Assessing the impact of the COVID-19 pandemic on tuberculosis case notifications in India

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Abstract

Coronavirus (COVID-19) pandemic has caused enormous health impacts since 2020. Globally, in 2020, there was a substantial fall in number of people diagnosed with tuberculosis and reported to national authorities compared with 2019. This study aimed to determine the impact of COVID-19 on tuberculosis case notification in India. Monthly notified tuberculosis cases from January 2017 to December 2019 were collected from the Ni-kshay Dashboard and were used to build the time-series model. ARIMA and SARIMA models were made using time-series data. Based on the fit and seasonality of the data, the seasonal ARIMA model was used for forecasting. The prediction based on notified tuberculosis incidence data was compared to the monthly reported tuberculosis cases from January 2020 to June 2021 to find the difference in the notifications. The highest difference between the reported tuberculosis cases and the forecasted tuberculosis cases was during the lockdown period of 2020. The mean difference was approximately 50 percent during April, May and June 2020. Again, with the high surge during the second wave of April 2021 to June 2021, a high contrast between notified cases and predicted cases was observed. These results are evident of high number of missing cases during the pandemic that went undiagnosed and untreated thus posing a serious public health risk.

Key words: COVID-19 pandemic; lockdown; forecasting; tuberculosis case notification.

Background

Since the onset of the coronavirus pandemic (COVID-19) in 2020, it has had significant social, health, and economic impacts. It was first detected in Wuhan, China, and was declared a pandemic by the World Health Organization (WHO) on 11 March 2020 (WHO, 2020). The government imposed various lockdowns to prevent the spread of the virus. Tuberculosis services were disproportionately affected by the lockdowns imposed due to the pandemic (Chatterjee et al., 2022). It included impacts on providing and accessing essential tuberculosis services, the number of people diagnosed with tuberculosis and notified as tuberculosis cases through national disease surveillance systems, and the tuberculosis disease burden. India bears the most tremendous burden of tuberculosis mortality, witnessing the occurrence of two deaths resulting from this ailment every three minutes (Global Tuberculosis Report 2016).

Globally, in 2020, there was a substantial decline in the number of people newly diagnosed with tuberculosis and reported to national authorities compared with 2019 (Global Tuberculosis Report, 2021). The WHO estimates that nearly 10 million people developed tuberculosis in 2020. Of them, just 58 percent of the cases were diagnosed and reported. This decrease was primarily concentrated in 16 countries, with Asian countries (mainly India, Indonesia, the Philippines, and China) seeing the most considerable reductions in case reporting. These countries had major COVID-19 outbreaks and healthcare service disruptions (Global Tuberculosis Report, 2021). A similar decline was seen in India's tuberculosis notification rate (India TB Report, 2022). The overall impact of the

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COVID-19 pandemic can be seen in terms of a 26 percent reduction in tuberculosis case notifications compared to the same period last year ("Rapid Response Plan to Mitigate Impact of COVID-19 Pandemic on TB Epidemic and National TB Elimination Program (NTEP) Activities in India," 2020). This decrease relative to before the COVID-19 pandemic suggested an increase in undiagnosed and untreated tuberculosis cases. Missing tuberculosis cases is a massive challenge in combatting the epidemic (Pande et al., 2020).

The WHO's END TB strategy has set a target to end the tuberculosis epidemic by 2030 (The END TB Strategy, 2015). However, the Indian government is committed to achieving the Sustainable Development Goal of eliminating tuberculosis from the country by 2025, five years ahead of the target (Devarshi, 2020; Laura, 2018). To achieve this, in 2017, the National Strategic Plan (2017-25) was introduced by the government. It advocates for early identification of presumptive tuberculosis cases at the first point of care, be it private or public sector, and prompt diagnosis using susceptible diagnostic tests to provide universal access to quality diagnosis of tuberculosis, including drug-resistant tuberculosis in the country (Sachdeva & Mase, 2019). Although advances in diagnostics and new drugs to treat tuberculosis have been made, reducing tuberculosis cases is very slow. India accounts for 27 percent of the 10 million tuberculosis cases globally, the highest globally and three times the share of tuberculosis cases in China, the country with the second-most tuberculosis cases (9 percent) (Global Tuberculosis Report, 2023). Looking at the magnitude of the tuberculosis burden, ending it seems like an ambitious target.

The COVID-19 pandemic severely hindered national and international organizations' attempts to stop the tuberculosis epidemic. This study aims to evaluate the impact of the COVID-19 pandemic on tuberculosis notification rate in India. The difference between the forecasted and actual tuberculosis notifications will be calculated.

Materials and Methods

The monthly tuberculosis notifications are available on the Ni-kshay Dashboard. It is a case-based web-based surveillance system in India. It is developed and maintained by the Central TB Division (CTD), Ministry of Health and Family Welfare, Government of India, in collaboration with the National Informatics Centre (NIC) and the World Health Organization Country Office for India. Data on case notifications of tuberculosis at the national and state levels is available in the public domain. Daily tuberculosis case notifications have been updated in the portal since 2017. It also provides data on public as well as private healthcare notified cases. It is used by health functionaries at various levels across the country, both in the public and private sector, to register cases under their care, order various tests from labs nationwide, record treatment details, monitor treatment adherence, and transfer cases between care providers. It also functions as the National TB Surveillance System and enables reporting of various surveillance data to the Government of India.

Also, data on monthly COVID-19 cases in India is available on the website of the COVID-19 India organization. It can be accessed from https://www.covid19india.org/. It was a crowd-sourced initiative. It used data from state bulletins and official handles to update the COVID-19 cases. Data on the website is available till 31st October'2021. It provides daily and cumulative data on COVID-19 cases, and deaths at the state and district level. These datasets were extracted and compiled using MS Excel.

Data from January 2017 to December 2019 was used to make the model and forecast the incidence of tuberculosis. Autoregressive integrated moving average (ARIMA) models are used to predict future values based on past values. It uses time series data to predict the future tuberculosis incidence based on past tuberculosis incidence (Box et al., 2015). The ARIMA model is a generalization of the ARMA model. These models are fitted to time series data to comprehend the data better or forecast upcoming series points. The evolving variable of interest is regressed on its own lagged (i.e., prior) values, as indicated by ARIMA's autoregressive (AR) portion. The regression error is shown to be a linear combination of error terms whose values happened simultaneously and at different points in the past by the moving average (MA) component. The integrated (I) indicates that the data values have been substituted—and it is possible that this differencing process was carried out more than once with the difference between their values and the prior values. The purpose of each feature is to make the model fit the data as well as possible. ARIMA models are generally denoted ARIMA (p, d, q) where parameters p, d, and q are non-negative integers, p is the order (number of time lags) of the autoregressive model, d is the degree of differencing (the number of times the data have had past values subtracted), and q is the order of the moving-average model. Seasonal autoregressive integrated moving average (SARIMA) is an extension of ARIMA that incorporates the time series data of the seasonal component. Seasonal-ARIMA (SARIMA) model includes both non-seasonal (p, d, q) and seasonal (P, D, Q) factors to account for the seasonality of the time series data in a uniform pattern that repeats over the S period until the seasonal cycle changes again.

The general SARIMA model includes non-seasonal and seasonal factors that are given below:

$$\text{SARIMA (pdq) (PDQ)}_s$$

Where p = non-seasonal AR order, d = non-seasonal differencing, q = non-seasonal MA order, P = seasonal AR order, D = seasonal differencing, Q = seasonal MA order, and S = period of repeating seasonal pattern.

Before using these time series models, it is essential to convert data into stationary. It was tested using the Augmented Dickey–Fuller (ADF) test. ADF tests the null hypothesis that a unit root is present in a time series sample. The alternative hypothesis differs depending on the test version but is usually stationarity or trend-stationarity. Monthly tuberculosis notification data was converted into stationary using the difference transform. The first-order difference transform consists of taking the data point at the current time and subtracting it from the point before. To identify optional model parameters (P, D, Q, and p, d, q) to establish one or more alternative models was followed by the autocorrelation coefficient (ACF) and partial autocorrelation coefficient (PACF) of the stationary sequence. ACF correlates with the previous time-series data of tuberculosis, whereas PACF correlates with time-series data with its time-series criterion lagged values. Also, the auto-ARIMA function was used to find the values of the parameters. The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) were used to select the best model for time series data on tuberculosis. For a given set of data, the AIC is an estimator of prediction error and, consequently, of the relative quality of statistical models. With a set of models for the data, AIC calculates each model's quality about all the other models. As a result, AIC offers a method for choosing models. According to AIC, a model's relative information loss is estimated; the lower the model's information loss, the higher its quality (McElreath, 2018; Stoica & Selen, 2004). Also, The BIC is a measure of model fit that considers goodness of fit and the number of parameters used to achieve the fit (Schwarz, 1978). Both AIC and BIC were penalized on the likelihood criterion. Models with lower AIC and BIC values are considered the best choices for the time series (Hyndman & Khandakar, 2008; Maravall et al., 2015).

Using the best-fit model, tuberculosis notifications were forecasted for January 2020 to June 2021 and compared with the actual tuberculosis notification during the same period. Also, the monthly COVID-19 data was extracted from the COVID-19 India data set and plotted along with the difference in the predicted and actual tuberculosis notifications. A two-tailed p-value of <0.05 for all analyses was considered statistically significant. All statistical analyses were performed using STATA 17 (StataCorp. 2021. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC).

Results

A time-series analysis used the tuberculosis notification data from January 2017 to December 2019 for forecasting. Also, the data till June 2021 was extracted to compare with the forecasted values.

Trends of tuberculosis notifications

Figure 1 shows the monthly tuberculosis case notifications in India from January 2017 to June 2021. There was a visible upward trend in tuberculosis case notifications from 2017 through 2020. Seasonal variations in tuberculosis case notifications can be observed from the spikes in the summer months of April, May, and June.

Figure 1 Tuberculosis Case Notifications in India from Jan 2017 to Jun 2021

Notes. The line shows monthly tuberculosis case notifications from January 2017 to June 2021 taken from the Ni-kshay dashboard, CTD.

However, a steep decline in tuberculosis notifications can be observed since March 2020. Furthermore, another steep decline in the notifications can be observed in April 2021.

The total number of tuberculosis cases in India increased from 17.4 lacs in 2017 to 24 lacs in 2019. This increase in tuberculosis notifications can be attributed to the increase in case notifications from private facilities. Case notifications increased by more than twice in private facilities from 2017 to 2019. Private facilities notified just 2.9 lacs cases in 2017 which increased to 6.2 lacs in 2019. Also, the number of notified cases increased in public facilities from 2017 to 2019. However, in 2020, the total number of tuberculosis case notifications in India was reduced by almost 25 percent. A higher decline was seen especially in public facilities in 2020 where case notifications were reduced by approximately 28 percent compared to 2019. Also, in the private facilities, a decline of 14.5 percent was seen in tuberculosis notifications from 2019 to 2020.

The state-wise difference in notified tuberculosis cases between 2019 and 2020

Figure 3 shows the percent difference in state-wise notified tuberculosis cases between 2019 and 2020. The highest percent difference was seen in the union territory of Puducherry where the notified tuberculosis cases declined by more than 40 percent in 2020. In Ladakh, Manipur, Chandigarh, Tamil Nadu, Dadra & Nagar Haveli, Daman & Diu, Andhra Pradesh, Chhattisgarh, West Bengal, and Goa, the decline was more than 30 percent. In the states and union territories of Maharashtra, Mizoram, Karnataka, Assam, Madhya Pradesh, Nagaland, Tripura, Uttar Pradesh, Gujarat, Meghalaya, Uttarakhand, Jammu & Kashmir, Himachal Pradesh, Rajasthan, and Punjab, the percent decline was more than 20 percent. Only in Lakshadweep, the number of notified tuberculosis cases increased from 15 in 2019 to 18 in 2020.

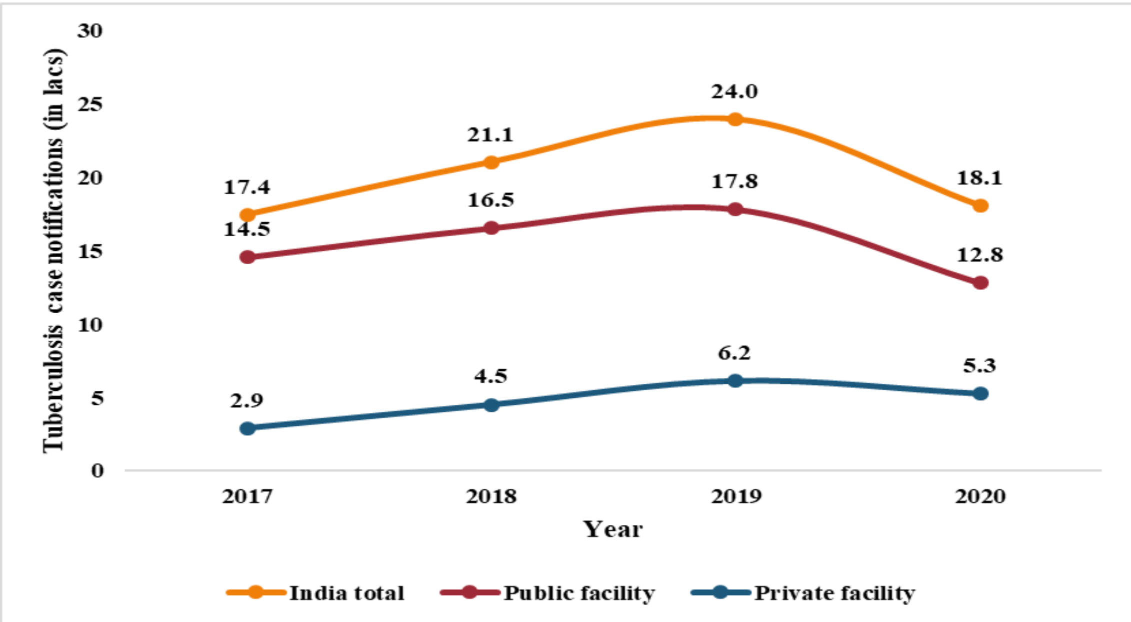

Figure 2: Tuberculosis case notifications in India from different types of hospital facilities

Notes. The India total line (orange) shows the total tuberculosis case notifications from January 2017 to December 2020. The Public facility line (red) shows the tuberculosis notifications from public hospitals while the Private facility line (blue) shows the tuberculosis notifications from the private hospitals taken from the Ni-kshay dashboard, CTD.

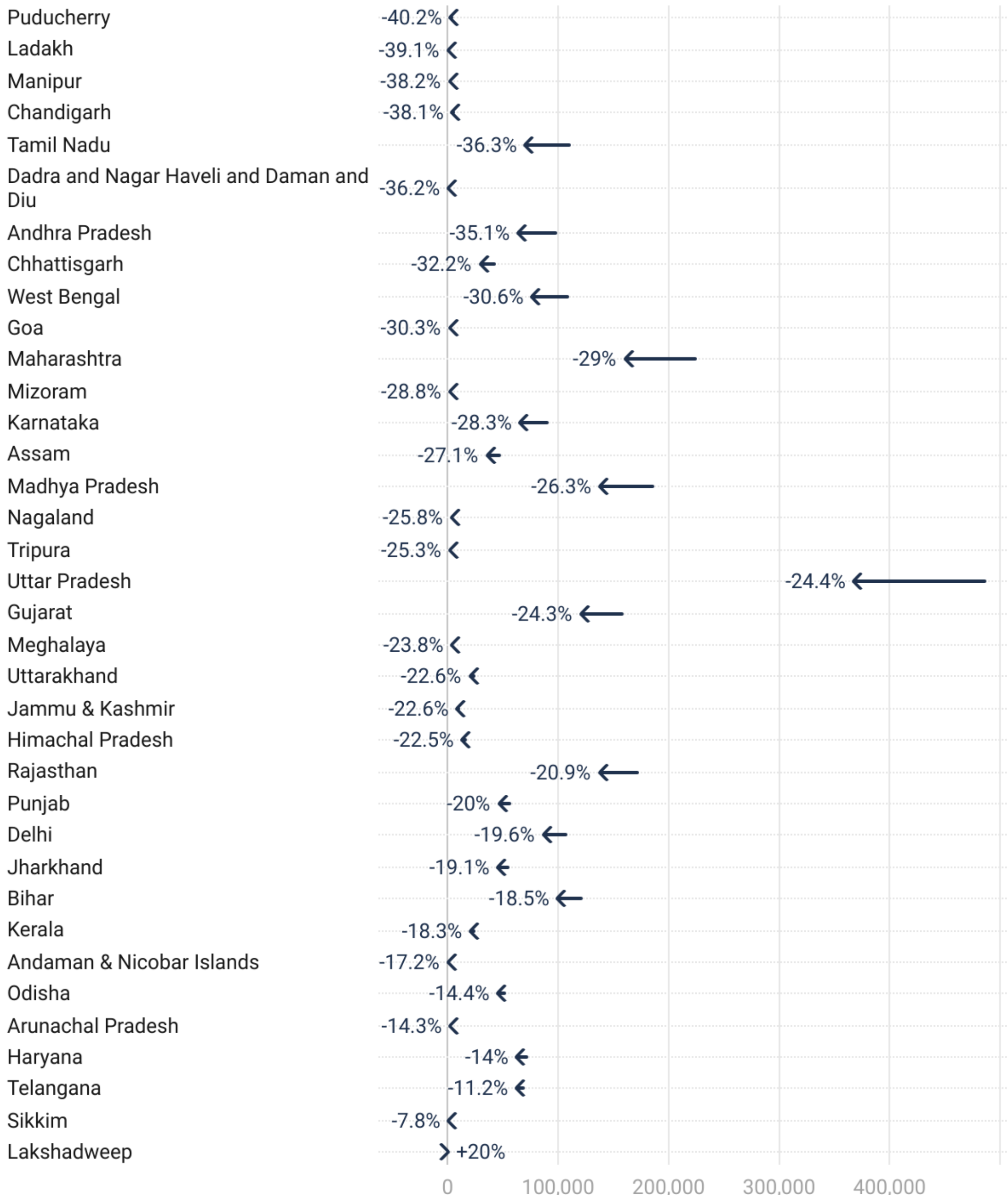

Figure 3 Difference in state-wise tuberculosis case notification from 2019 to 2020

Notes. The x-axis shows the total number of tuberculosis cases in 2019 and 2020. The arrow shows the percent difference in the total notified cases between 2019 and 2020.

Test for stationarity

Table 1 shows the result of the Augmented Dickey-Fuller (ADF) test. The null hypothesis of the ADF test is that an AR model has a unit root, which implies that the data series is not stationary. Since the p-value is greater than 0.05, the null hypothesis is accepted. Hence, the data from January 2017 to December 2019 is not stationary.

Table 2 shows the Dickey-Fuller (ADF) test result for first-ordered stationarity. Various methods like Log transformation and the ordered difference can convert the data into stationarity. Here, the first-ordered difference is used. Since the p-value is less than 0.05, the null hypothesis is rejected, and we conclude that the data is stationary.

Table 1 Dickey-Fuller test for stationarity

Dickey-Fuller test	Test statistic
Z(t)	-1.763
MacKinnon approximate p-value for Z(t) = 0.722	

Table 2 Dickey-Fuller test for stationarity of first-ordered difference

Dickey-Fuller test	Test statistic
Z(t)	-5.566
MacKinnon approximate p-value for Z(t) = 0.000	

Fitting the model

ARIMA model, as well as Seasonal ARIMA (SARIMA) models, were tested to get the best fit for the data. Based on the ACF and PACF plot and the auto-Arima function, the p-value will be 1 or 2, d will be one as we have taken the first order difference to make the data stationary, and q will be 0. For the SARIMA model, the seasonal P will be 1 and 2, D will be 0 and 1, and Q will be 0. S will be 12 as monthly data is used. So, the resulting models will be ARIMA (1,1,0), ARIMA (2,1,0), SARIMA (1,1,0) $(1,0,0)_{12}$, and SARIMA (2,1,0) $(1,0,0)_{12}$.

Comparison of the model

Table 3 provides Log Likelihood, Akaike information criterion (AIC), and Bayesian information criterion (BIC) for the four selected models. The lower the value of log-likelihood, the better the fit. Similarly, the lower the AIC value, the better the model fits the data while considering the complexity of the model. On the other hand, BIC is similar to AIC but has a more substantial penalty for including additional variables in the model. Based on all the parameters, Seasonal ARIMA (1,1,0) $(1,0,0)_{12}$ was the best model for prediction and forecasting.

Forecasting the tuberculosis notification from January 2020 to June 2021

Figure 3 shows the monthly tuberculosis notifications in India from January 2020 to June 2021 and the forecasted tuberculosis cases using the Seasonal ARIMA (1,1,0) $(1,0,0)_{12}$ model. As we can see, before March 2020, tuberculosis-reported and predicted cases overlapped. However, a considerable difference in the reported and projected cases can be seen after March 2020.

Differences in the reported and forecasted tuberculosis cases

Figure 4 shows the difference in the reported and forecasted cases during different phases of COVID-19 in India. The highest difference between the reported and projected tuberculosis cases was during the lockdown period of 2020. The mean difference was approximately 50 percent during April, May and June 2020. The difference also reduced as the cases declined from September 2020 to March 2021. Again, with the high surge in COVID-19 cases during the second wave of April 2021 to June 2021, a high contrast between the notified cases and the predicted cases can be seen.

Table 3 Comparisons of Predictive Performance Measures

	Non-Seasonal		Seasonal	
	(1,1,0)	(2,1,0)	(1,1,0) $(1,0,0)_{12}$	(2,1,0) $(2,1,0)_{12}$
Log Likelihood	-384.2	-383.3	-250.9	-250.9
AIC	772.5	772.5	507.9	511.7
BIC	775.6	777.2	511.3	517.4

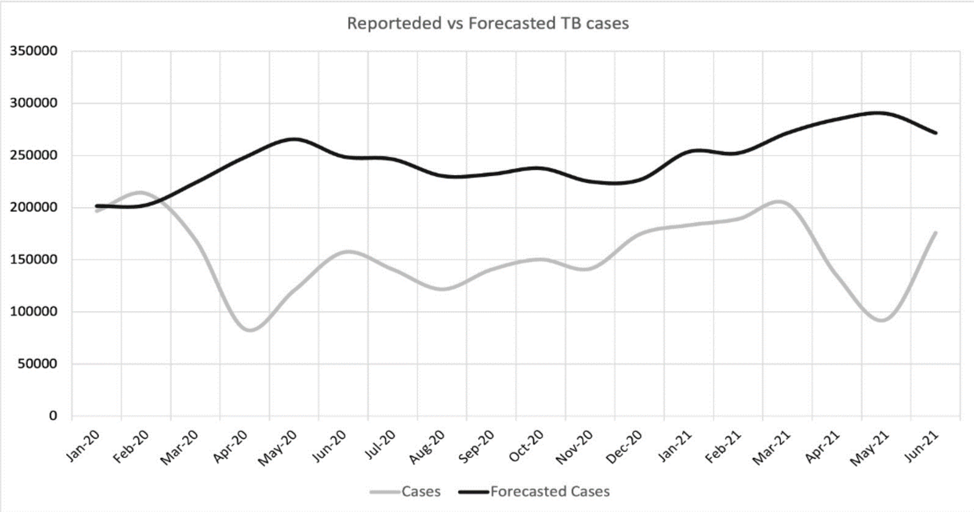

Figure 3 Tuberculosis Case Notifications vs. Tuberculosis Forecasted Cases (Jan 2020 to June 2021)

Notes. The cases line (light) shows the frequency of reported tuberculosis case notifications. The forecasted cases line (dark) shows the forecasted tuberculosis cases using SARIMA.

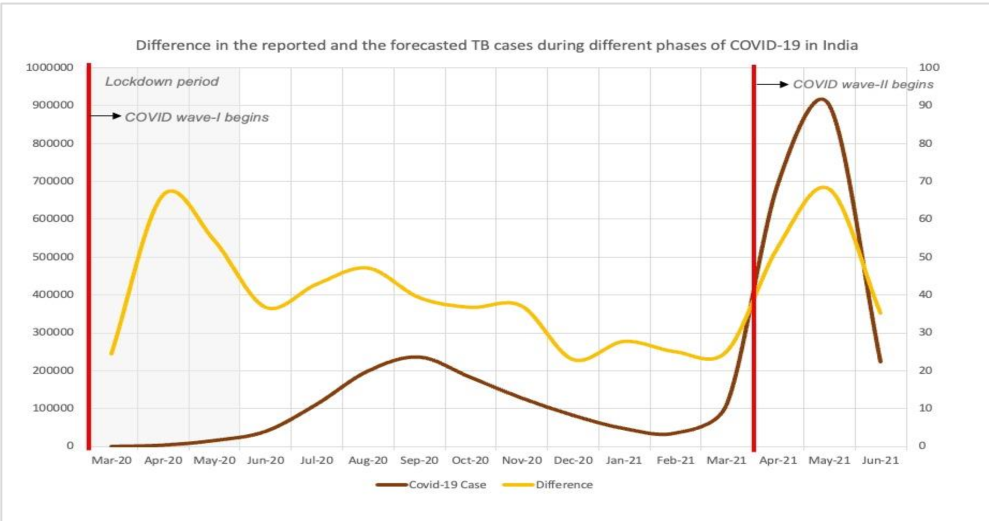

Figure 4 Difference in the reported and forecasted cases during different phases of COVID-19 in India

Notes. The difference line (yellow) shows the percentage difference in reported and forecasted tuberculosis cases. The COVID-19 case line (brown) shows the frequency of monthly COVID-19 cases in India. The two vertical lines (red) mark the onset of different waves of COVID-19.

Discussion

Tuberculosis continues to be a global health crisis, especially in low-middle-income countries. Moreover, it has been considered a global public health emergency for the last 25 years. India accounts for the highest burden of both tuberculosis cases and deaths, even though it has engaged in tuberculosis control activities for more than 50 years (Global Tuberculosis Report, 2022). Tuberculosis notification rates have increased quickly, but the COVID-19 pandemic took a significant toll on it.

Total tuberculosis notification increased from 18.20 lacs in 2017 to 24.04 lacs in 2019 (India TB Report, 2021). The findings from this study reveal that tuberculosis case notifications witnessed a tremendous increase in India until 2019 that is synonymous with the existing literature (Golandaj et al., 2022). The private healthcare facilities played a pivotal role in gauging the actual tuberculosis case notifications during this period thereby causing a surge in the case notifications. As seen in the results, notifications from the private facilities increased by three folds between 2017 and 2019. The share of tuberculosis notifications from the private facilities increased by 21 percent in 2017 to 31 percent in 2020 (Suseela & Shannawaz, 2023). Almost 50 percent of the patients with tuberculosis symptoms sought care from the private sector, according to the National TB Prevalence Survey (National TB Prevalence Survey in India 2019 – 2021, Ministry of Health and Family Welfare). It is important to note that NTEP offered an incentive of INR 500 for notifying each tuberculosis case and an additional INR 500 for reporting the treatment outcome, to all the private healthcare facilities (Central TB Division, MoHFW, Government of India, 2020).

The COVID-19 pandemic has significantly impacted tuberculosis control efforts in India, with disruptions to tuberculosis services and a decline in tuberculosis notification rates (Rodrigues et al., 2022). A study aimed to estimate the impact of COVID-19 on tuberculosis notification rates in India found that the number of tuberculosis notifications reported from January to June 2020 was 25 percent lower than expected. April and May of 2020 saw the most significant drop in tuberculosis notifications, which coincided with the nationwide lockdown to contain the COVID-19 pandemic (Sahu et al., 2023). Such missing cases go undiagnosed and continue to spread the infection in the population. It puts an additional burden on the country's efforts to end tuberculosis (Thakur et al., 2021). The results from this study show monthly tuberculosis case notifications dropped significantly during 2020 compared to 2019, that aligns with the above-mentioned studies. Applying the time-series model in this study gave depth to this grave issue. The forecasted cases from January 2020 to June 2021 reveal that the highest difference between the reported and forecasted tuberculosis cases were during the lockdown period of 2020. With the surge in COVID-19 cases during the second wave of April 2021 to June 2021, a high contrast between the notified cases and the predicted cases can be seen again.

Putting the spotlight on the impact of the COVID-19 pandemic on tuberculosis, the report includes data collected by WHO's Global Tuberculosis Programme that show sharp drops in tuberculosis case notifications in several high tuberculosis-burdened countries in 2020 (Global Tuberculosis Report, 2021). World Health Organization's modelling and analysis of the impact of the COVID-19 pandemic on tuberculosis mortality indicate that a 50 percent drop in the detection of tuberculosis cases over three months will lead to almost 400,000 more people dying from tuberculosis (WHO, 2021).

Conclusion

The study's findings suggest that tuberculosis case notifications have significantly declined during the COVID-19 pandemic. Lockdowns and public health recommendations have made traditional tuberculosis management extremely difficult. It emphasizes the pressing need for action to lessen COVID-19's adverse effects on India's efforts to combat tuberculosis. These measures could include strengthening tuberculosis services, improving access to tuberculosis diagnosis and treatment, and increasing awareness about tuberculosis among the general public. These measures are essential to achieve the goal of ending the tuberculosis burden in India.

With the current situation of the tuberculosis epidemic in the country, meeting the 2025 targets seems like an ambitious target. However, by establishing an ambitious plan for tuberculosis elimination, the Indian government signaled its commitment to fighting the disease– the country with the highest burden of tuberculosis in the world. This is a huge step, and, significantly, the government is recognising the importance of stopping tuberculosis, given that it has not received much prominence previously.

Strengths & limitations

The study is based on national-level data which provides robust information on tuberculosis cases. The data on tuberculosis case notification is provided from a verified government source. While the existing studies have provided evidence of year-on-year difference in tuberculosis case notifications from 2019 to 2020, this paper utilizes the strength of a time-series model to predict the actual difference in the underreported cases. Furthermore, the SARIMA model is a suitable choice in predicting tuberculosis notifications as it accounts for seasonality. It may be noted that the tuberculosis case notification data in the public domain has been available since January 2017. Time-series models require larger amounts of data to predict more accurately, therefore, the results from this prediction may be taken with caution. For the same reason, analyses based on smaller units like states or district was not feasible.

Conflict of interest

The authors declare no conflict of interest.

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