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NOVEL COVID-19 BURDEN IN KARNATAKA AND INDIA: AN ATTEMPT TO FORECAST FUTURE TREND

Community Medicine

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ABSTRACT

Introduction: In December 2019, Wuhan city of Hubei province in China witnessed the outbreak of novel coronavirus (SARS-CoV 2) which has become an International Public health emergency and WHO has declared it as Pandemic disease which is affecting more than 210 countries of the world. The transmission rate and infection rate of COVID-19 is very high. This is an attempt to predict the short-term trend of incidence rate, case recovery and case fatality of COVID-19 by using suitable mathematical models.

Material and Methodology: COVID-19 data was collected from Ministry of Health and Family Welfare (MOHFW), Government of India. Here, we collected data daily through internet from March 2nd 2020 to May 15th 2020. A total cumulative number, recovered cases and death cases was collected for statistical analysis. The ten days interval growth rate and exponential doubling time is calculated by using the exponential equation. For prediction of future cases, various types of exponential smoothing like Double Exponential, Brown Exponential, Holt-Winter Exponential Smoothing was used along with ARIMA model, models are selected based on model fits criteria.

Results: The first COVID-19 case was reported on March 2nd,2020 in India and by May 15th 2020 cumulative incidence reached up to 85967 cases with Average growth rate of 11.1. In Karnataka, first COVID-19 case was reported on March 9th 2020 and the cumulative Incidence raised to 1056 cases with mean growth rate 8.8%. The recovery percentage in India and Karnataka are 34.1% and 51.1% respectively at the end of May 15th of 2020. A 3.2% Case fatality rate was observed in India against 3.4% in Karnataka. Maximum doubling time observed was 13 days and 21 days for India and Karnataka respectively. After 2nd phase of lockdown, the doubling period is 12.3days and 15days in India and Karnataka.

The ARIMA, Exponential models was used to forecast future cases. About 1,81,868 cases in India and 1800 cases in Karnataka are predicted by the end of May and about 5,56,170 cases and 3170 cases are expected by the end of June-2020. The predictive number of deaths is about 4480 in India and 43 in Karnataka by the end of May and it may reach 7710 and 55 deaths by end of June-2020 respectively.

Conclusion: Based on model's predictions, COVID-19 cases show increasing trend in both Incidence and Mortality in India and Karnataka till June-2020. The current health facility measures taken for the containment of the dreadful COVID-19 must be strengthened by more effective testing, detection and supportive treatment strategies to reduce the causalities from this viral infection until an effective drug for treatment is found in the near future. The details of novel Corona virus behavior is still evolving and future research must be done to find the vaccine at the earliest.

KEYWORDS

COVID-19; Case fatality rate; ARIMA; Exponential model; Forecast.

INTRODUCTION:

In December 2019, Wuhan city of Hubei province in China witnessed the outbreak of novel coronavirus (SARS-CoV-2) which has become an International Public health emergency and WHO declared it as Pandemic disease on March 12th 2020 which is affecting more than 210 countries of the world (1).

COVID-19 is caused by novel SARS- COV2. Coronaviruses are a family of enveloped, single-stranded, RNA viruses that belong to the Nidovirales order. The classic symptoms of COVID-19 are fever, cough, breathlessness, sore throat, myalgia. Other atypical symptoms affect enteric, hepatic, dermatologic and neurological systems. The Coronavirus has largest genome among all the RNA viruses. It is packed inside a helical capsid formed by the nucleocapsid protein and further surrounded by an envelope. The three structural proteins associated with the viral envelope are the membrane protein (M), envelope protein (E) and spike protein (S). This spike protein gives the appearance of crowns in the form of large protrusions from the virus surface (2).

It was reported in a cluster of patients with pneumonia like features of unknown cause which was linked to a local Huanan South China seafood Market in Wuhan, Hubei Province, China. It was observed that initial cases had some contact history with the original seafood seller in market. Soon a secondary source of infection was found that transmitted between humans by close contact. COVID-19 has triggered a global health emergency alert. The confirmed cases worldwide have come up to 45 lakhs and 3 lakh deaths globally (3). The first case of the COVID-19 pandemic in India was reported on 30th January 2020(4), which originated from China. Presently there are 85,967 cases with doubling rate of 12.3 days in India. Susceptibility of corona infection is associated with age, biological sex and other comorbid health conditions. The COVID-19 is found to have high transmissibility levels and pandemic risk than the SARS-CoV in 2003. The incubation period is found to be between 2 to 14 days with a median of 5 days but many cases are being detected even after a month, which makes us to think as what the exact incubation period of COVID-19 to determine the correct quarantine period (5). There is a continuous exponential rise in COVID-19 infected cases all over the world with countries like US, Russia, UK, Spain, Italy among the top five list as on 15th may 2020.

Case fatality rate varies with Age, Co-morbid conditions, Geographical region. In India, the overall case fatality rate is 3.2% and in Karnataka it is 3.5%. India is the second largest populated country in the World with population of 135 crores and majority of the people are in the age group of 20-60 years, which is a very productive age for industrialization. The population density in India is 464 per Km^2. The

median age in India is 28.4 years (6). Hence the transmission rate and infection rate of COVID-19 is very high in India. This is an attempt to predict the short-term trend of incidence, case recovery and case fatality of COVID-19 by using suitable mathematical models.

MATERIALS AND METHODS

Worldwide data was obtained from WHO COVID-19 update report. Indian data was collected from Ministry of Health and Family Welfare (MOHFW): Covid-19 India. Here we have collected data at given stipulated time from March 2nd 2020 to May 15th 2020. Date wise confirmed cases of COVID-19, recovered cases and deaths are analyzed using statistical analysis.

Statistical analysis

Auto-regression integrated moving average model (ARIMA) and Exponential model was used for analysis. The projected data is used for prediction up to June 30th 2020. Data was analyzed using python 3.7. software.

1. Exponential Model

This is a very popular scheme to produce a smoothened Time Series. Whereas in Single moving averages the past observations are weighted equally, Exponential Smoothing assigns exponentially decreasing weights as the observation get older. Recent observations are given relatively more weight in forecasting than the older observations. In the case of moving averages, the weights assigned to the observations are the same and are equal to 1/N. In exponential smoothing, however, there are one or more smoothing parameters to be estimated and these choices determine the weights assigned to the observations (7).

A. Double exponential smoothening: Single smoothening does not excel in following the data when there is a trend. This situation can be improved by the introduction of a second equation with a second constant, γ, which must be chosen in conjunction with α.

Here are the two equations associated with Double Exponential smoothening.

Stbt==αyt+(1−α)(St−1+bt−1)γ(St−St−1)+(1−γ)bt−10≤α≤10≤γ≤1

Note that the current value of the series is used to calculate its smoothed value replacement in double exponential smoothing (8).

B. Brown Model: The simple moving average model described above has the undesirable property that it treats the last k observations equally and completely ignores all preceding observations. Intuitively, past data should be discounted in a more gradual fashion.

$$\hat{Y}_{t+1} = \alpha[Y_t + (1-\alpha)Y_{t-1} + (1-\alpha)^2 Y_{t-2} + (1-\alpha)^3 Y_{t-3} + \ldots]$$

The interpolation version of the forecasting formula is the simplest to use if you are implementing the model on a spreadsheet, it fits in a single cell and contains cell references pointing to the previous forecast, the previous observation and the cell where the value of α is stored (9).

C. Holt-Winter Model

This algorithm allows users to smooth a time series and use that data to forecast areas of interest. Exponential smoothening assigns exponentially decreasing weights and values against historical data to decrease the value of the weight for the older data. In other words, more recent historical data is assigned more weight in forecasting than the older results (10).

2. ARIMA Model

Autoregressive moving average model (ARIMA) for forecasting a time series, ARIMA modeling is one of the best modeling techniques. ARIMA models are always represented with the help of some parameters and the model is expressed as ARIMA (p, d, q). Here 'p' stands for the order of auto-regression 'd' signifies the degree of trend difference while 'q' is the order of moving average. We have applied an ARIMA model to the time series data of confirmed COVID-19 cases in India. Autocorrelation function (ACF) graph and Partial autocorrelation (PACF) graph is used to find the initial number of ARIMA models. These ARIMA models are then tested for variance in normality and stationary.

The built model is employed to forecast confirmed COVID-19 cases for the next 45 days, from 16th may 2020 to 30th June 2020. Time series analysis is used to recognize the trends in confirmed COVID-19 cases in India and Karnataka. Graph is plotted for actual confirmed cases and predicted confirmed cases with respect to time to verify the efficiency of the model (11).

RESULTS:

The COVID-19 cumulative incidence has reached 85,967cases with average growth rate of 11.1 and the active cases are 5,5811 with 2,750 deaths as on May 15th 2020. In Karnataka, cumulative Incidence raised to 1065 cases with mean growth rate 8.8%. The recovery percentage in India and Karnataka are 35.1 and 51.1 respectively. A 3.2% Case fatality rate is observed in India against 3.4% Karnataka. The Overall doubling time of COVID-19 in India and Karnataka is about 6 and 9 days respectively. The detailed analysis is given in Table no.1.

Fig no.1 and Fig no.2 gives the COVID-19 trend of Active cases, Cumulative cases, Cumulative recovery and Death in India and Karnataka. The ten days interval growth trend of India and Karnataka is depicted in fig 3. The Compound growth rate is calculated for each interval, during the first interval 12% growth was observed in India. A maximum growth rate was observed between Mar 11th to Mar 21st (18%) in India. The doubling rate is depicted in Fig4, during the beginning of COVID-19 crisis, India observed 4.7 doubling rate compared to 3.9 of Karnataka. Maximum doubling time observed was 13 days and 21 days for India and Karnataka respectively. After 30th of April doubling days has reduced in both India and Karnataka.

The short term forecast of the infected cases, case fatality and recovered cases of novel COVID-19 is attempted up to 30th of June 2020. Any unpredictable events (cluster infection) may lead to underestimated forecasting and if effective treatment strategy is given then there can be over estimation. The two data modelling algorithm is used to predict the outbreak of COVID-19 during its next level of influence. Estimation of the best-fit solution for each model by using the nonlinear least-squares fitting, in which the test model provides the better goodness of fit. The ARIMA, Holt-Winter, Brown and Double Exponential of the growth models are used to forecast future cases. The model validation is based on Coefficient of determination (R^2), higher R^2 lead to high accuracy in fitting followed by Root Mean Square Error (RMSE), its value should be lower and Bayesian Information Criteria (BIC), the value should be lower, the above three condition provides the information for good model fit and results are likely to be reliable.

We observed that ARIMA and Brown Exponential Smoothened model is best model to predict the Cumulative cases or Number of Infected cases for India and Karnataka, which shows 1.000 co-efficient of determination with 290.0 and 11.0 Root Mean Square Error, 7.7 and 8.97 Mean absolute percentage error and 11.5% and 4.8 BIC for India and Karnataka respectively. In Karnataka, after May 03rd rapid increase in COVID-19 cases is seen in few days Brown exponential model is found to be good fit model. ARIMA model is found to be best model for COVID-19 recoveries for India and Karnataka. To Predict death, Brown Exponential model shows good fit. The detailed model fitting statistics given in table2.

The best fitted model is used for short time forecasting of COVID-19 Cases in India. Accordingly, above models predict about [1,81,868, 1,57,780-1,91,230] cases by 31st of May and [5,56,170, 4,50,765 to 6,69,650] by 30th of June in India and [1800, 1480-2100] by 31st of May and [3170, 1820-4520] by 30th of June in Karnataka. The predictive number of deaths is about [4480, 3920-5040] cases by 31st of May and [7710, 5240-10,170] by 30th of June in India and [43, 38-50] by 31st of May and [55, 47-65] by 30th of June in Karnataka. The recovery of COVID-19 cases in India is forecasting about [8,1600, 60,000-1,05,600] cases by 31st of May and [2,60,200, 60,800-3,55,200] by 30th of June in India and [610, 390-830] by 31st of May and [880, 876-1845] by 30th of June in Karnataka. The detailed estimated value with lower and upper limit is given in Fig 5 to10.

DISCUSSION:

In India, we have completed 8 weeks of lockdown phase. The WHO has advised for a 10-week lockdown period for effective control of virus transmission in every country (12). The division of all the districts into Red, Orange and Green zones based on the case detections and recovery which is the guidelines from the Government of India (13), for the specific region has simplified the protocols which

must be followed by local health bodies for effective control of COVID-19. Compared to other developed countries, India has so far been able to control the COVID-19 with effective healthcare measures. The compound growth rate of COVID-19 in India has reduced from the peak of 18.2 to 6.8 due to strict lock down from 24-03-2020 to 03-05-2020, afterwards some relaxation was made for upliftment of economy, we can expect an increase in growth rate and decrease in doubling rate with the phasing out from strict lockdown, similar trend is observed in Karnataka. The strategy of social distancing (14,15) personal protective measures and hand sanitization has made wonders in reducing the number of cases, throughout India during the first and second lockdown phase. Our Country is second highest populated country in the world and the infection rate and death rate was expected to be very high, but effective measures from Government bodies has helped in decreasing the disease burden. Karnataka was initially in the 3rd position of being the most affected state in India and reported the first death due to COVID-19 in India but has dropped down to 13th position of COVID-19 positive cases with around 50% of cases being recovered due to better health infrastructure and management. Countries like USA, Russia, Spain, UK, Italy, Brazil are experiencing the wrath of COVID-19 at an exponential rate in both infection and deaths. Indian strategy of tackling COVID-19 is well appreciated by the WHO. ICMR testing potential has increased by leaps and bounds with every passing day and presently every day about I Lakhs cases can be tested in India. The effective strong measures taken in the initial days of the outbreak has reaped benefits by the reduced number of deaths in India and also given time to gear up at war pace to tackle even the worst health crisis.

In Karnataka, Bangalore is thickly populated with more than 1 crore people and has reported 232 COVID-19 positive cases. In Belagavi and Davangere, 108 and 89 cases were identified (16). Effective screening and triage in health Institutions with increased testing, isolation, management of the cases has reduced the death rate in the State. The main problems faced with this novel COVID-19 is not knowing the correct incubation period, as cases are being reported even after a month of quarantine period. Valid data on testing accuracy, population group to be tested, frequency of testing, the different strains of corona virus outbreak, variable behavior in different regions and different people, corona negative accuracy and viral relapse in treatment completed cases is limited (17-19).

In our study using the various mathematical models- Number of COVID-19 cases, Case fatality and recovery is projected (20-22). We can expect exponential increase in trend due to relaxation of lock down. Although, there is an increasing trend of disease burden, Social distancing, Hand washing and using of Masks will definitely limit the viral transmission among people. Future research outcomes of the definitive treatment approach and identifying the drug of choice for COVID-19 is the need of the hour. Currently, all the countries are striving hard to find the vaccine for this dreadful disease which has affected the most known to mankind till date.

CONCLUSION:

Based on model's predictions, COVID-19 cases show increasing trend in both Incidence and Mortality in India and Karnataka till June-2020. The current health facility measures taken for the containment of the dreadful COVID-19 must be strengthened by more effective testing, detection and supportive treatment strategies to reduce the causalities from this viral infection until an effective drug for treatment is found in the near future. There can be further exponential increasing trend due to phasing off lock down. The details of novel Corona virus behavior is still evolving and future research must be done to find the vaccine at the earliest and the whole humanity must work towards keeping the causalities from corona virus as least as reasonably achievable.

Table No.1 COVID-19 Summary Statistics as on 15.05.2020

Descriptive	India	Karnataka
Cumulative Cases	85967	1056
Mean Growth % Overall	11.1	8.8
Cumulative Recoveries	30156	540
Recovery %	35.1	51.1
Active Cases	55811	516
Cumulative Death	2750	36
Case fatality Rate	3.2	3.4
Doubling Time in days	6	9

Table no2: Different types of Models Used to Forecast Future Trend

INDIA					
	Models	**R-Square**	**RMSE**	**MAPE**	**BIC**
Cumulative Cases	**ARIMA (0,2,1)**	1.000	290.0	7.7	11.5
Recovery	**ARIMA (0,2,10)**	1.000	104.1	15.0	9.0
Death	**Brown**	1.000	16.6	9.4	5.6
KARNATAKA					
	Models	**R-Square**	**RMSE**	**MAPE**	**AIC**
Cumulative Cases	**Brown**	1.000	11.0	8.9	4.8
Recovery	**ARIMA (0,2,2)**	0.999	4.1	14.0	3.2
Death	**ARIMA (1,1,1)**	0.998	0.7	14.6	-3.07

Fig no1: COVID-19 Trend in India

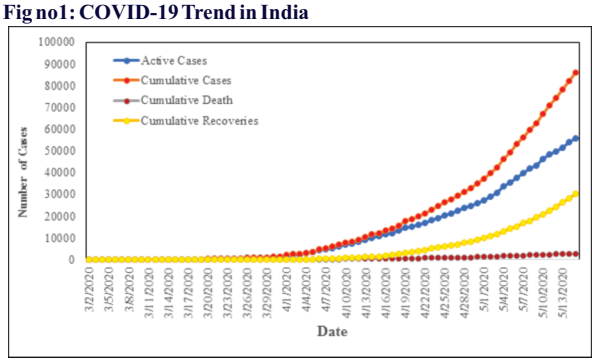
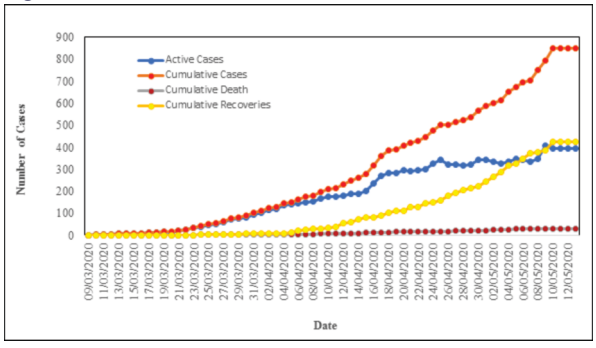


Fig no2: COVID-19 Trend in Karnataka



Figno.3: Compound Growth Rate: COVID19, India and Karnataka

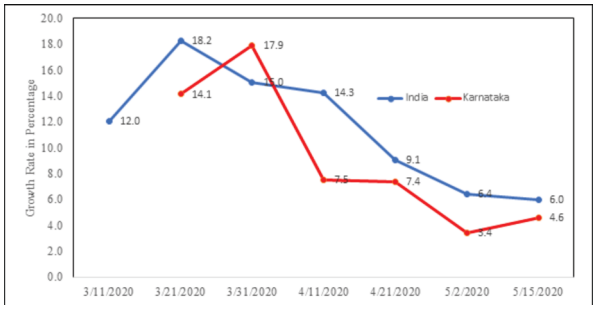


Fig no.4: Doubling Rate: COVID19, India and Karnataka

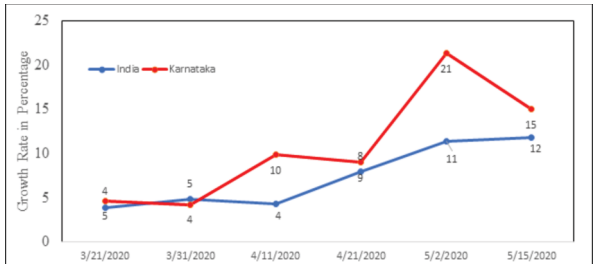
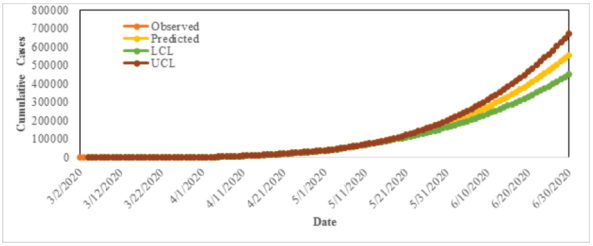
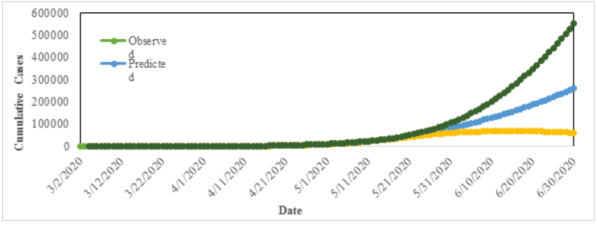


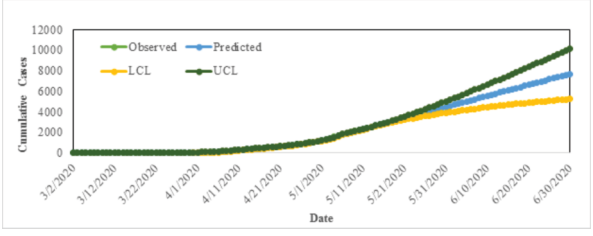
Fig no.5: Predicted number of Cumulative COVID-19 Cases: India



Figno6: Predicted number of Cumulative COVID-19 Recoveries: India



Figno7: Predicted number of Cumulative COVID-19 Deaths: India



Figno.8: Predicted number of Cumulative COVID-19 Cases: Karnataka

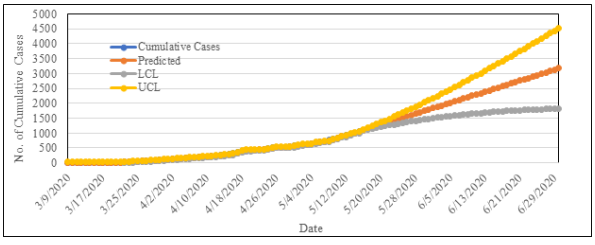
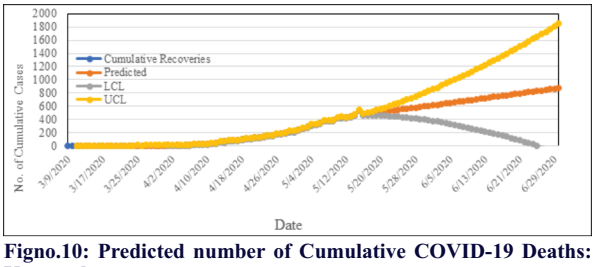
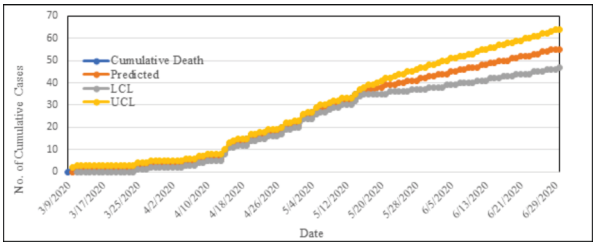


Fig no.9: Predicted number of Cumulative COVID-19 Recoveries: Karnataka



Figno.10: Predicted number of Cumulative COVID-19 Deaths: Karnataka



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