

Analysis of COVID-19 Case Fatality Rates in the States and Union Territories of India

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Research Article

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Abstract

Although the Covid-19 Case Fatality Rate (CFR) in the Indian States and UTs has been changing with time, some states constantly appear to show significantly higher CFR than the national average. Our objective is to calculate the CFR of all the states/UTs of India and analyse the possible factors behind the disparities in it. Research papers and news articles on Covid-19 were explored to understand the factors responsible for the CFR disparities in the States/UTs. State-wise CFR was calculated and Correlated with Covid-19 Testing Rates and data from Demographic & Healthcare factors, using Spearman's Rank Correlation Coefficient Methodology. The overall Covid-19 CFR in India was among the lowest (1.76%) in the world but varied vastly from one state to another. Where the states like Punjab and Maharashtra constantly have the highest CFR in the country, states like Assam, Kerala, and Bihar have the lowest. In the correlation analysis, a weak agreement (+0.33) between state-wise CFR and 'Test Positive Rate' was found. CFR and 'Life Expectancy at 60' showed a moderate agreement (+0.49). Healthcare components like 'Number of Doctors Per Million People' and 'Number of Hospital Beds' showed very weak agreement with CFR. Where the higher Life Expectancy and Test Positive Rates clearly tend to increase CFR, Healthcare Facilities had surprisingly little effect on it. Analyses of various news articles suggested that Comorbidities, Availability of Essential Drugs, Trained Manpower, Contact Tracings, and Hospital Referral Time were also some of the major factors affecting CFR.

1. Introduction

Coronavirus Disease 2019 (Covid-19) is an infectious disease caused by a newly discovered coronavirus called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) ¹. The first case of Covid-19 in India was reported on 30th January 2020 in the state of Kerala ². By October 9, 2020, the total number of confirmed Covid-19 (SARS-CoV-2) cases in India stood approximately 70 lakhs, of which nearly 1,07,000 people, unfortunately, lost their lives ³. Although the number of active cases in India started declining from the second half of September, there were still approximately 75,000 new cases and 1000 deaths daily due to Covid-19 in India ³. The cumulative number of Covid-19 Cases and the Recoveries with time is shown in Figure 1. The cumulative number of Deaths from Covid-19 with time is shown in Figure 2.

Before going for any analysis, we need to agree upon a definition of Case Fatality Rate (CFR) for an ongoing pandemic and understand Test Positive Rate (TP). For an ongoing pandemic, it may be a little confusing to precisely calculate its 'Case Fatality Rate' (CFR). According to Piotr Sychalski et al. ⁴, during an epidemic, cases might be defined as either total confirmed cases, or by cases which had an outcome (deceased + recovered). Hence, the denominator for calculating CFR might be either of these numbers. In the initial phase of the epidemic, the 'number of cases with outcome' is relatively small, so CFR calculated per 'cases with outcome' will be an overestimate. But CFR calculated per total cases will be an underestimate as the numerator will be underestimated. But since we are well past the initial phase of the Covid-19 pandemic in India on October 9, 2020, as per a WHO scientific brief ⁵ it would be more appropriate for us to be using 'cases with outcome' in the denominator to calculate CFR. Hence, we have used the following formula to calculate the CFR of Covid-19 in India:

$$\text{CFR} = \frac{\text{Total Number of Deaths}}{\text{Total Number of Cases which had an Outcome}} \times 100$$

Here, 'Total number of cases with Outcome' = 'Total number of patients recovered' + 'Total number of patients deceased' till given date.

'Test Positive Rate' shows the proportion of the total number of people who were tested positive for a virus to the total number of people who got tested. The Test Positive Rate (TP) till a given date can be calculated using the following formula:

$$TP = \frac{\text{Total Number of Positive Cases}}{\text{Total Number of Tests}} \times 100$$

The CFR of India was calculated based on the above-mentioned CFR formula, and plotted with time as shown in Figure 3. We can observe a continuously decreasing trend in the CFR with time, primarily due to the improvements in recovery rates and increased number of testing, resulting in more positive cases with mild or no symptoms.

Since our primary objective is to calculate the Covid-19 CFR in the different States and UTs of India and analyse the various possible causes for the difference in their CFR, we have analysed recent research papers and news articles on Covid-19 to know about the possible factors affecting CFR.

*Jennifer Beam Dowd et al.*⁶ highlighted the role of demographics, particularly the age structure of a population in determining the Covid-19 death rate. They suggested that the progression of Covid-19 and its mortality rate are strongly connected to the age structure of the population affected. It was found after analysing the Covid-19 data from countries like China, South Korea, Italy, and Germany, etc. that mortality risk was highly concentrated at older ages, particularly for people aged above 80. *John P.A. Ioannidis*⁷ concluded that infection fatality rates inferred from seroprevalence studies tend to be much lower than earlier speculations during the initial days of the pandemic. He also pointed out that the infection fatality rate of Covid-19 can vary substantially across different locations depending on the population age structure, case mix of infected and deceased patients as well as various other factors.

*Arghadip Samaddar et al.*⁸, showed that the severity of Covid-19 in India was among the lowest in the world with low fatality rates, ICU admissions rate, and need for ventilators. In this paper, they suspected several factors having a role in reducing the susceptibility of Indians to Covid-19. These factors included several ongoing mutations in the circulating SARS-CoV-2 strains with lesser virulence, host factors like innate immunity, genetic diversity in immune responses, epigenetic factors, genetic polymorphisms of ACE2 receptors, micro RNAs and universal BCG vaccination, and environmental factors like temperature and humidity. *Graziano Onder, Giovanni Rezza, and Silvio Brusaferrero in their paper*⁹, after analysing the early data of Covid-19 in Italy, found that deaths were concentrated in older male patients with multiple comorbidities. *Shahbaz A. Shams, Abid Haleem, and Mohd Javaid*¹⁰ compared the Covid-19 data of the top 18 worst affected countries to conclude that there is a positive relationship between average life expectancy and fatality rates due to Covid-19. This was mainly because the vulnerability to this disease increases exponentially with age, especially after the age of 60, due to weak respiratory and immune systems and other comorbidities that occur at later ages.

*Sourendu Gupta*¹¹ found that younger adults in India have more Covid-19 infection as compared to their proportion in the population. He also suggested that women are half as likely to be infected by Covid-19 as men with significantly lower infection rates for women between puberty and menopause. Similarly, *Manisha Mandal and Shyamapada Mandal*¹² found that the relative susceptibility of developing symptoms (RSODS) and relative susceptibility of developing an infection (RSODI) was almost 33 times higher among younger people aged below 45 years. *William Joe et al.*¹³ found that males share a higher rate of Covid-19 infection than women, but the infection is evenly distributed in under 5 and elderly age groups. The study found a CFR of 14.3% for people aged above 60 as compared to an overall CFR of 3.2% in India.

Therefore, to establish a relation (if any) between Covid-19 Case Fatality Rates (CFR) and Covid-19 Test Positive Rates, Demographic Factors like Life Expectancy, Healthcare Factors like Number of Government Doctors per Million People, etc. in the States and UTs of India, we first analysed the Covid-19 data to calculate the CFRs of all the States and UTs. Then we

calculated Spearman's Rank Correlation Coefficients for State-wise CFR and various data-sets like state-wise Test Positive Rates, Life Expectancy, and Number of Government Doctors per million people.

2. Data And Methodology

2.1 Data Sources

The Indian state-wise data of Covid-19 testing, cases, recoveries, and deaths till October 9, 2020 was taken from Covid19-India API (www.api.covid19india.org/documentation/csv)³. Healthcare statistics like 'Number of Allopathic Government Doctors by Indian States and Union Territories' is taken from National Health Profile 2019 (MoHFW)¹⁴. Demographic data like 'Life Expectancy by Indian States/UTs' is taken from Government of India Census Data (www.censusindia.gov.in/), and Healthcare Infrastructure data like 'Indian states/UTs by number of Hospital beds, ICU beds, and Ventilators' is taken from Kapoor et al. (2020) COVID-19 in India: State-wise estimates of current hospital beds, intensive care unit (ICU) beds and ventilators¹⁷.

2.2 Correlation Methodology

To find the correlation between state-wise CFR and other data sets, we have applied the "Spearman's Rank Correlation Coefficient Methodology". The value of the correlation coefficient (r_s) varies between -1 to +1, where +1 suggests perfect correlation and -1 suggests perfectly correlated in the opposite order, and 0 (or near 0) suggests uncorrelated. The formula for calculating correlation coefficient (r_s) is given below:

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}$$

Here $d_i = X_i - Y_i$ is the difference between the ranks of each data sets and n is the number of elements in each of the data sets. Here X_i and Y_i are the rank data columns of first and second data sets after sorting them in ascending order (or descending order) respectively. Interpretation of Spearman's Rank Correlation Coefficient Value is given below. Spearman's Rank Correlation Coefficient statistically measures the strength of a monotonic (increasing/decreasing) relationship between the pair of data.

Positive Range	Negative Range
0.01-0.19: Very Weak Agreement	(-0.01) - (-0.19): Very Weak Disagreement
0.20-0.39: Weak Agreement	(-0.20) - (-0.39): Weak Disagreement
0.40-0.59: Moderate Agreement	(-0.40) - (-0.59): Moderate Disagreement
0.60-0.79: Strong Agreement	(-0.60) - (-0.79): Strong Disagreement
0.80-1.0: Very Strong Agreement	(-0.80) - (-1.0): Very Strong Disagreement

Most of the data analyses including the calculation of Spearman's rank correlation coefficients are done on Microsoft Excel. Correlation Plots are drawn using MS Excel Scatter Charts and all the other plots are drawn using MATLAB.

3. Results And Discussion

3.1 Indian States by Case Fatality Rates:

Using the CFR formula, the Case Fatality Rates (CFR) of Covid-19 for all the states and Union Territories of India was calculated using the Covid-19 data ¹³ till October 9, 2020. The overall Covid-19 CFR in India stood at 1.76%, which was among the lowest in the world. The Covid-19 CFR has also been continuously decreasing from 5.44% on June 9, 4.18% on July 9, 2.82% on August 9 to 1.76% on October 9, 2020. The trend of Covid-19 CFR in India with time is shown in Figure 3.

Some States and UTs had vastly different CFR than the others. Where the states like Punjab (3.36%), and Maharashtra (3.13%) had very high CFR, states like Assam (0.49%), Kerala (0.54%), and Bihar (0.51%) had very low. Indian states according to their respective CFR are shown in Figure 4, dividing them into 5 different categories of CFR from Very Low (0-0.671%) to Very High (2.688-3.360%). The figure was prepared using ArcGIS 10.5 software.

The different CFR categories from Very Low to Very High and Indian states and UTs falling in those categories are shown in Table 1.

Table 1: Indian States in 5 different categories of Case Fatality Rates.

Category	CFR Range	States/UTs
Very Low	0.00% to 0.671%	Telangana, Odisha, Mizoram, Daman and Diu, Dadar Nagar Haveli, Arunachal Pradesh, Nagaland, Kerala, Assam, Bihar, Lakshadweep
Low	0.672% to 1.344%	Andhra Pradesh, Manipur, Rajasthan, Meghalaya, Tripura, Chhattisgarh, Jharkhand, Haryana
Moderate	1.345% to 2.015%	Sikkim, Goa, Uttarakhand, Himachal Pradesh, Ladakh, Chandigarh, Andaman and Nicobar, Jammu and Kashmir, Uttar Pradesh, Karnataka, Tamil Nadu
High	2.016% to 2.687%	West Bengal, Gujrat, Delhi, Madhya Pradesh, Puducherry,
Very High	2.688% to 3.360%	Punjab, Maharashtra

There may be multiple reasons for the disparity in the Covid-19 CFRs of the different Indian States and UTs. Based on our literature survey, analysis of initial data, and news articles on Covid-19, we inferred that the CFR disparity could be the result of differences in the Covid-19 response and management, Pre-existing comorbidities, Availability of essential drugs, Healthcare Infrastructure, availability of doctors, and demographic characters like Life Expectancy from one state/UT to another.

We, therefore, collected the latest data from the best possible sources to find the correlation between the Covid-19 CFR of Indian States/UTs and various other state-wise data sets like Testing Rates, Healthcare Infrastructure, Availability of Doctors, and Demographic data like Life Expectancy, etc.

3.2 Correlation between CFR and Test Positivity Rate (TP):

The Indian state-wise data of Covid-19 testing, cases, recoveries, and deaths till October 9, 2020 was taken from Covid19-India API (www.api.covid19india.org/documentation/csv) ³.

First, we calculated the Spearman's Rank Correlation Coefficient for state-wise Case Fatality Rates (CFR) and the corresponding Test Positivity Rate (TP). The correlation coefficient was calculated to be $r_s = +0.33$. The value $r_s = +0.33$ is a moderate value in the positive direction, indicating a moderate agreement between Test Positive Rates (TP) and Covid-19 CFR of Indian States/UTs, which means that the states with more Test Positive Rates, somewhat tend to have more Covid-19 CFR. This suggests that the states doing more Covid-19 tests with respect to infection prevalence in their state may possibly have a lower CFR, which is understandable as more tests will result in more cases with mild or no symptoms, resulting in the lowering of CFR¹⁸. The correlation between CFR and Test Positive Rates in the Indian States/UTs is graphically shown in **Figure 5**.

3.3 Correlation between CFR and Demographic Data:

The demographic data for this analysis is taken from the Census of India, Sample Registration System (SRS) publication Life Expectancy Data (2013-2017)¹⁵. To understand the relationship between age and CFR, the correlation coefficient (r_s) for CFR and the 'Expected Life at the age of 60' of Indian States/UTs was calculated. It resulted in a value of $r_s = +0.49$, which suggests a moderate agreement of CFR with 'Life Expectancy at the age of 60'. Similar calculations for 'at birth' gave correlation coefficients of $r_s = +0.44$, which again suggests a moderate agreement between CFR and Life Expectancy at birth. Additionally, the correlation coefficient for CFR and Median Ages of different Indian states/UTs is calculated to be $r_s = +0.29$. The correlation between CFR and the Expectation of Life at the age of 60 in the Indian States/UTs is graphically shown in **Figure 6**.

We may infer from the above results that the higher CFR moderately agrees with the higher life expectancies and median age as states with higher life expectancies and median ages will have more older people who, as the studies⁶ suggest may be more susceptible to the Covid-19 disease.

3.4 Correlation between CFR and Healthcare Data:

The Healthcare Data is taken from Kapoor et al. (2020) paper: 'COVID-19 in India: State-wise estimates of current hospital beds, intensive care unit (ICU) beds and ventilators'¹⁷. Healthcare statistics like 'Number of Allopathic Government Doctors by Indian States and Union Territories' is taken from National Health Profile 2019 (MoHFW)¹⁴.

The correlation coefficient for CFR and the number of 'Government Allopathic Doctors Per Million People' in the Indian states and UTs was calculated $r_s = -0.04$, suggesting almost no relation between them. The correlation between CFR and 'Government Allopathic Doctors Per Million Population' in the Indian States/UTs is graphically shown in **Figure 7**.

To correlate CFR with healthcare infrastructure, we calculated correlation coefficients for CFR and the total number of Hospital beds, ICU beds and Ventilators per 1000 Covid-19 Cases in the different states and Union Territories of India. The correlation coefficients for Hospital beds, ICU Beds and Ventilators per 1000 Covid-19 Cases with CFR were all found to be around $r_s = +0.07$, suggesting almost no relation between CFR and the availability of healthcare infrastructure items like Hospital beds, ICU Beds and Ventilators. The correlation between CFR and 'Hospital Beds per 1000 Covid-19 cases' in the Indian States/UTs is graphically shown in **Figure 8**.

We can infer from the above analysis related to the healthcare data indicates that the state-wise CFR is surprisingly not related to the availability of healthcare infrastructure and government doctors. This indicates that other factors overwhelm the availability of healthcare facilities in deciding the Covid-19 CFR in the states and UTs of India.

All of the above data analysis related to Testing Rates, Demographics, and Healthcare exhibit a moderate to no relation with the Case Fatality Rates (CFR) which points towards the possibility of other factors, that may be responsible for the vast differences in the CFR of Covid-19 in the States and UTs of India. Because of the lack of updated data for any other possible factor for correlation analysis, we analysed several news articles about Covid-19 CFR in India in some of the leading News Papers to know about the other possible factors affecting the Covid-19 CFR.

3.5 Analysis of News Articles related to Covid-19 CFR in India Published in some of the Leading News Papers:

In a News Article ¹⁹ on 'Covid-19 fatality rates in India, Gujarat and Maharashtra', from The Indian Express, it was found that reporting the cases to hospitals within 24-72 hrs of a patient showing symptoms gives the treating clinicians sufficient time to save a lot of lives. This helps bring the CFR down. In the editorial, it was also pointed that in the states of Maharashtra, Gujarat, and West Bengal where CFR is higher than the national average, the majority of cases have been coming late to the hospitals, in addition to the state's weak tracing and isolation process of the Covid-19 cases.

A similar reason for high CFR in Maharashtra was given in a Hindustan Times News Article ²⁰ on 'Covid-19 fatality rate in Maharashtra'. In the article, it was revealed from a report by the expert committee of doctors that 29% of Covid-19 related deaths in Maharashtra have occurred within hours or on the same day of the admission of the patient in the hospital, while many of the remaining deaths occurred within 4 days. The editorial concluded that the high Covid-19 CFR in Maharashtra was primarily attributed to poor healthcare infrastructure, lack of trained manpower and medical expertise, inadequate contact tracing, late referral to hospitals, and a lacklustre implementation of lockdown.

The Week, in its News Article ²¹, reported that presence of comorbidities, lack of access to essential drugs, and delay in approaching hospitals for treatment were the main reason for high Covid-19 CFR in Mumbai, Maharashtra. Another Hindustan Times News Article ²² attributed the high Covid-19 CFR in Maharashtra to shortage of Oxygen, medicines, besides failure of tracking vulnerable people and monitoring of the people who have come into the contact with infected patients. A News Report ²³ by The Tribune, suggested that the high Covid-19 CFR in Punjab is due to the high incidences of comorbidities (cases (diabetes, coronary ailments and obesity) in Punjab's population, and late testing of positive cases after the infection has reached a late stage. On the other hand, Times of India, in its report ²⁴, held high percentage of ageing population and urbanisation, along with high prevalence of non-communicable diseases as the key reasons for the higher number of Covid-19 deaths in Punjab.

4. Conclusion

Analysis of recent research papers on Covid-19 suggested that factors like age structure of the population, ongoing mutations in circulating SARS-CoV-2 strains with altered virulence, innate immunity, and environmental factors affect the Covid-19 CFR of a particular region.

After analysing the Covid-19 data, we found that although the Covid-19 CFR in India was among the lowest in the world (1.76%), it varied vastly from one State/UT to another. Even though the CFR changed with time, states like Maharashtra (3.31%) and Punjab (3.36%) consistently reported very high CFR as compared to the national average. Whereas states like Assam (0.49%), Kerala (0.54%), and Bihar (0.51%) consistently reported very low CFR as compared to the national average. To establish the possible relation between CFR and other factors, Spearman's Rank Correlation Methodology was used to find correlation coefficients between CFR of Indian States/UTs and various other state-wise data sets like Covid-19 Testing Rates, Healthcare Infrastructure, Availability of Doctors, and Life Expectancy, etc.

In these analyses, a moderate agreement (+0.33) between CFR and Test Positive Rate was found, suggesting that states with a lesser number of testing per positive case may tend to have more Covid-19 CFR. We can infer from this result that more testing rate results in a greater number of positive people having mild or no symptoms, thus reducing the CFR. 'Expected Life at the age of 60' and CFR in the States/UTs showed a moderate agreement (+0.49), indicating that the states where people live longer after the age of 60, tend to have higher CFR. This is understandable as states with higher life expectancy will have a greater number of older people, who are more vulnerable. The correlation coefficient for CFR and the 'Number of Government Allopathic Doctors per Million People' in the Indian states and UTs was -0.04, suggesting no significant relationship between the availability of Government Allopathic Doctors and CFR. Healthcare items like the number of hospital beds, ICU beds, and Ventilators also showed no relation with Covid-19 CFR with correlation coefficient values for all of them

with CFR was around +0.07. Correlation analysis for Healthcare data surprisingly suggested that there is no significant relationship between the state-wise availability of healthcare facilities and CFR.

Due to the lack of updated data for any other possible factor for correlation analysis, analysis of several news articles about Covid-19 CFR in some of the leading newspapers was done, which suggested that pre-existing comorbidities, availability of essential drugs, trained manpower, medical expertise, effective contact tracing, and timely referral to hospitals were also some of the major factors affecting Covid-19 CFR in the States and UTs of India.

Declarations

Declaration of competing interest

The authors declare that they have no known competing financial or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

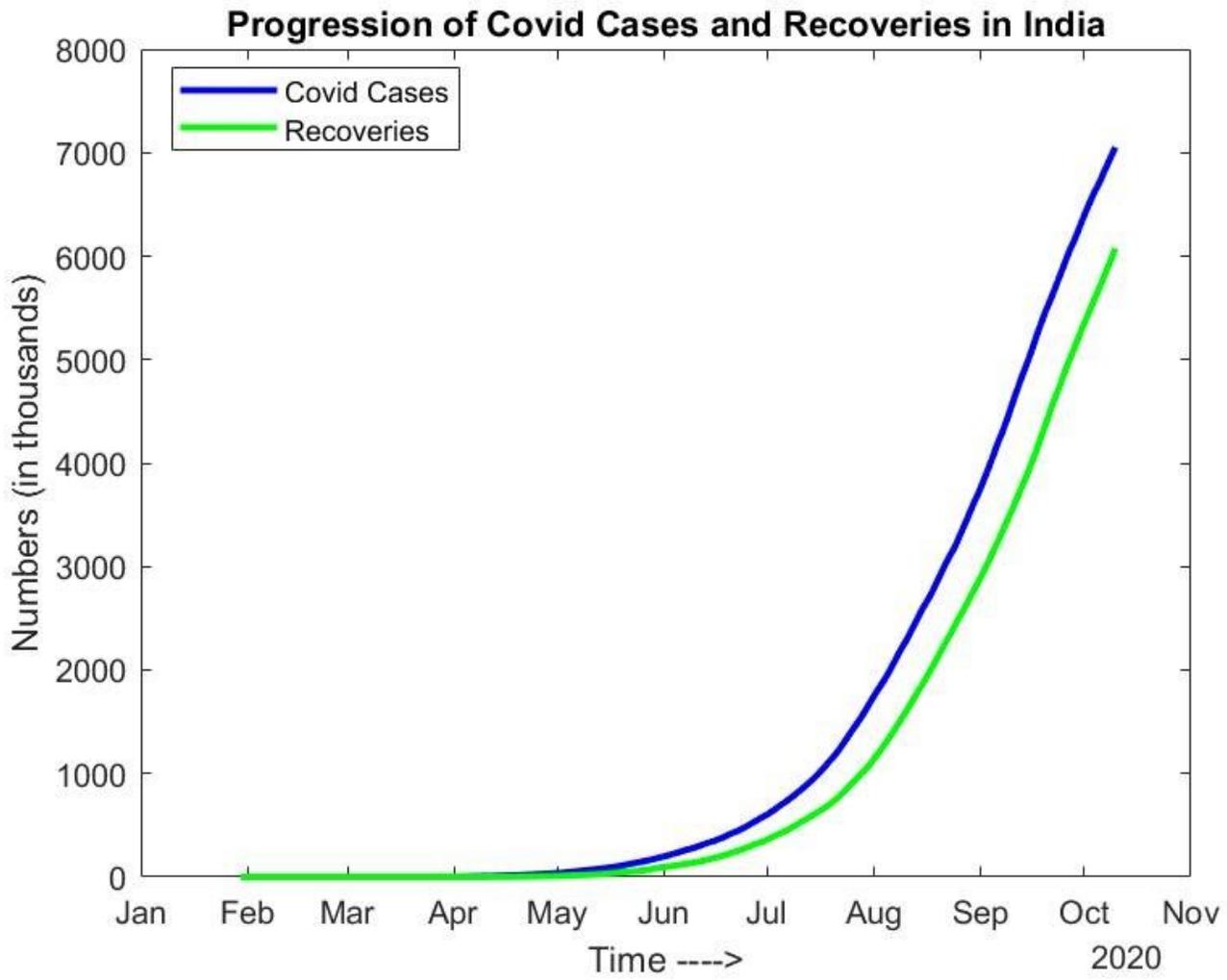


Figure 1

Progression of Covid-19 Cases and Recoveries in India with time

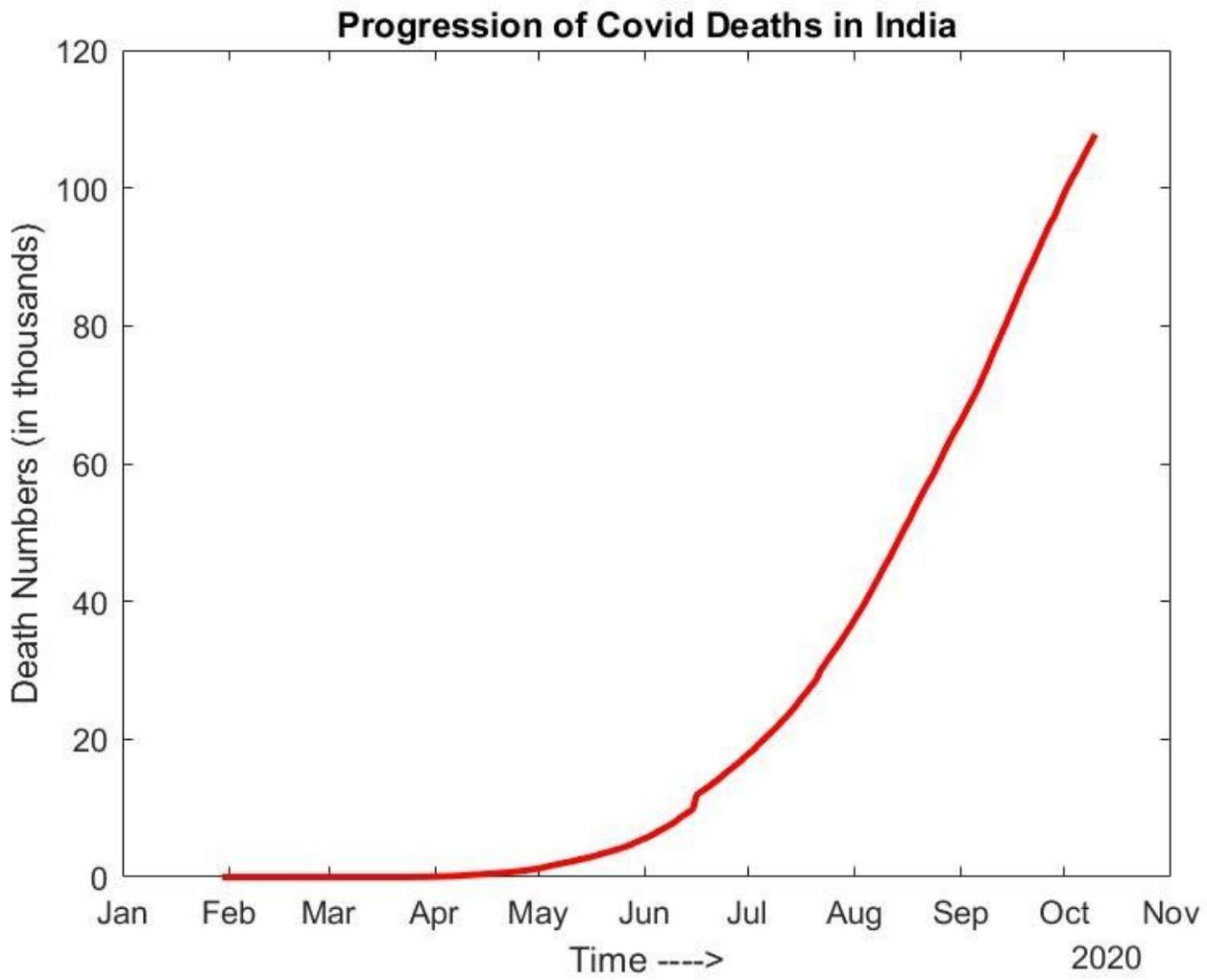


Figure 2

Progression of Covid-19 Deaths in India with time

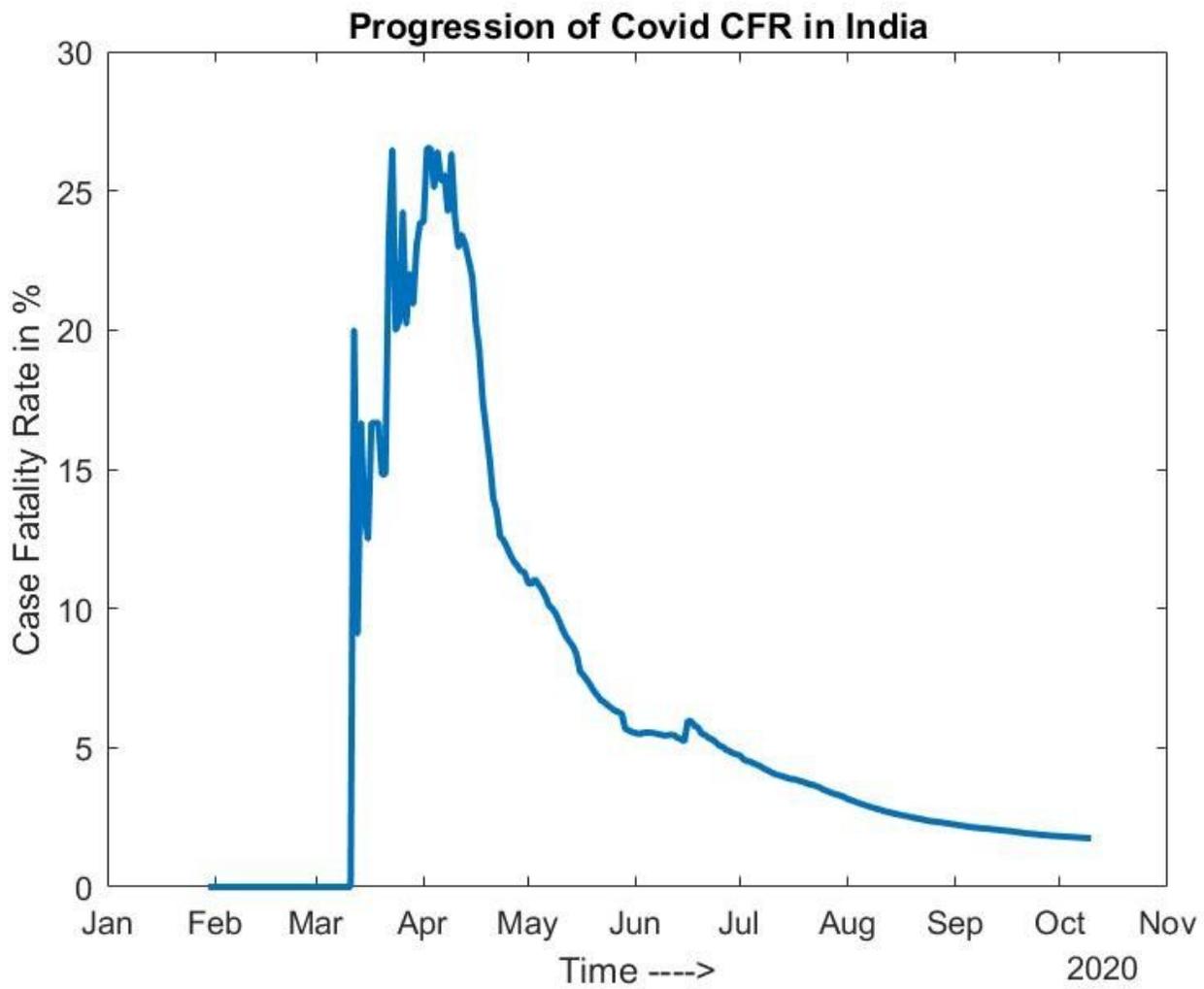


Figure 3

Progression of Case Fatality Rate (CFR) in India with time

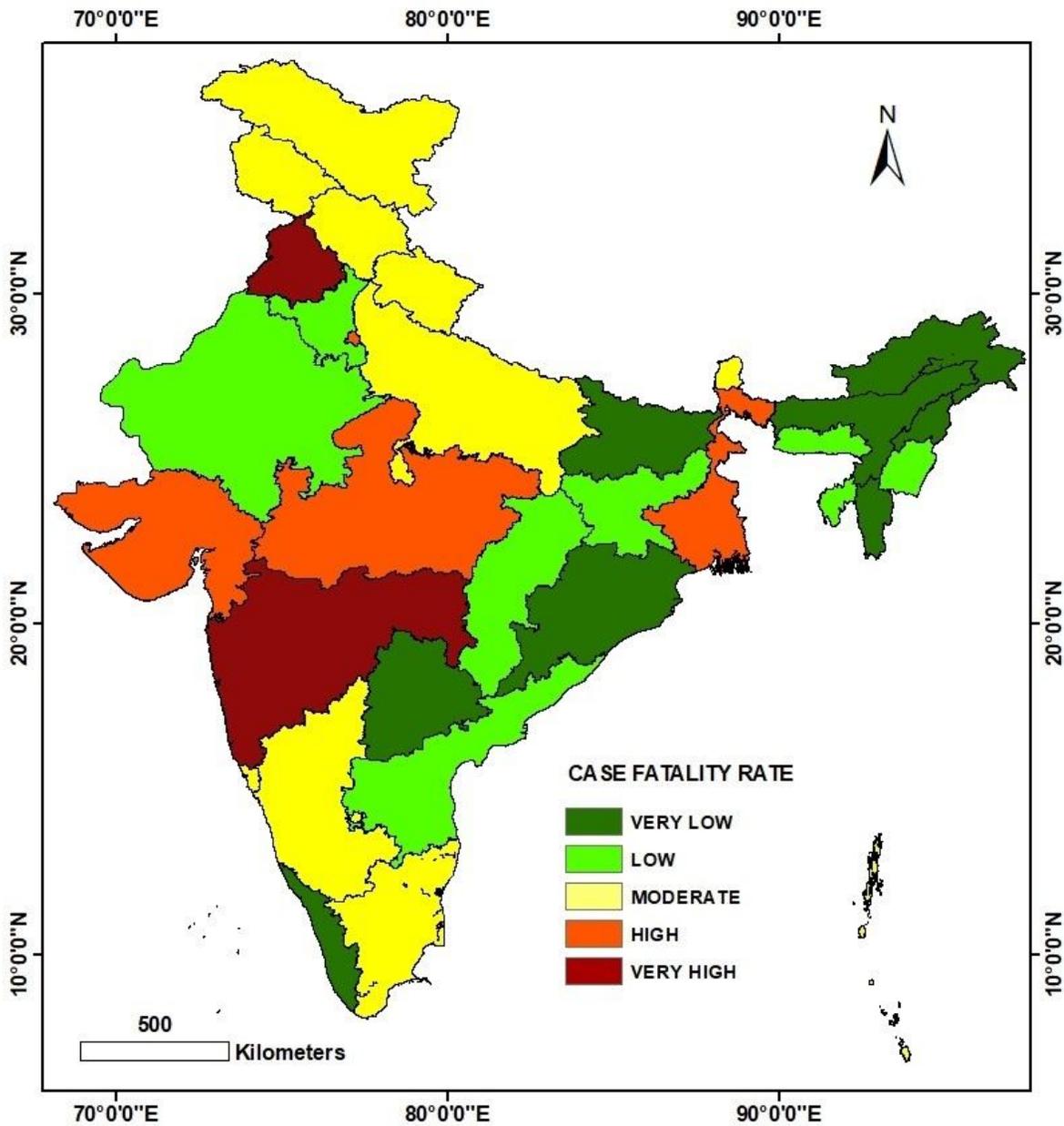


Figure 4

Indian States by Covid-19 Case Fatality Rate (CFR) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

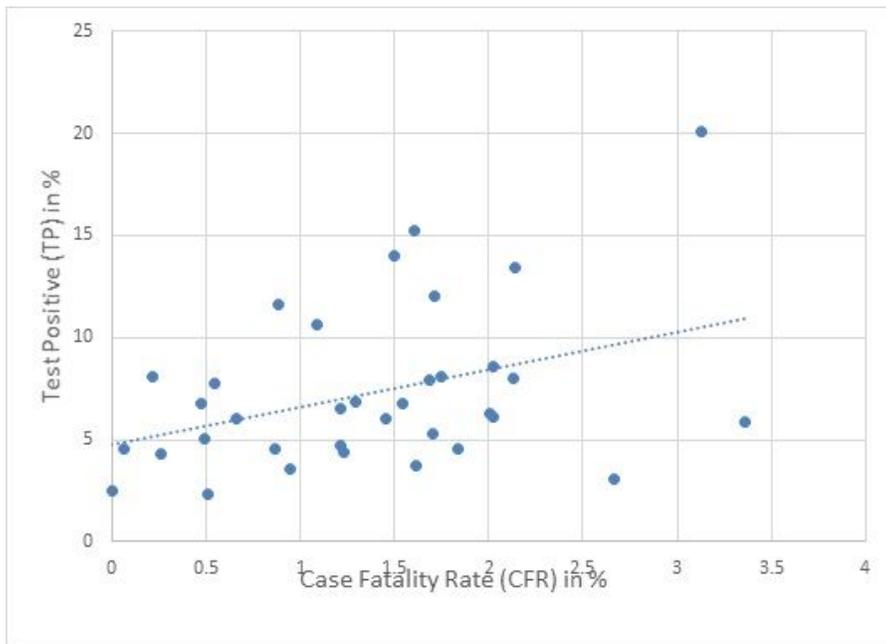


Figure 5

Correlation Between CFR and 'Test Positive Rate' in the Indian States and Union Territories

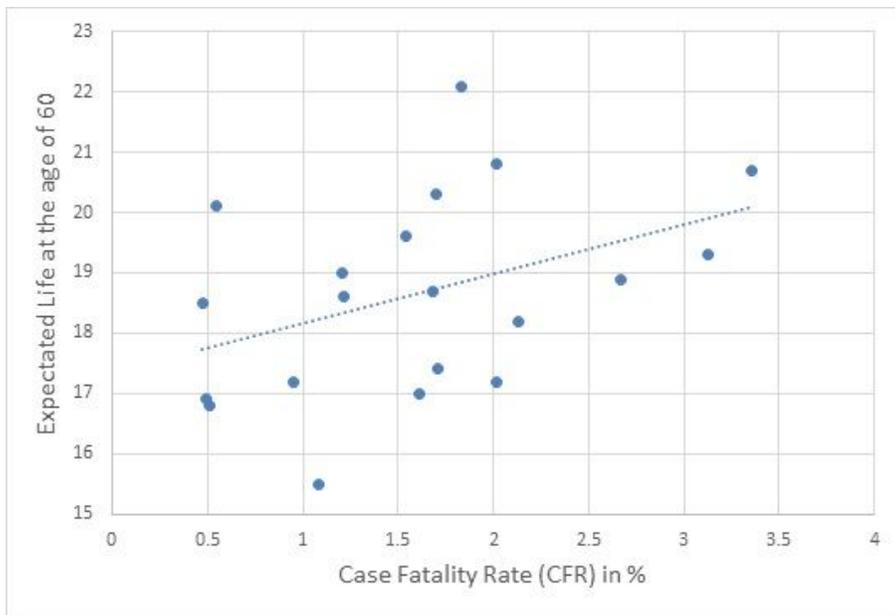


Figure 6

Correlation Between CFR and the 'Expectation of Life at The Age of 60' in the Indian States/UTs

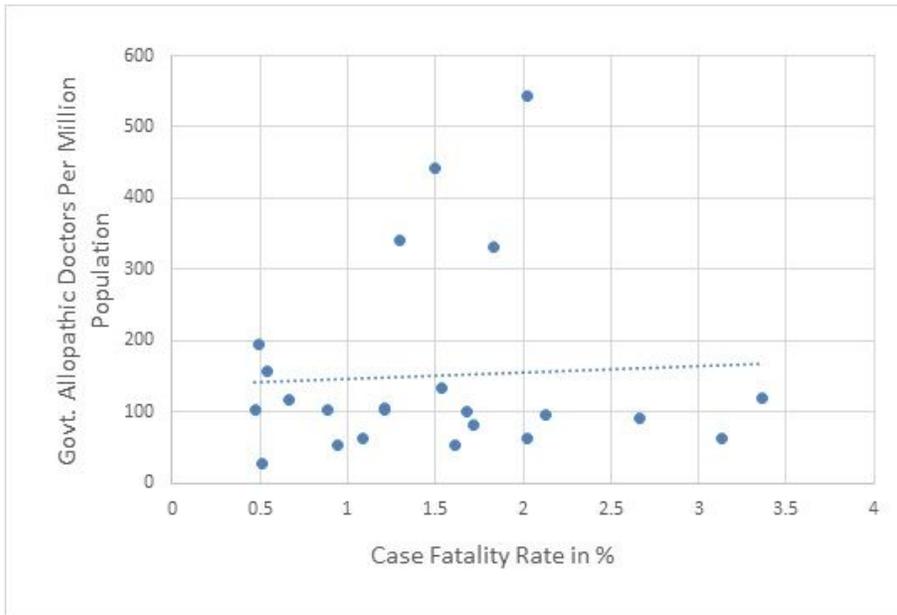


Figure 7

Correlation Between CFR and 'Number of Govt. Allopathic Doctors Per Million Population' in the Indian States and Union Territories

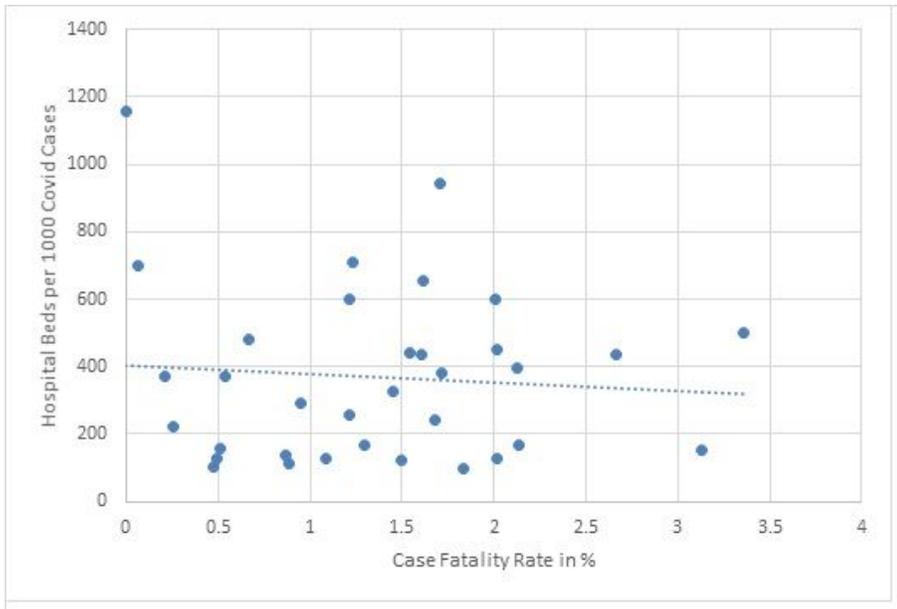


Figure 8

Correlation Between CFR and 'Number of Hospital Beds Per 1000 Covid-19 Cases' in the Indian States and Union Territories