well as the decay phase. The serial interval time of COVID-19 infection is reported to have mean 4.7 days with SD 2.9 days.[3] The serial interval time is the difference between the time of illness onset in an index case and time of illness onset in a secondary case. The serial interval time is assumed to have gamma distribution with mean 4.7 days and SD 2.9 days to estimate the reproduction number. The estimated median reproduction number in the growth phase was 1.88 (min = 1.09, max = 2.51), which is in line with the WHO estimate of R_0 (1.4–2.5). The value of R_0 is reported to be larger than the estimates of the WHO in severely affected countries like China (mean R_0 = 3.28).[4] The median reproduction number in the decay phase is estimated as 0.76 (min = 0.56, max = 0.99), which has been reduced by 40% in the decay phase compared to the growth phase. The reproduction number <1 indicates the decay in the pandemic outbreak.[5] The decay in the COVID-19 infection shows the success of the controlling measures such as lockdown, quarantine, and screening of suspected people implemented by the central and state governments and the health sector.

The state had screened 210,538 passengers till the closure of the airports. As on April 16, 2020, 100,031 were observed under home quarantine for 28 days, and a total of 26,005 samples were tested. The state also increased the number of COVID-19 testing facilities to 27, which was three till March 9, 2020. Figure 2 describes the frequency of positive cases and the count of patients who completed treatment successfully each day. The increase in the number of discharged patients and dip in the incidence are also confirming the slowdown of the outbreak and the success of the controlling measures. The

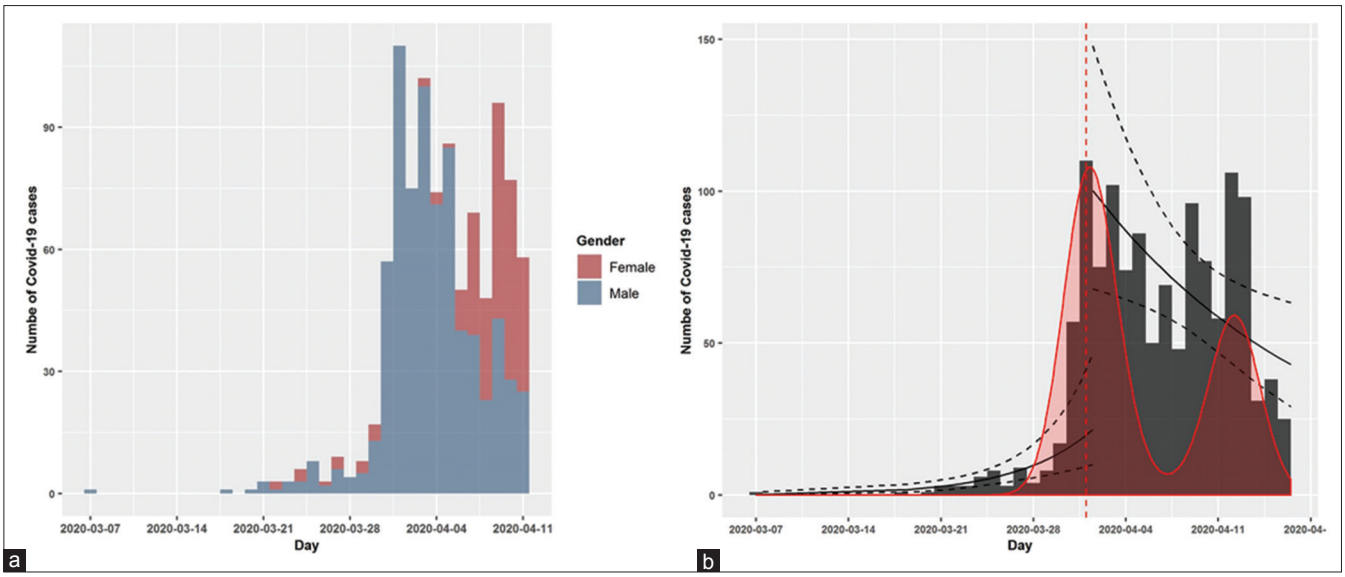

Figure 1: (a) The epidemic curve of COVID-19 in Tamil Nadu among males and females (n = 969). (b) The log-linear model fitted to estimate the growth rate of the number of COVID-19 positive cases in Tamil Nadu.

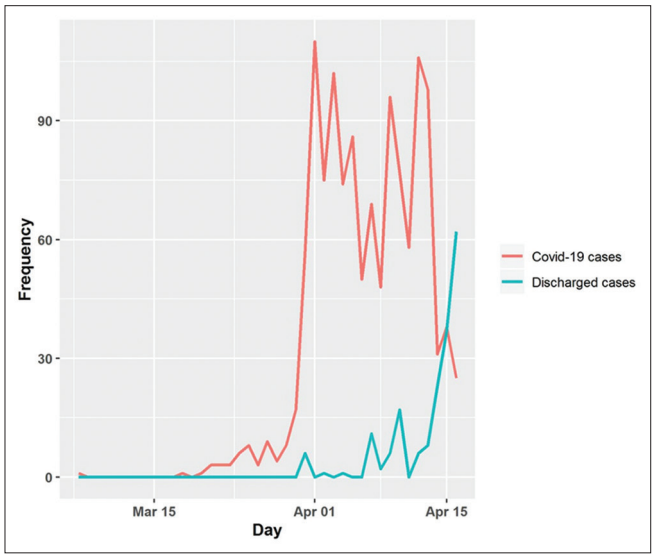

Figure 2: Progression of COVID-19 infection in Tamil Nadu.

figure shows that the count of new COVID-19 positives has gone below fifty in the late stages.

Discussion

This study has assessed the distribution of COVID-19 outbreak in Tamil Nadu. In addition, the growth rate and severity of the outbreak in the state since the outbreak started are also assessed. With the estimated reproduction number and doubling time, we could quantify the pace of the outbreak in Tamil Nadu. We have also observed that the pandemic started to decay which indicates the influence of the various controlling measures taken.

The log-linear model is one of the approaches used for modeling disease outbreaks. As the number of cases indicated an exponential growth, the log-linear model was used to assess the COVID-19 outbreak. The log-linear regression could model the decay phase and growth phase of the outbreak separately. Spatial models are useful for high-dimensional data, and Spatial Poisson regression was also employed to identify the spatial pattern as well as the high-risk districts.

In most of the countries rather than spreading uniformly, the disease has spread in the cluster where the index cases had close contacts and further expanded outside the cluster. In Tamil Nadu, although 34 districts were affected with the pandemic outbreak, only two districts had more than 10% of cases, and in 29 districts, the COVID-19 cases were limited to below 5%. However, there were 11 high-risk districts in the state as on April 16, 2020. The most affected district, Chennai, had the highest population density (26,553/km^2) as per 2011 census.[6] Coimbatore with 10.03% of cases had the density of 731 people per km^2 which is higher than the state population density (555/km^2).[7] The early call of lockdown was effective in reducing the contacts, thereby reducing the spread of the disease outside the clusters or restricting within the index cases and households.

The prevalence of the disease was low among women during the beginning of the outbreak. This might be due to the less exposure of women with the society or COVID-19 screening facilities. In Republic of Korea, the infection was reported with 62.3% of females cases, and in China, 51% of COVID-19 positive cases were male.[8] Another study showed that 40% of the positive cases diagnosed in China between January 13, 2020 and January 31, 2020 were female.[9] The late increase in the number of female cases in Tamil Nadu hints the spread of disease from the index cases within the family members or to close contacts.

A mathematical model developed for COVID-19 outbreak in India estimated that the R_0 will be 1.5 in an optimistic scenario

and 4 in a pessimistic scenario.[10] The study also reported that the measures will reduce the cumulative incidence of the disease by 62%. The estimates of R_0 from various studies in China and its provinces were reported to be ranging from 1.95 to 6.47 as the country experienced a severe outbreak.[4] Italy and Spain, the severely affected European countries, had the reproduction number as 3.27 and 5.08, respectively, by March 9, 2020.[11] Lower value of reproduction number in the growth phase obtained from the log-linear model shows that the outbreak of the disease did not go to an uncontrolled level in Tamil Nadu. When Tamil Nadu reported an average doubling time of 3.96 days in the growth phase of the pandemic, in China, the doubling time in various provinces was 1.4 days (Hunan), 3.1 days (Xinjiang), and 2.5 days (Hubei) during January 20, 2020–February 9, 2020.[12] Considering the serial interval of COVID-19 (mean = 4.7 days, SD = 2.9 days), the slowdown in the number infection from the 10th day of national lockdown (April 2, 2020) indicates the effectiveness of the social distancing strategy. In addition, the number of people completed treatment also started increasing.

This study was able to assess the distribution and trend of COVID-19 pandemic in Tamil Nadu with the available data. The findings might be useful for extending the COVID-19 controlling strategies in Tamil Nadu till the outbreak of the disease suppresses. The data used in the study did not have identifiers on gender, age, and traveling history for all positive cases as the pandemic outbreak is still active.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Kamvar ZN, Cai J, Pulliam JRC, Schumacher J, Jombart T. Epidemic curves made easy using the R package incidence. F1000Res 2019;8:139.
2. Holme P, Masuda N. The basic reproduction number as a predictor for epidemic outbreaks in temporal networks. PLoS One 2015;10:e0120567.
3. Nishiura H, Linton NM, Akhmetzhanov AR. Serial interval of novel coronavirus (COVID-19) infections. Int J Infect Dis 2020;93:284-6.
4. Liu Y, Gayle AA, Wilder-Smith A, Rocklöv J. The reproductive number of COVID-19 is higher compared to SARS coronavirus. J Travel Med 2020;27:1-4.
5. Khan A, Hassan M, Imran M. Estimating the basic reproduction number for single-strain dengue fever epidemics. Infect Dis Poverty 2014;3:12.
6. Directorate of Census Operations Tamil Nadu. District census Handbook 2011. Chennai: Directorate of Census Operations Tamil Nadu; 2014.
7. Directorate of Census Operations Tamil Nadu. District Census Handbook 2011. Coimbatore: Directorate of census operations Tamil Nadu; 2014.
8. Korean Society of Infectious Diseases, Korean Society of Pediatric Infectious Diseases, Korean Society of Epidemiology, Korean Society for Antimicrobial Therapy, Korean Society for Healthcare-associated Infection Control and Prevention, Korea Centers for Disease Control and Prevention. Report on the Epidemiological Features of Coronavirus Disease 2019 (COVID-19) Outbreak in the Republic of Korea from January 19 to March 2, 2020. J Korean Med Sci 2020;35:e112.
9. Sun K, Chen J, Viboud C. Early epidemiological analysis of the coronavirus disease 2019 outbreak based on crowdsourced data: A population-level observational study. Lancet Digit Health 2020;2:e201-e208.
10. Mandal S, Bhatnagar T, Arinaminpathy N, Agarwal A, Chowdhury A, Murhekar M, *et al*. Prudent public health intervention strategies to control the coronavirus disease 2019 transmission in India: A mathematical model-based approach. Indian J Med Res 2020;151:190-9.
11. Yuan J, Li M, Lv G, Lu ZK. Monitoring transmissibility and mortality of COVID-19 in Europe. Int J Infect Dis 2020;95:311-5.
12. Muniz-Rodriguez K, Chowell G, Cheung CH, Jia D, Lai PY, Lee Y, *et al*. Doubling Time of the COVID-19 Epidemic by Province, China. Emerg Infect Dis 2020;26.

Polybion®
ACTIVE

Provides **Energy**[1]

Supports **Immunity**[2]

BE ALWAYS ON

Ref: 1. Laquale, Kathleen M (2006). B-complex vitamins' role in energy release. In Movement Arts, Health Promotion and Leisure Studies Faculty Publications. Paper 25. 2. EFSA Journal 2011;9(4):2063