India reported having 498 cases COVID-19 (including 40 foreign tourists) as of 23 March 2020 (ref. 1) and out of which 32 cases were recovered and 9 deaths occurred. The number of COVID-19 cases worldwide as of 23 March 2020, was 378,000 with 16,500 deaths. Overall more than 1.5 million passengers were screened at airports in India, 17,237 people were clinically tested for COVID-19 as of 23 March 2020 (ref. 1) and out of which 19 (including 40 foreign tourists) as of 23 March 2020 (ref. 1).

India: continued efforts required to contain the virus spread

Model-based retrospective estimates for COVID-19 or coronavirus in India: continued efforts required to contain the virus spread

Appendix 1. Data, methods and models

The model specifically considered the proportion of populations in the year 2020 in the age groups (0–14 (27.1%), 15–64 (66.8%), 65+ (6.2%)), population density (464 km$^2$), level of urbanization in India (35%) from the sources $^{7-8}$. In the first phase of the community spread the urban population will be affected. Uncontrolled transmission between urban to rural might lead to the second phase of the epidemic. We have assumed our results reflect the first phase of the spread. The two coupled differential equations $s(t) = -\beta s(t)k(t)$ and $k(t) = \beta s(t)k(t)$, where $s(t)$ and $k(t)$ represent susceptible and infected at time $t$, $\beta$ is the average transmission rate from an infected to susceptible and $\beta = 1.5E-09$ for 15–64 age group and $\beta = 7.5E-09$ for 65+ age group. We further assumed that $\beta$ is constant during 1–15 March 2020. We have divided model predicted numbers with the reported numbers during the same period to obtain degree of reporting, say, $d(t)$ is given by $d(t) = k(t)/R(t)$, where $R(t)$ represent reported COVID-19 cases at time $t$. We plotted $d(t)$ values for $t = (1–15$ March) shown in Figure 1. The above procedure also gives us under-reported COVID-19 cases (that includes under-diagnosed). Using reported and total cases constructed, the Meyer wavelets were constructed. The Meyer wavelets $\psi(t)$ are infinitely differentiable functions within a certain domain. See details in refs 5, 6, 12. These wavelets are accompanied by a function $u(t)$ given below

$$\psi(t) = \begin{cases} \frac{1}{\sqrt{2\pi}} \sin \left( \frac{\pi}{2} u \left( \frac{3|\omega|}{2\pi} - 1 \right) \right) e^{it^2} & \text{if } 2\pi/3 < |\omega| < 4\pi/3 \\ \frac{1}{\sqrt{2\pi}} \cos \left( \frac{\pi}{2} u \left( \frac{3|\omega|}{2\pi} - 1 \right) \right) e^{it^2} & \text{if } 4\pi/3 < |\omega| < 8\pi/3 \\ 0 & \text{otherwise} \end{cases}$$

Here $u(x) = 0$ for $x < 0$, and

$$u(x) = \begin{cases} x & \text{for } x \in (0,1) \\ 1 & \text{for } x > 1 \end{cases}.$$
During the next eight days of 16–23 March, additional 361 cases have been reported. This could indicate that the spread mechanism had initiated a couple of weeks ago.

To understand the current status of COVID-19 spread during the first two weeks of March, model-based estimates were developed for India based on Indian-centric data. We applied them on the harmonic analysis methods and dynamic models developed earlier for emerging epidemics and modified for COVID-19 epidemic. See Appendix 1 for the details on data, models and methods. The model estimates show that the number of COVID-19 infected would be 9225 (if there were 10 infected individuals as of 1 March 2020, who were not taking any precautions to spread), 17,986 (if there were 20) and 44,265 (if there were 50). We have used China-level parameters that were used in the earlier paper. We have plotted the Meyer wavelets that were plotted for the reported numbers and for the model-based adjusted numbers to give us an idea of the degree of variation in reporting. As the testing for COVID-19 was not done widely for general population but done for travelers from abroad or returned travelers, so for the general population we are not sure whether \( N = 50 \) on 1 March is a real beginning. Even if medium range values were happened during 1–15 March then that would lead to very large infections in the future because controlled social distances and other precautions would be not practically possible for a longer period.

India has launched several social distancing measures and personal hygiene measures during the second week of March. As soon as more data becomes available in the coming weeks on the impact of these measures in controlling the spread, that will help to generate more valid model-based predictions stratified on state level epidemic, level of health infrastructure and magnitude of preventive strategies employed. Identification of individuals at risk is more important when the virus is highly contagious and there were proposals to capture the community level severity through AI models, and now casting techniques are also very helpful. There are speculations that the virus spread will be restricted in hot temperature countries like India, and thus factors like treatment can be introduced in the models as soon as credible data is available. Natural positives factors like very hot summers and the urbanization level which is low in comparison with other COVID-19 affected countries such as China (61%) and Italy (83%) might play better roles in controlling the spread in India in the future.

The economic impact of COVID-19 will be widespread and significant but the government has already initiated steps to intervene. To remain prepared we need data based decisions which help us to shape our interventions. The projections produced by the model and after their validation can be used to determine the scope and scale of measures that governments need to initiate.

In conclusion, if the current mathematical model results can be validated within the range provided here, then the social distancing and other prevention, treatment policies that the central and various state governments and people are
currently implementing should continue until new cases are not seen. Importantly spread to urban to rural populations should be controlled.

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