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Statistical models in trends of COVID-19 case fatality rates, India: a secondary data analysis

Abstract

Background: The COVID-19 is potentially severe acute respiratory infectious disease, increasing day by day. Hence, to control of COVID-19 cases and deaths due to, study has been under taken with an objective to establish the models of trends in COVID-19 Case Fatality Rates for states of India, so that containment performance is assessed taking model as reference level.

Materials and methods: The state-wise data from Kaggle website were used to study the levels and trends in Case Fatality Rate per 100 cases (Cured + Deaths) using Modified Logistic Regression Model, using SPSS-22 and Microsoft Office-10. The model is useful, where; deaths due to COVID-19 were more than one.

Results: Himachal Pradesh was the best in controlling the disease, as per COVID-19 Active Cases and Case Fatality Rate. In Himachal Pradesh, COVID-19 stabilized by 45 days of presence of the disease, while, in Kerala by 100 days. Furthermore, the decline in COVID-19 in Himachal Pradesh was steadier and smoother as compared to comparable state Kerala. The worst group of states in controlling the COVID-19 Case Fatality Rate in poorest to better order was Maharashtra followed by Delhi, Rajasthan, Uttar Pradesh and Bihar, along with wide fluctuation in Active Cases and Case Fatality Rates.

Conclusion: The worst affected state by COVID-19 was Maharashtra followed by Delhi, Rajasthan etc., reasons may be large movements of daily wagers/ temporary workers. Hence, the containment of COVID-19 is expected to be achieved by restriction in public movement and unrest in communities.

Keywords: COVID-19, case fatality rate, states of India, modified logistic regression

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Introduction

The novel Corona Virus Disease 2019 (COVID-19), is a potentially severe acute respiratory infection caused by the corona virus 2 (SARS-CoV-2). The physical manifestation is comprised of respiratory infection with symptoms ranging from mild common colds to a severe viral pneumonia, leading to acute respiratory distress, usually fatal in nature. The earliest case of COVID-19 was confirmed in December 2019 in Wuhan China.[1] At the beginning, the morbidity remained low and became noticeable in the middle of January 2020. During the second half of January, a remarkable increase of infected patients in affected cities occurred outside Hubei province, because of the population movement for Lunar Chinese New Year festivities.[2] The outbreak occurred with exponential spread to other countries by January end, 2020, attracting attention around the world. Evidence of clusters of infected family members and medical workers confirmed the presence of human to human transmission through droplets, contact and fomite.[3-5]

The first spread of this COVID-19 was started from Wuhan (China) and now, almost all the parts of the world are exposed to this virus, due to large infections of the virus. By lockdown, countries tried to identify the infected persons, so that infected subject are identified and isolated easily, along with sensitization of the masses and social distancing. In countries USA, Italy, Spain, India etc., the number of new cases increased many fold, even after declaration of lockdown. The COVID-19 cases followed different trends of increasing in different countries.[6] Globally, mortality rate due to COVID-19 was 2% as mentioned by WHO on 29th January, 2020, increased to about 3.4% by March 03, 2020.[7,8] Case Fatality Rate (CFR) in India was 3.1% (in red) as of May 18, was lowest among countries with more than 1 lakh cases, and much below the world average (6.6%). Among nations with more than 1 lakh cases, only Turkey and Russia had a lower CFR than India.[9]

Studies estimated lockdown extension by modelling the growth of COVID-19, using data from many countries by fitting exponential model.[10-12] Since, no infection/ disease can ever follow exponential distribution, due to self-diminishing properties of virus. Hence, it is challenging to model the growth and forecast the number of affected persons and deaths, though, there has been a long history of research in epidemiology of diseases in statistical modelling.[13,14]

To ease the burden of the Healthcare System, and providing the best possible care for COVID-19 patients, appropriate models are expected to help in estimation of the risk of Case fatality for better planning, monitoring and cure of the disease. Every disease, more so communicable acute, is expected to follow a pattern, usually, i) Acceleratory phase, ii) Optimum level and ii) De-acceleratory phase. Usually at the time of evaluation, the time, when data is available, the disease is expected to be in de-acceleratory phase. Hence, an attempt has been made to study the levels and trends of the COVID-19 Case fatality Rate in states of India, so that necessary action as lockdown, de-lockdown and standardization of line of treatment are taken at appropriate time, to optimise health and economic benefits.

Materials and methods

The COVID-19 data have been retrieved from the website of Kaggle,[15] which provided platform for extracting the data on novel corona virus diseases 2019 to help the global community and health organizations for better decisions. The website has been hosting a variety of tasks focused on better understanding about COVID-19 infectious disease. The data were extracted for the period 31st January to 1st May 2020, when national lockdown was going on in four phases; 1) 25 March 2020 – 14 April 2020 (21 days), 2) 15 April 2020 – 3 May 2020 (19 days), 3) 4 May 2020 – 17 May 2020 (14 days), 4) 18 May 2020 – 31 May 2020 (14 days).

The state-wise trends of COVID-19 in Case Fatality Rate per 100 cases (Cured + Deaths) have been studied in Indian states. COVID-19 Case Fatality Rate (CFR) followed Modified Logistic Regression Model as:

$$\log_e\left(\frac{CFR}{100-CFR}\right)=b_0+\frac{b_1}{t}$$

$$\text{Resulting in } CFR=\frac{b_0 e^{\frac{b_1}{t}}}{1+b_0 e^{\frac{b_1}{t}}}$$

Where,

b_0 and b_1 are Modified Logistic Regression Coefficients, b_0 is constant and b_1 measures change in Logit(CFR) from time t_i to t_{i+1}.

$$CFR=\frac{Deaths}{Cured+Deaths}\times 100$$

CFR- COVID-19 Case Fatality Rate

95% CI for COVID-19 Estimated Case Fatality Rate (Est. CFR) for CFR less than 20% and above 80% has been computed as:[16,17]

$$95\%\,CI=e^{\left(\log_e(Est.CFR)\pm 1.96\sqrt{\frac{1}{Estimated\ Deaths}-\frac{1}{Cure+Deaths}}\right)}$$

95% CI for Estimated Case Fatality (Est. CFR) between 20 to 80% has been computed as:[16,17]

$$95\%\,CI\ of\ Est.CFR=e^{\left(\log_e(Est.CFR)\pm 1.96\sqrt{\frac{Est.CFR(100-Est.CFR)}{n}}\right)}$$

The estimated Odds Ration has been computed as:[16,17]

$$Est.OR=e^{b_1\left(\frac{1}{t_i}-\frac{1}{t_{i+1}}\right)}$$, with its 95% Confidence Interval

$$95\%\,CI\ of\ Est.CFR=e^{\left(\log_e(Est.CFR)\pm 1.96\sqrt{\frac{1}{Expected\ deaths\ at\ t_i}+\frac{1}{Expected\ deaths\ at\ t_{i+1}}+\frac{1}{Expected\ cured\ at\ t_i}+\frac{1}{Expected\ cured\ at\ t_{i+1}}}\right)}$$

The R^2 for the above Modified Logistic Regression Model has been computed between $\log_e\left(\frac{CFR}{100-CFR}\right)$ and $\frac{CFR}{100-CFR}$.

The data on number of confirmed cases, cured and deaths available in public domain for the period 31st January to 1st May 2020, were analyzed by SPSS-22 and Microsoft Excel 2016 Statistical Software. The data from the day, where, deaths due to COVID-19 were more than one were considered for construction of the model. Modified Logistic Regression Model has been constructed using daily outcome of COVID-19 cases in Indian states. Coefficient of Determination (R^2) has been computed to ascertain predictability of the model.

For the purpose of presentation, the states of India have been divided in three groups, as per trends in Case Fatality Rate due to COVID-19 conforming to the suggested model; a) R^2 from ≥0.75, b) 0.50-0.75 and c) <0.50.

Results

Table 1 reveals COVID-19 cases treatment performance by states, the best state in controlling the COVID-19 was Kerala with 22 percent active cases followed by Himachal Pradesh (27.5%) and Assam (28.6%), and the worst was Gujarat with active cases 81 percent, preceded by Bihar (80.3%), Jharkhand (79.3%) and Maharashtra (78.7%). Furthermore, the trends in performance of the state of India in controlling of the COVID-19 have been analyzed using modified Logistic Model, so that unusual trends in cure of COVID-19 are traced and reasoned out.

Table 1 COVID-19 cured, deaths and confirmed cases by states of India, May 01, 2020

States	Cured	Deaths	Confirmed	Active Cases (%)
Kerala	383	4	497	110 (22.13)
Himachal Pradesh	28	1	40	11 (27.5)
Assam	29	1	42	12 (28.57)
Haryana	209	3	313	101 (32.27)
Tamil Nadu	1258	27	2323	1038 (44.68)
Telengana	441	26	1039	572 (55.05)
Karnataka	235	22	576	319 (55.38)
Jammu and Kashmir	216	8	614	390 (63.52)
Rajasthan	836	58	2584	1690 (65.4)
Delhi	1094	59	3515	2362 (67.2)
Punjab	90	19	357	248 (69.47)

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Table Continued...

States	Cured	Deaths	Confirmed	Active Cases (%)
Andhra Pradesh	403	33	1463	1027 (70.2)
Odisha	41	1	143	101 (70.63)
Uttar Pradesh	555	41	2281	1685 (73.87)
Madhya Pradesh	482	137	2719	2100 (77.23)
West Bengal	139	33	795	623 (78.36)
Maharashtra	1773	459	10498	8266 (78.74)
Jharkhand	20	3	111	88 (79.28)
Bihar	82	2	426	342 (80.28)
Gujarat	613	214	4395	3568 (81.18)

Table 2a-2c, Modified Logistic Regression Models for COVID-19 by States of India, reveals explanatory power of the Regression Models varying from 5.9 in Rajasthan to 94.4% in Jharkhand. The states of India have been classified in three groups by their Modified Logistic Regression model's explanatory powers; visibly 75% and above as best states followed by 50-75% and less than 50%. In the first group, the best state was Jharkhand followed by Himachal Pradesh, Madhya Pradesh etc. In the second group, the best state was Gujarat followed by West Bengal, Telangana and so on. Furthermore, Uttar Pradesh was best in the third group followed by Delhi, Bihar etc.

Table 2a Modified Logistic Regression Models for COVID-19 by States of India, $R^2 \geq 0.75$

Days	Observed	Estimated	Observed	Estimated
	Case Fatality Rate/100	Case Fatality Rate/100 (95% CI)	OR (95% CI)	OR (95% CI)
Jharkhand: R Square = 0.944, F = 116.99; $p < 0.001$, $b_0 = 0.006$, $b_1 = 96.11$				
31	23.6	16.28 (10.16, 26.08)	1	1
38	13.43	8.92 (4.15, 19.17)	1.99 (0.85, 4.68)	1.77 (0.64, 4.87)
Himachal Pradesh: R Square = 0.934, F = 398.5; $p < 0.001$, $b_1 = 74.23$, $b_0 = 0.006$				
17	77.78	54.29 (21.75, 86.84)	1	1
24	30.43	16.86 (6.81, 41.79)	8.00 (1.32, 48.65)	3.57 (0.65, 19.68)
31	7.78	7.73 (3.79, 15.79)	5.19 (1.60, 16.82)	2.01 (0.53, 7.66)
38	5.69	4.70 (2.12, 10.42)	1.40 (0.47, 4.14)	1.55 (0.50, 4.85)
45	4.14	3.35 (1.49, 7.53)	1.40 (0.48, 4.09)	1.36 (0.42, 4.42)
Madhya Pradesh: R Square = 0.895, F = 145.25; $p < 0.001$, $b_1 = 75.29$, $b_0 = 0.051$				
31	53.02	43.02 (39.10, 46.94)	1	1
38	35.96	30.60 (28.25, 32.95)	2.01 (1.66, 2.43)	1.56 (1.29, 1.90)
45	24.88	23.55 (22.08, 25.02)	1.70 (1.48, 1.94)	1.36 (1.19, 1.56)
Assam: R Square = 0.887, F = 109.475; $p < 0.001$, $b_1 = 56.57$, $b_0 = 0.005$				
24	9.46	6.75 (2.89, 15.74)	-	-
31	4.49	3.56 (1.57, 8.05)	2.22 (0.75, 6.59)	1.7 (0.49, 5.90)
38	3.41	2.40 (0.63, 9.10)	1.33 (0.34, 5.28)	1.4 (0.28, 6.98)
Kerala: R Square = 0.873, F = 220.43; $p < 0.001$, $b_1 = 384.70$, $b_0 = 0.000$				
66	4.59	5.10 (2.27, 11.46)	-	-
73	4.13	2.84 (1.52, 5.29)	1.12 (0.39, 3.17)	1.75 (0.6, 5.09)
80	1.62	1.74 (1.10, 2.74)	2.62 (1.28, 5.36)	1.59 (0.72, 3.5)
87	1.12	1.15 (0.76, 1.75)	1.46 (0.77, 2.78)	1.47 (0.79, 2.76)
94	1.08	0.81 (0.52, 1.27)	1.03 (0.58, 1.84)	1.39 (0.75, 2.57)
101	1.05	0.60 (0.24, 1.50)	1.03 (0.46, 2.28)	1.33 (0.48, 3.68)

Table Continued...

Days	Observed	Estimated	Observed	Estimated
	Case Fatality Rate/100	Case Fatality Rate/100 (95% CI)	OR (95% CI)	OR (95% CI)
Odisha: R Square = 0.866, F = 148.233; $p < 0.001$, b_1 = 153.15, b_0 = 0.001				
31	20	13.70 (5.58, 33.63)	1	1
38	5.11	5.05 (2.44, 10.44)	4.64 (1.43, 15.02)	2.48 (0.68, 9.04)
45	3.23	2.50 (1.09, 5.74)	1.62 (0.55, 4.71)	1.87 (0.6, 5.88)
52	2.56	1.50 (0.48, 4.68)	1.27 (0.40, 4.06)	1.58 (0.38, 6.64)
Karnataka: R Square = 0.808, F = 172.666; $p < 0.001$, b_1= 37.67, b_0 = 0.058				
17	63.64	46.03 (16.57, 75.48)	1	1
24	35.29	25.80 (11.10, 40.51)	3.21 (0.78, 13.22)	1.91 (0.46, 7.84)
31	26.51	18.17 (11.51, 28.69)	1.51 (0.64, 3.56)	1.43 (0.55, 3.68)
38	15.28	14.51 (10.59, 19.87)	2 (1.09, 3.66)	1.25 (0.64, 2.44)
45	12.38	12.42 (10.11, 15.26)	1.28 (0.83, 1.96)	1.17 (0.75, 1.81)
52	11.04	11.09 (9.38, 13.12)	1.14 (0.84, 1.54)	1.12 (0.83, 1.51)
59	8.86	10.18 (8.58, 12.08)	1.28 (0.97, 1.68)	1.09 (0.83, 1.42)
Jammu and Kashmir: R Square = 0.785, F = 124.243; $p < 0.001$, b_1= 118.95,b_0 = 0.007				
24	44.44	65.57 (34.53, 96.61)	1	1
31	43.75	31.61 (15.5, 47.72)	1.03 (0.23, 4.56)	3.06 (0.64, 14.63)
38	39.29	16.50 (9.15, 29.74)	1.2 (0.50, 2.90)	2.03 (0.73, 5.66)
45	12.05	10.08 (6.96, 14.61)	4.72 (2.45, 9.12)	1.63 (0.72, 3.68)
52	5.55	6.96 (5.26, 9.22)	2.33 (1.40, 3.88)	1.43 (0.86, 2.38)
59	4.01	5.24 (3.98, 6.89)	1.4 (0.88, 2.25)	1.31 (0.86, 1.99)
Andhra Pradesh: R Square = 0.781, F = 100.01; $p < 0.001$, b_1= 112.49, b_0= 0.015				
31	56	45.70 (26.17, 65.23)	1	1
38	38.21	27.37 (19.49, 35.25)	2.06 (0.86, 4.91)	1.95 (0.81, 4.69)
45	21.68	18.07 (15.18, 21.51)	2.23 (1.48, 3.38)	1.58 (1.01, 2.48)
52	12.57	13.08 (11.56, 14.79)	1.93 (1.51, 2.46)	1.40 (1.08, 1.81)
59	8.12	10.14 (8.24, 12.49)	1.63 (1.21, 2.18)	1.29 (0.98, 1.70)

Table 2b Modified Logistic Regression Models for COVID-19 by States of India, R^2= 0.50-0.75

Days	Observed	Estimated	Observed	Estimated
	Case Fatality Rate/100	Case Fatality Rate/100 (95% CI)	OR (95% CI)	OR (95% CI)
Gujarat: R Square = 0.745, F = 93.474; $p < 0.001$, b_1= 26.12, b_0 = 0.206				
17	66.67	57.09 (43.89, 70.30)	1	1
24	37.39	41.67 (35.19, 48.16)	3.35 (1.79, 6.27)	1.57 (0.86, 2.86)
31	35.06	34.36 (30.21, 38.52)	1.11 (0.8, 1.54)	1.28 (0.92, 1.77)
38	37.33	30.29 (27.79, 32.78)	0.91 (0.73, 1.12)	1.17 (0.94, 1.45)
45	30.06	27.73 (26.25, 29.20)	1.39 (1.21, 1.58)	1.11 (0.97, 1.28)
52	25.88	25.98 (22.99, 28.97)	1.23 (1.04, 1.46)	1.08 (0.91, 1.28)

Table Continued...

Days	Observed	Estimated	Observed	Estimated
	Case Fatality Rate/100	Case Fatality Rate/100 (95% CI)	OR (95% CI)	OR (95% CI)
West Bengal: R Square = 0.707, F = 69.982; p < 0.001, b_1= 32.34, b_0 = 0.076				
24	29.17	26.11 (15.97, 36.26)	1	1
31	21.2	19.39 (14.44, 26.03)	1.53 (0.82, 2.84)	1.36 (0.71, 2.57)
38	15.35	16.03 (12.99, 19.78)	1.48 (0.96, 2.29)	1.21 (0.78, 1.89)
45	15.16	14.06 (11.85, 16.70)	1.01 (0.74, 1.40)	1.14 (0.83, 1.57)
52	16.78	12.79 (10.07, 16.24)	0.89 (0.65, 1.21)	1.10 (0.78, 1.55)
Telangana: R Square = 0.691, F = 71.494; p < 0.001, b_1 = 192.67, b_0 = 0.002				
31	12.5	70.29 (38.62, 101.96)	1	1
38	43.28	37.40 (25.81, 48.99)	0.19 (0.02, 1.61)	3.14 (0.64, 15.49)
45	16.93	19.27 (15.36, 24.17)	3.74 (2.12, 6.6)	2.20 (1.25, 3.89)
52	10.97	11.03 (9.34, 13.02)	1.65 (1.17, 2.35)	1.78 (1.27, 2.49)
59	9.79	7.05 (5.94, 8.36)	1.14 (0.89, 1.45)	1.55 (1.19, 2.02)
66	6.82	4.92 (4.04, 5.99)	1.48 (1.17, 1.88)	1.41 (1.07, 1.87)
Tamil Nadu: R Square = 0.69, F = 78.057; p < 0.001, b_1 = 114.96, b_0 = 0.004				
24	22.22	51.11 (18.45, 83.77)	1	1
31	17.95	21.01 (8.22, 33.80)	1.31 (0.22, 7.68)	2.95 (0.65, 13.45)
38	29.92	10.48 (6.30, 17.42)	0.51 (0.21, 1.26)	1.98 (0.76, 5.16)
45	12.35	6.34 (4.72, 8.51)	3.03 (1.94, 4.73)	1.60 (0.84, 3.06)
52	3.2	4.38 (3.76, 5.09)	4.26 (3.16, 5.72)	1.41 (0.99, 2.00)
59	2.22	3.30 (2.93, 3.72)	1.46 (1.15, 1.85)	1.30 (1.06, 1.59)
Punjab: R Square = 0.564, F = 42.693; p < 0.001, b_1 = 87.11, b_0 = 0.066				
24	77.78	80.66 (58.58, 111.07)	1	1
31	78.79	59.65 (42.92, 76.39)	0.94 (0.16, 5.58)	2.27 (0.38, 13.65)
38	66.3	44.25 (34.10, 54.40)	1.89 (0.74, 4.83)	1.68 (0.75, 3.76)
45	37.14	34.39 (28.44, 40.34)	3.33 (2.01, 5.51)	1.43 (0.88, 2.33)
52	22.94	28.04 (24.10, 31.99)	1.99 (1.42, 2.77)	1.30 (0.93, 1.80)
59	19.14	23.79 (20.00, 27.57)	1.26 (0.92, 1.71)	1.22 (0.92, 1.62)
Haryana: R Square = 0.543, F = 29.738; p < 0.001, b_1 = 140.25, b_0 = 0.002				
38	1.79	8.68 (5.32, 14.18)	1	1
45	9.21	4.65 (2.58, 8.37)	0.18 (0.05, 0.61)	1.78 (0.78, 4.02)
52	4.33	2.94 (1.76, 4.90)	2.24 (1.20, 4.19)	1.52 (0.68, 3.42)
59	1.85	2.07 (1.39, 3.09)	2.40 (1.30, 4.44)	1.38 (0.71, 2.68)
66	1.42	1.58 (0.85, 2.91)	1.31 (0.60, 2.88)	1.29 (0.61, 2.71)

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Table 2c Modified Logistic Regression Models for COVID-19 by States of India, $R^2 < 0.50$

Days	Observed Case Fatality Rate/100	Estimated Case Fatality Rate/100 (95% CI)	Observed OR (95% CI)	Estimated OR (95% CI)
Uttar Pradesh: R Square = 0.154, F = 5.266; p = 0.029, b_1 = 20.48, b_0 = 0.074				
38	11.59	11.77 (7.45, 18.58)	1	1
45	10.27	10.79 (7.76, 15.01)	1.15 (0.60, 2.18)	1.09 (0.58, 2.05)
52	13.91	10.14 (8.21, 12.52)	0.71 (0.46, 1.09)	1.06 (0.69, 1.65)
59	9.09	9.67 (8.46, 11.05)	1.62 (1.25, 2.09)	1.05 (0.79, 1.38)
66	6.98	9.32 (8.02, 10.83)	1.33 (1.05, 1.70)	1.04 (0.83, 1.30)
Delhi: R Square = 0.116, F = 6.155; p = 0.017, b_1= 19.79, b_0 = 0.137				
17	40	35.98 (0, 78.04)	1	1
24	22.58	25.97 (10.53, 41.4)	2.29 (0.32, 16.51)	1.40 (0.19, 10.33)
31	16.33	21.70 (10.16, 33.24)	1.49 (0.48, 4.64)	1.20 (0.42, 3.45)
38	28.72	19.39 (12.84, 29.29)	0.48 (0.20, 1.17)	1.12 (0.48, 2.63)
45	33.19	17.96 (13.67, 23.61)	0.81 (0.48, 1.37)	1.08 (0.59, 2.00)
52	42.25	16.99 (14.15, 20.4)	0.68 (0.49, 0.93)	1.06 (0.71, 1.58)
59	6.97	16.29 (15.29, 17.36)	9.76 (7.99, 11.92)	1.05 (0.83, 1.32)
66	5.23	15.76 (14.81, 16.78)	1.36 (1.15, 1.60)	1.04 (0.93, 1.15)
Bihar: R Square = 0.098, F = 1.953; p = 0.179, b_0 = 0.028, b_1= 10.88				
31	3.79	3.91 (2.00, 7.63)	1	1
38	4.39	3.63 (2.06, 6.39)	0.86 (0.35, 2.08)	1.07 (0.43, 2.65)
45	3.14	3.45 (2.03, 5.87)	1.42 (0.65, 3.11)	1.05 (0.47, 2.34)
Maharashtra: R Square = 0.083, F = 3.259; p = 0.079, b_0 = 0.287, b_1= 15.78				
24	27.17	37.79 (27.88, 47.7)	1	1
31	27.54	33.48 (28.70, 38.27)	0.98 (0.59, 1.64)	1.16 (0.72, 1.86)
38	40.45	31.02 (28.59, 33.45)	0.56 (0.44, 0.72)	1.10 (0.86, 1.40)
45	39.07	29.44 (27.88, 31.00)	1.06 (0.93, 1.20)	1.07 (0.93, 1.22)
52	25.62	28.33 (27.3, 29.36)	1.86 (1.71, 2.03)	1.05 (0.96, 1.15)
59	21.7	27.52 (26.61, 28.44)	1.24 (1.16, 1.34)	1.04 (0.97, 1.11)
Rajasthan: R Square = 0.059, F = 1.445; p = 0.242, b_0= 0.032, b_1= 43.63				
45	12.5	8.31 (5.03, 13.73)	1	1
52	4.68	7.25 (5.92, 8.87)	2.91 (1.71, 4.94)	1.14 (0.63, 2.06)
59	8.76	6.53 (5.60, 7.61)	0.51 (0.38, 0.69)	1.10 (0.84, 1.45)
66	6.34	6.02 (5.26, 6.90)	1.42 (1.16, 1.73)	1.08 (0.87, 1.35)

In Table 2a-2c, classification of duration of COVID-19 disease has been classified by 7 days group intervals, however, the Modified Logistic Regression model has been constructed by the day of duration of infection.

Table 2a the best state as per COVID-19 Case Fatality Rate was Kerala, with average Case Fatality Rate in first seven days of the presence of disease 4.59 and OR of first seven days 1.12 as compared to next seven days, and decreased on 101 days to 1.05 per 100 COVID-19 cured and deaths with OR on preceding 7 days 1.05 as compared to just succeeding 7 days. Whereas, as per Coefficient of Determination (R^2), Jharkhand had highest (R^2=0.94) with respective COVID-19 Case Fatality Rate varying from 23.6 to 13.4 from in follow up period.

Table 2b with best state as per COVID-19 Case Fatality Rate was Haryana, average Case Fatality Rate in second seven days of the presence of disease was 9.21 with OR of third seven days 2.24 as compared to next seven days, and decreased on 66 days to 1.42 per 100 COVID-19 cured and deaths with OR on preceding 7 days 1.31 as compared to just succeeding 7 days. Whereas, as per Coefficient of determination (R^2), the best state was Gujarat (R^2=0.75) with respective COVID-19 Case Fatality Rate from 66.7 to 25.9.

Citation: Tyagi NK, Prasad JB, Patil AP. Statistical models in trends of COVID-19 case fatality rates, India: a secondary data analysis. *J Cancer Prev Curr Res.* 2021;12(3):97‒105. DOI: 10.15406/jcpcr.2021.12.00461

Table 2c with best state as per COVID-19 Case Fatality Rate was Bihar, average Case Fatality Rate in first seven days of the presence of disease was 3.79 with OR of second seven days 0.86 as compared to next seven days, and decreased on 45 days to 3.14 per 100 COVID-19 cured and deaths with OR on preceding 7 days 1.42 as compared to just succeeding 7 days. Whereas, as per Coefficient of determination (R^2), the best state was Uttar Pradesh (R^2=0.15) with respective COVID-19 Case Fatality Rate from 11.59 to 6.98.

Figure 1a, reveals that average COVID-19 Case Fatality Rate in Kerala could be computed after 65 days of first case with Case Fatality Rate around 4.2 per 100 (cured + deaths), thereafter, Case Fatality Rate remains constant around 15 days, and thereafter, it decreased and stabilized by 90 days at around 1 per 100 (cured + deaths). Whereas, COVID-19 Case Fatality Rate for Himachal Pradesh could be computed after 15 days with mortality rate as high as 78 per 100 (cured + deaths), and decreased consistently by 60 days at 5 per 100 (cured + deaths), stabilizing around at 40 days at around 3 (cured + deaths) (Figure 1b).

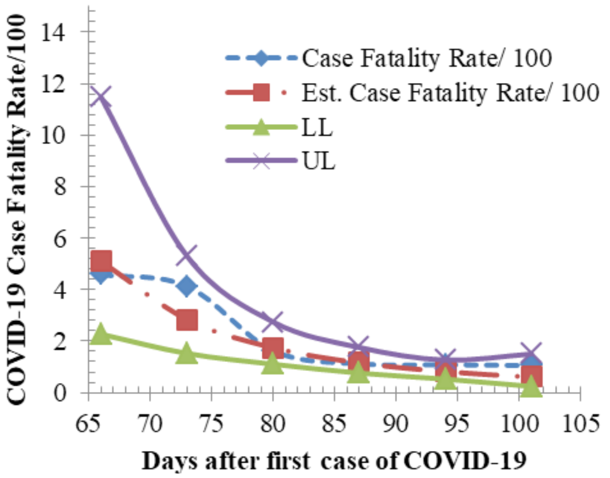

Figure 1a Average COVID-19 fatality rate, Kerala.

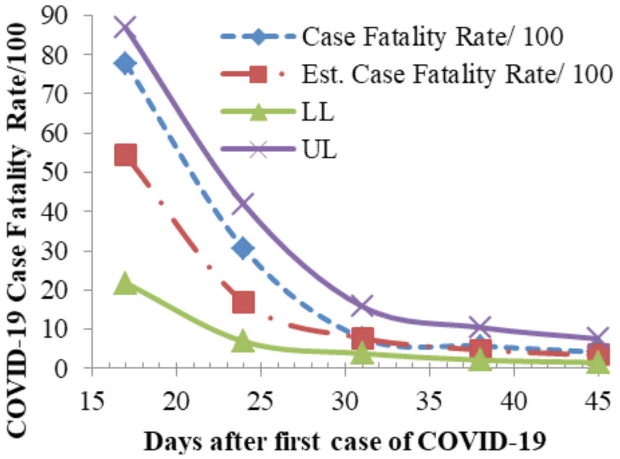

Figure 1b Average COVID-19 case fatality rate, Himachal Pradesh.

Note: LL, expected lower 95% confidence limit; UL, expected upper 95% confidence limit.

Figure 2a, reveals that average COVID-19 Case Fatality Rate in Gujarat could be computed after 15 days of first case with Case Fatality Rate around 66 per 100 (cured + deaths), thereafter, Case Fatality Rate decreased around 8 days, and thereafter, it slightly increased by 38 days at around 37 per 100 (cured + deaths). After 38 days, Case Fatality Rate started to decline by 52 days at nearly 26 per 100 (cured + deaths). However, COVID-19 Case Fatality Rate for West Bengal could be computed after 20 days with Case Fatality Rate as high as nearly 30 per 100 (cured + deaths), and decreased consistently by 40 days at 17 per 100 (cured + deaths), thereafter, steadily increased around at 55 days at around 20 per 100 (cured + deaths) (Figure 2b).

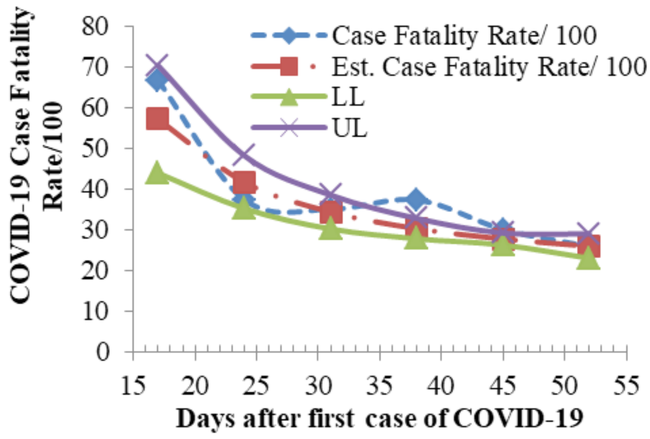

Figure 2a Average COVID-19 case fatality rate, Gujarat.

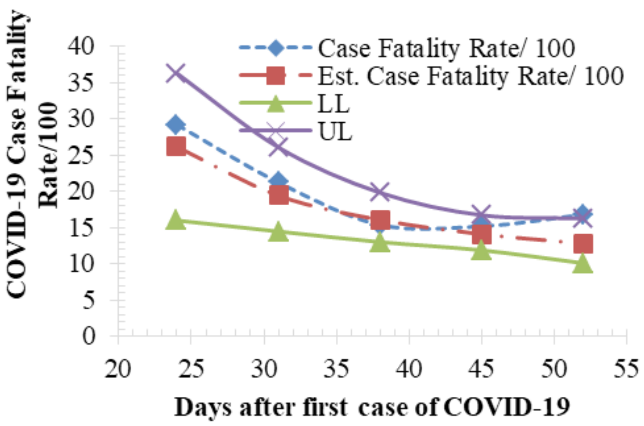

Figure 2b Average COVID-19 case fatality rate, West Bengal.

Figure 3a, reveals that average COVID-19 Case Fatality Rate in Maharashtra could be computed after 20 days of first case with Case Fatality Rate around 22 per 100 (cured + deaths). COVID-19 Case Fatality Rate remained constant up to 5 days. Thereafter, Case Fatality Rate increased two-fold in subsequent 10 days, thereafter, Case Fatality Rate decreased consistently up to 60 days, at around 21 per 100. The observed Case Fatality Rate did not remain in 95% Confidence Limits of the estimated Case Fatality Rate (Modified Logistic Regression Model).

Delhi COVID-19 Case Fatality Rate could be computed after 15 days of the first case, with Case Fatality Rate as high as around 40 per 100, and then decreased to 17 per 100 by 30 days. Thereafter, Case Fatality Rate again increased and reached to the level of 42 per 100 by 50 days of first cases. Thereafter, Case Fatality Rate followed usual pattern of decreasing with level of 5 per 100 at 60^{th} day. The observed Case Fatality Rate did not remain in 95% Confidence Limits of the estimated Case Fatality Rate (Figure 3b).

Citation: Tyagi NK, Prasad JB, Patil AP. Statistical models in trends of COVID-19 case fatality rates, India: a secondary data analysis. *J Cancer Prev Curr Res.* 2021;12(3):97‒105. DOI: 10.15406/jcpcr.2021.12.00461

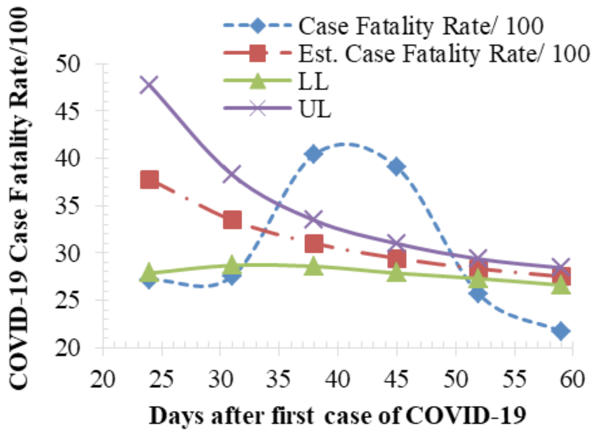

Figure 3a Average COVID-19 case fatality rate, Maharashtra.

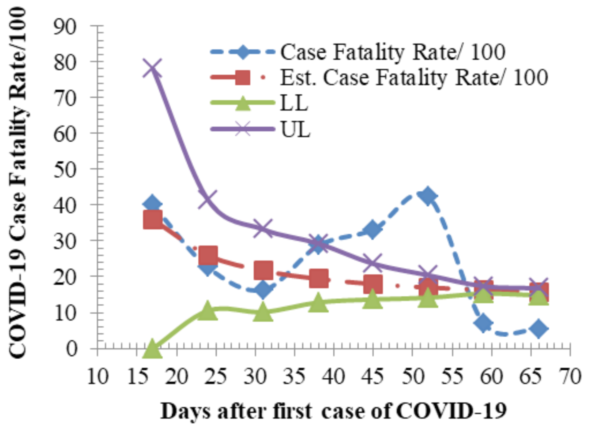

Figure 3b Average COVID-19 case fatality rate, Delhi.

Note: LL, expected lower 95% confidence limit; UL, expected upper 95% confidence limit.

Discussion

The physical manifestation consists of a respiratory infection with symptoms ranging from mild common cold to a severe viral pneumonia leading to acute respiratory distress (failure) that is potentially fatal. The initial symptom of the onset of COVID-19 was confirmed on December 2019.[1] Thereafter, the pandemic matures the numbers of cases, is rising at an alarming rate. First cases were reported from Wuhan, China and thereafter, on January 20, 2020 five countries Japan, Republic of Korea and Thailand along with China reported 282 cases, indicating spread and gravity of the disease, by January 30, 2020 almost 7818 Cases and 170 deaths were reported from 19 countries, including India. By April 06, 2020 pandemic spreading in 210 nations.[18]

The first case of COVID-19 in India was reported on 30th January, 2020 from Kerala, the subject was known to have visited Wuhan, China, thereafter, two more cases were detected, though, they also have visited Wuhan, China. Furthermore, 16 Italian tourists were found positive with COVID-19, making the disease as pandemic. Many researchers took interest in predicting further aggravation of the on slot of the disease. Looking at the diseases spread government of India declared first phase of lockdown.

Third degree and quadratic polynomials along with exponential regression models have been used to study the trends of COVID-19 effectively in the states of India.[12,19,20] However, these models have been used to study the trends in COVID-19 cases. In the present study Modified Logistic Regression Model has been successfully used to assess the Case Fatality Rate due to COVID-19. Bhattacharya et al. (2020) have used fourth degree polynomial in COVID-19 Case Fatality Rates, and indicated that model is best fitted for Italy, China and Spain.[20] Usually four and above order polynomial are used to study the reoccurrence of disease. Furthermore, stochastic transmission model was used to study COVID-2019 transmission over time in Wuhan during January to February, 2020.[21] However, Ghosal et al. (2020) had predicted the number of deaths in India with Linear Regression Model.[22] The linear Regression Model assumes ever increasing trends with the same speed, usually not suitable to study trends in communicable diseases in the beginning of endemic.

The best state in controlling the COVID-19 as per percent active cases was Kerala with 22 percent active cases and Case Fatality Rate 1.05 per 100 (cured + deaths) as on May 1, 2020. However, as per Modified Logistic Regression Model fit (Coefficient of Determination) the Kerala (87.3%) was fifth, well below Jharkhand (94.4%), Himachal Pradesh (93.4%) etc. The worst group as per fitting of the Modified Logistic Regression Model was comprised of Rajasthan (5.9%), Maharashtra (8.3%), Bihar (9.8%) etc. with fluctuating active cases and Case Fatality Rate. However, as per control of COVID-19 as assessed by active cases and Case Fatality Rate, Maharashtra was the worst with wide fluctuation in Case Fatality Rate and active cases followed by Delhi, Rajasthan etc.

As a standard rule in practice of the treatment, if health services are adequate, then Case Fatality Rates are expected to decline and stabilize by time, under the assumption that the severity of the disease remains constant. The reasons of the Case Fatality Rate fluctuation cannot be reasoned out by available data. However, as per news and discussion (media), the reasons of fluctuations in Case Fatality Rate, seem to be unrest due to movement of Labour and population density slum of the cities.

Conclusion

Himachal Pradesh was the best in controlling the disease, if the event of the COVID-19 disease active cases and rate is studied by time, the COVID-19 stabilization by Himachal Pradesh was achieved by 45 days of presence of the disease, whereas, the same level was achieved in Kerala by 100 days. Furthermore, the declined in COVID-19 in Himachal Pradesh was steady and smoother as compared to comparable state Kerala. The worst group of states in controlling the COVID-19 disease (active cases and Case Fatality Rate) in order of poorest to poor was comprised of Maharashtra, Delhi, Rajasthan, Uttar Pradesh and Bihar along with wide fluctuation in active cases and Case Fatality Rate. Furthermore, these were the states, where large movements of daily wagers/ temporary workers were observed. The end result could have been much- much better, if the movement of the Labour was restricted. Appropriate model is useful in estimation of the risk of Case fatality for better planning, monitoring and cure of the disease, so that the burden on Healthcare System, and Healthcare provider of COVID-19 patients is eased.

Availability of supporting data

The state-wise data available on Kaggle website were used to study the trends in Case Fatality Rate per 100 cases (Cured + Deaths) in Indian states.

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Competing interests

The authors declare that they have no conflict of interest.

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