Preliminary Analysis of Excess Mortality in India During the Covid-19 Pandemic (Update September 26, 2021).

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Abstract.

As both testing for SARS Cov-2 and death registrations are incomplete or not yet available in many countries, the full impact of the Covid-19 pandemic is currently unknown in many world regions.

We studied the Covid-19 and all-cause mortality in 19 Indian states (combined population of 1.27 billion) with available all-cause mortality data during the pandemic for the entire state or for large cities. Excess mortality was calculated by comparison with available data from years 2015-2019. The known Covid-19 deaths reported by the Johns Hopkins University Center for Systems Science and Engineering for a state were assumed to be accurate, unless excess mortality data suggested a higher toll during the pandemic. Data from one state were not included in the final model due to anomalies.

In several regions, fewer deaths were reported in 2020 than expected. The excess mortality in Mumbai (in Maharashtra) in 2020 was 137.0 / 100K. Areas in Andhra Pradesh, Delhi, Haryana, Karnataka, Madhya Pradesh, Tamil Nadu, and Kolkata (in West Bengal), saw spikes in mortality in the spring of 2021.

The pandemic-related mortality through August 31, 2021 in 18 Indian states was estimated to be 198.7 per 100,000 population (range 146.1 to 263.8 per 100K). If these rates apply to India as a whole, then 2.69 million people (range 1.98 to 3.57 million) may have perished in India as a result of the Covid-19 pandemic by August 31, 2021.

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Introduction.

As both testing for SARS Cov-2 and death registrations are incomplete or not yet available in many countries, the full impact of the Covid-19 pandemic is unknown in many world regions. One approach to assess the impact of the evolving pandemic is to examine excess mortality from all causes. An increase in all-cause mortality during the pandemic is assumed to be a direct result of infection with the Sars Cov-2 virus, or indirect effects from health system overload or social responses to the pandemic.

For many countries, national tallies of mortality during phases of the pandemic have already become available. Early in the pandemic, India was believed to have suffered Covid-specific per-capita mortality well below that of the United States.¹ Regional government websites and data journalists are publishing up-to-date mortality figures for an ever-increasing number of cities and states in India. We sought to integrate these data to estimate the impact of the Covid-19 pandemic in India as a whole. We understand that the picture might change as the pandemic proceeds, and as more data become available.

Methods.

Sources of All-Cause Mortality Data.

We used the publicly available mortality figures published by regional governments and by data journalists in India, often obtained from Right-to-Information (RTI) requests (Supplemental References, Table S1). Much of these data are stored on the websites maintained by the Local Mortality project of Ariel Karlinsky,²,³ or the Development Data Lab.⁴ These were supplemented by data from government hospitals, funeral counts, and handwritten death registers when available, as detailed below.

We acquired mortality data from 19 states (or union territories) with 1.27 billion population, either for the entire state, or for large cities or districts within the state (Table 1). As a convenient shorthand, we refer to these 19 administrative regions as “states”, even though two of them (Chandigarh and Delhi) are actually union territories. The inclusion of a state or large city in the analysis was based on whether reliable mortality data were available. Some smaller states were not included because governments, reporters, nonprofits and academics have not yet published relevant mortality data for the pandemic period.

All of these publicly available regional-level mortality data contain no individually-identifiable information. The study was approved by the Office of Research Subjects Protection of Virginia Commonwealth University.

For Chhattisgarh, mortality data from the online portal of the state CRS have been released,⁴ and we included these data in the appendix. However, as the baseline data for this online portal appear to be only about one tenth complete, as compared with
the national vital statistics registry, we deemed the Chhattisgarh data too unreliable to include in the model.

For Gujarat, journalists tabulated deaths from March 2020 through April 2021 for 68 of the 170 municipalities, which comprised 6.01% of the state’s population, from the bound handwritten official municipal death registers (Table S1, Supplemental References). For 3 of these Gujarat municipalities (Chorvad, Idar, and Khedabrahma), death register data were available from May 1 to June 10, 2021.

For the urban portions of 25 districts in Madhya Pradesh, the numbers of funerals in April 2021 have been tabulated (Supplemental References).

For Uttar Pradesh, the raw mortality data obtained from a Right-to-Information request contained anomalies, such as multiple districts with zero deaths for numerous months. Therefore, the Uttar Pradesh data were analyzed, but were not included in the top-line model.

**Reported Covid-19 Mortality.**

Mortality attributed to Covid-19 has been tabulated by the Johns Hopkins University Center for Systems Science and Engineering (CSSE, Table S2). Our model assumed that the CSSE figures for Covid-19 mortality accurately reflected the pandemic-related mortality in a given state for each year of the pandemic (2020 and 2021), unless the excess mortality data suggested a higher toll.

The CSSE in turn obtains Covid mortality data from the governmental health authorities of the respective countries. In the case of India, the CSSE links to the Covid-19 webpage for the Health Ministry of India. According to reports, local physicians and health authorities in India were in some cases not reporting deaths as caused by Covid-19 if SarsCov-2 tests were not performed or if the patient had contributing comorbidities.

**Analysis of Mortality.**

For some states, several data sources were available, which permitted the calculation of multiple estimates of per-capita excess mortality. In this case, we presented both the median estimate and the lowest and highest estimates available.

For Gujarat and the urban portions of 25 districts in Madhya Pradesh, mortality data from entire year(s) before 2020 were available. Therefore, to estimate excess mortality for portions of 2021, it was necessary to assume that mortality was evenly distributed throughout the year.

For the analysis of data from 68 municipalities in Gujarat, the per-capita mortality for 2021 was estimated by summing the mortality rate through April 2021 with that from available municipalities for May 1 through June 10 (Table S1).
We calculated excess mortality in a region by comparing the mortality for a given time period in 2020 or 2021 with the value expected based on the years 2015 to 2019. If data from more than one year before 2019 were available, the expected value was calculated by creating a trend line for mortality by linear regression for the years 2015 to 2019, and carrying this trend one year (for 2020) or two years (for 2021) into the future. Carrying the trend line two years into the future for 2021 yielded conservative estimates of excess deaths.

For some states, reported mortality from the state government websites or right-to-information (RTI) requests was only available for 2018 and 2019, which was too short a period to generate a robust trend line. Moreover, the numbers of deaths from the state sources did not match the central government figures exactly, because the state information systems did not capture all of the registered deaths. In these cases, the vital statistics reports for India were used to generate a trend line for expected deaths, using the data from 2015 to 2019. The expected number of deaths was scaled up or down by multiplying the 2015 to 2019 trend line by the ratio of deaths in the state and federal systems for 2018 and 2019. For instance, if the state website average mortality for 2018 and 2019 was 97% of the figures for 2018 and 2019 in the federal reports, the trend line was multiplied by 0.97. This method was used to scale the trend line for Delhi, Bengaluru, Mumbai, Nagpur, Ahmedabad (for 2020), Madhya Pradesh, Tamil Nadu, for 6 city hospitals in Tamil Nadu, and for Madurai district.

Completeness of death registrations has been estimated by the Indian government in the vital statistics reports for each state by comparison with the Sample Registration System (Table S1). For years in which the completeness was less than 100%, the total number of deaths for each year 2015 to 2019 was determined by dividing the death registrations by the completeness fraction. Unlike the trend line for unadjusted death registrations, the trend line for the adjusted registrations did decrease over time for some states. In order to ensure the estimated excess deaths were conservative, the expected deaths for 2020 and 2021 were the maximum of the 2019 value and the value predicted by the trend line. The completeness fraction for 2020 and 2021 was extrapolated by linear regression from the 2015 to 2019 completeness fraction. Once again, in order to be conservative, the maximum of the 2019 value and the linear extrapolation was used.

The national mortality rate was estimated by summing the estimated pandemic-related deaths for the states analyzed and then dividing by the population of these states. The population size of Indian states was taken from the Hopkins mortality dataset. Raw data are tabulated in the appendix (Table S1).

**Graphical analysis of mortality.**

In order to present the timing of the mortality graphically, the per-capita mortality rates (total monthly deaths divided by total population) were calculated for the states for which monthly data were available from Jan 2019 through May 2021 (Andhra Pradesh,
Bihar, Chandigarh, Delhi, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu, and West Bengal). For subsequent months, the per-capita mortality was calculated from states with data available (Punjab through June 2021, Andhra Pradesh through July 2021, Karnataka and Tamil Nadu through August 2021, and Odisha in July and August 2021). For the purposes of generating this figure, the Odisha cumulative annual mortality for August 1, 2021 was estimated by linear interpolation from the July 1 and August 8 values. This graphical analysis was completely separate from the tabulated estimate of total mortality in India.

Results.

Excess Mortality.

We studied 19 states, with a population of 1.27 billion, for which excess mortality could be estimated for at least a portion of the state (Tables 1, 2). Excess mortality could be estimated for regions in all 19 states in 2020, and in 18 states in 2021 (Table 1).
### Table 1. Excess mortality in India, January 2020-August 2021.

| State            | Region.         | Population | Excess deaths | Excess mortality / 100K | Final Date |
|------------------|-----------------|------------|---------------|-------------------------|------------|
|                  |                 |            | 2020          | Jan-Aug 2021            | 2020       | Jan-Aug 2021 |
| Andhra Pradesh   |                 | 53,903,393 | 65,493        | 173,446                 | 121,501    | 321,772     | 7/31        |
| Assam            |                 | 35,607,039 | 15,246        | --                      | 42,819     | --          |            |
| Bihar            |                 | 124,799,930| 134,244       | 126,388                 | 107,567    | 101,272     | 5/31        |
| Chandigarh       |                 | 11,584,730 | -8,238        | -2,707                  | -71,114    | -23,368     | 5/31        |
| Delhi            |                 | 18,710,920 | 1,202         | 43,099                  | 6,421      | 230,342     | 6/30        |
| Gujarat          | Entire state    | 63,872,400 | -70,333       | 32,376                  | -110,115   | 50,688      | 5/10        |
| Ahmedabad        |                 | 8,059,000  | 5,276         | 2,935                   | 65,466     | 36,417      | 5/10        |
| 68 cities        |                 | 3,838,730  | 7,004         | 9,908                   | 182,464    | 258,094     | 4/30        |
| 3 cities         |                 | 83,900     | --            | 145                     | --         | 172,295     | 6/10        |
| 68 cities        |                 | 3,838,730  | --            | --                      | 430,389    | 6/10        |            |
| Haryana          |                 | 28,204,692 | 11,087        | 41,026                  | 39,311     | 145,458     | 5/31        |
| Himachal Pradesh | Entire state    | 7,451,955  | 291           | 2,976                   | 3,902      | 39,930      | 5/31        |
| Karnataka        | Entire state    | 67,562,700 | 12,627        | 111,876                 | 18,689     | 165,588     | 8/30        |
| Bengaluru        |                 | 8,443,675  | 6,510         | 54,740                  | 77,103     | 648,291     | 6/15        |
| Kerala           | Entire state    | 35,699,440 | -27,367       | 6,484                   | -76,659    | 18,163      | 5/31        |
| Madhya Pradesh   | Entire state    | 85,358,970 | -28,598       | 181,159                 | -33,503    | 212,232     | 5/31        |
| 25 districts     |                 | 25,412,510 | --            | 11,785                  | --         | 46,376      | 4/30        |
| Maharashtra      | State less 6 districts | 102,598,050 | 103,152 | 104,946 | 100,540 | 102,288 | 5/31 |
| Mumbai city      |                 | 12,875,213 | 17,641        | 6,467                   | 137,018    | 50,227      | 5/31        |
| Nagpur city      |                 | 2,405,000  | --            | 4,144                   | 172,308    | --          |            |
| Odisha           |                 | 46,356,334 | 20,035        | 58,238                  | 43,220     | 125,631     | 8/31        |
| Punjab           |                 | 30,141,373 | -11,415       | 36,247                  | -37,873    | 120,255     | 6/30        |
| Rajasthan        |                 | 81,032,689 | 6,629         | 32,311                  | 8,181      | 39,874      | 5/31        |
| Tamil Nadu       | Chennai         | 7,088,000  | 5,921         | 19,199                  | 83,540     | 270,866     | 8/01        |
|                  | Entire state    | 77,841,270 | 72,052        | 206,274                 | 92,563     | 264,993     | 8/31        |
|                  | 6 cities        | 5,980,370  | -1,032        | 14,160                  | -17,261    | 236,776     | 5/31        |
|                  | Madurai         | 3,038,250  | 2,018         | 2,325                   | 66,412     | 76,508      | 5/31        |
| Telangana        | Hyderabad       | 9,482,000  | 8,359         | 6,805                   | 88,157     | 71,768      | 5/31        |
| Uttar Pradesh    | 237,882,725     | -37,468    | 48,458        | -15,751                 | 20,371     | 4/30        |
| West             | Entire state    | 99,609,300 | 53,355        | 49,122                  | 53,564     | 49,315      | 5/31        |
| Bengal           | Kolkata         | 4,496,694  | 2,075         | 2,901                   | 46,145     | 64,514      | 5/23        |

Data sources listed in supplemental references for: Andhra Pradesh (Banaji), Delhi (Radhakrishnan), Kolkata (Karinsky), Bengaluru (Chatterjee 2021), Tamil Nadu (crstn.org), Madurai district (Radhakrishnan 2021), Kerala (devdatalab), Uttar Pradesh data (Das), Rajasthan (devdatalab), Haryana (Ranani), Punjab (Ranani), and Himachal Pradesh (Ranani). Gujarat 2020 data available Jan.-Nov. Ahmedabad 2020 data available Apr.-May. Gujarat, including Ahmedabad, 2021 mortality available from Mar 1 to May 10, 2021. Death register data from 68 municipalities in Gujarat, with 6.01% of state population, available through April 2021 (Jalihal 2021). Mortality data for May 1 to June 10, 2021 were available from 3 municipalities in Gujarat (Choravad, Idar, Khedbrahma) with 0.13% of the state population (wallofgrief.org). Nagpur data available Apr. to Dec. 2020. The 6 government hospitals in Tamil Nadu studied by Arappor Iyakkam from Jan-May in 2020 and 2021 were in Madurai, Coimbatore, Trichy, Vellore, Karur, and Tirupur. The urban areas in Madhya Pradesh from which funeral counts were tabulated for April 2021 were from the following 25 districts: Barwani, Bhind, Bhopal, Burhanpur, Chhatarpur, Chhindwara, Dewas, Dhar, Gwalior, Indore, Jabalpur, Jhabua, Khandwa, Mandsaur, Morena, Neemuch, Ratlam, Sagari, Satna, Seoni, Shahdol, Shivpuri, Singroli, Tikamgarh, Vidisha (Datta 2021). Maharashtra data did not include 6 districts: Pune, Satara, Sangli, Yavatmal, Sindhudurg and Gondiya (Ranani).
### Table 2. Reported and Estimated Covid-19 Deaths in India, 2020 through August 2021.

| State            | Population       | Year | Reported Deaths/100K | Estimated Covid-19 Deaths |
|------------------|------------------|------|----------------------|---------------------------|
|                  |                  |      |                      | Deaths/100K | Number |
| Andhra Pradesh   | 53,903,393       | 2020 | 13.179               | 121.501      | 65,493 |
|                  |                  | 2021 | 12.493               | 321.772      | 173,446 |
| Assam            | 35,607,039       | 2020 | 2.929                | 42.819       | 15,246 |
|                  |                  | 2021 | 12.952               | --           | --     |
| Bihar            | 124,799,930      | 2020 | 1.116                | 107.567      | 134,244 |
|                  |                  | 2021 | 6.619                | 101.272      | 126,388 |
| Chandigarh       | 11,584,730       | 2020 | 2.728                | 2.728        | 316    |
|                  |                  | 2021 | 4.290                | 4.290        | 813    |
| Delhi            | 18,710,920       | 2020 | 56.240               | 56.240       | 10,523 |
|                  |                  | 2021 | 77.805               | 230.342      | 43,099 |
| Gujarat          | 63,872,400       | 2020 | 6.735                | 65.466       | 41,815 |
|                  |                  | 2021 | 9.048                | 50.688       | 32,376 |
| Haryana          | 28,204,692       | 2020 | 10.278               | 101.272      | 126,388 |
|                  |                  | 2021 | 24.024               | 145.458      | 41,026 |
| Himachal Pradesh | 7,451,955        | 2020 | 12.493               | 12.493       | 931    |
|                  |                  | 2021 | 35.749               | 39.930       | 2,976  |
| Karnataka        | 67,562,700       | 2020 | 17.881               | 47.896       | 32,360 |
|                  |                  | 2021 | 37.316               | 406.940      | 274,939 |
| Kerala           | 35,699,440       | 2020 | 8.521                | 8.521        | 3,042  |
|                  |                  | 2021 | 49.387               | 49.387       | 17,631 |
| Madhya Pradesh   | 85,358,970       | 2020 | 4.212                | 4.212        | 3,595  |
|                  |                  | 2021 | 8.108                | 129.304      | 110,373 |
| Maharashtra      | 123,144,200      | 2020 | 40.167               | 137.018      | 168,730 |
|                  |                  | 2021 | 71.255               | 86.772       | 106,854 |
| Odisha           | 46,356,334       | 2020 | 4.036                | 43.220       | 20,035 |
|                  |                  | 2021 | 13.008               | 125.631      | 58,238 |
| Punjab           | 30,141,373       | 2020 | 17.687               | 17.687       | 5,331  |
|                  |                  | 2021 | 36.634               | 120.255      | 36,247 |
| Rajasthan        | 81,032,689       | 2020 | 3.318                | 8.181        | 6,629  |
|                  |                  | 2021 | 7.731                | 39.874       | 32,311 |
| Tamil Nadu       | 77,841,270       | 2020 | 15.556               | 74.976       | 58,362 |
|                  |                  | 2021 | 29.278               | 250.885      | 195,292 |
| Telangana        | 39,362,732       | 2020 | 3.915                | 88.157       | 34,701 |
|                  |                  | 2021 | 5.922                | 71.768       | 28,250 |
| Uttar Pradesh    | 237,882,725      | 2020 | 3.511                | 3.511        | 8,352  |
|                  |                  | 2021 | 6.082                | 20.371       | 48,458 |
| West Bengal      | 99,609,300       | 2020 | 9.721                | 49.855       | 49,660 |
|                  |                  | 2021 | 8.785                | 56.915       | 56,692 |
| Total, except    | 1,030,244,067    | 2020 | 12.610               | 64.266       | 662,100 |
| Uttar Prad.      | 994,637,028      | 2021 | 24.128               | 134.416      | 1,336,951 |
| Total            | 1,268,126,792    | 2020 | 10.903               | 52.869       | 670,452 |
|                  | 1,232,519,753    | 2021 | 20.645               | 112.405      | 1,385,409 |

Reported Covid-19 deaths are taken from the Hopkins dataset.
Table 3. Estimated Covid-19 Mortality in India by August 31, 2021.

|                  | Estimated Covid Mortality (per 100,000) | Covid-19 deaths (estimated) |
|------------------|----------------------------------------|-----------------------------|
|                  | Median | Range          | Median | Range                  |
| 2020             | 64.266 | 47.496 - 79.341 | 869,289 | 642,451-1,073,200      |
| 2021             | 134.416| 98.632 - 184.443| 1,818,168| 1,334,138-2,494,854   |
| Both years       | 198.682| 146.128 - 263.784| 2,687,457| 1,976,589-3,568,054   |

Assumes population of India of 1,352,642,280. Per-capita excess mortality based on all states analyzed except Uttar Pradesh.

The timing of the excess per-capita mortality during the pandemic is illustrated in Figure 1. In 2020, there was a slight increase in all-cause mortality from August through October, as compared with 2019. However, the most prominent rise in all-cause mortality came in the spring of 2021, and was evident in April and May (Figure 1). After May 2021, the available data suggest that mortality registrations continued to rise through June, but had begun to wane in the summer of 2021 (Figure 1).

**Figure 1.** Per-capita all-cause mortality in India by month, 2019 to 2021. Based on 13 states and 2 union territories, as described in the Methods section.
For Chandigarh, Delhi, Kerala, Madhya Pradesh, Punjab, and Uttar Pradesh, the excess mortality based on registered deaths was actually negative for 2020 (Table 1). This may be because fewer people were willing to register deaths during lockdown, or because fewer people died from accidents and other causes during lockdown.

At the other extreme, the excess mortality in Mumbai (in Maharashtra) was 137.0 / 100K in 2020 (Table 1). Similarly, Andhra Pradesh had an excess mortality of 121.5 / 100K in 2020 (Table 1).

For 2020, intermediate levels of excess mortality were seen for Kolkata in West Bengal (46.1 / 100K), Chennai in Tamil Nadu (83.5 / 100K), and Hyderabad in Telangana (88.2 / 100K) (Table 1).

For 2021, a prominent peak in all-cause mortality was seen for March through June for Chennai in Tamil Nadu, Kolkata in West Bengal, Delhi, Madhya Pradesh, Haryana, Punjab, and Andhra Pradesh (Table 1). These findings correspond with news reports of increasing severity of the pandemic in India. Data available by August 31, 2021 suggested excess mortality of at least 64.5 / 100K for Kolkata, 120.3 / 100K for Punjab, 145.5 / 100K in Haryana, 212.2 / 100K for Madhya Pradesh, 230.3 / 100K for Delhi, 265.0 / 100K for Tamil Nadu, and 321.8 / 100K for Andhra Pradesh (Table 1).

**Reported Covid-19 Mortality.**

The mortality related to Covid-19, based on viral testing and the clinical picture, as tabulated by Johns Hopkins, was reasonably low: 10.9 / 100K in 2020, and 20.4 / 100K in 2021, for a combined total of 31.4 / 100K for the pandemic, as of August 31, 2021 (Table S2). There was some variation, with lower mortality rates in Assam, Bihar, Gujarat, Odisha, Rajasthan, Telangana, Uttar Pradesh, and West Bengal and higher mortality rates in Delhi, Maharashtra, and Punjab (Table S2).

**Integrated Model of Covid-19-related Mortality.**

The best available estimates of the pandemic-related mortality, whether based on reported Covid-19 deaths, or on excess mortality, are presented in Table 2. We also presented the range of mortality estimates for each state and for India as a whole (Tables 3, S3). Table 3 presents the top-line model to estimate excess mortality during the pandemic in India.

Generally, the excess mortality exceeded the Covid-19 mortality figure reported by Hopkins, and was therefore taken as the pandemic-related mortality. However, the Covid-19 deaths reported by Hopkins were used in the model for Chandigarh, Delhi, Himachal Pradesh, Kerala, and Punjab in 2020 (Table 2).

Despite the wide uncertainty ranges for several states and time periods, the overall uncertainty range was narrower. In the primary model, data from Uttar Pradesh were excluded because of identified anomalies. For 2020, the pandemic-related...
mortality for 18 states with a population of 1.03 billion was estimated to be 64.3 / 100K (range 47.5 to 79.3 / 100K, Tables 2, 3). For 2021, through August 31, the pandemic-related mortality for 17 states with a population of 995 million was estimated to be 134.4 / 100K (range 98.6 to 184.4 / 100K, Tables 2, 3).

Summing these estimates for 2020 and 2021, we estimate the pandemic-related mortality to be: 198.7 / 100K (range 146.1 to 263.8 / 100K) population for the entire pandemic (through August 31, 2021, Tables 2, 3). Assuming a population of India of 1,352,642,280, these rates correspond with 2.69 million people (range 1.98 to 3.57 million) perishing during the pandemic in India from Covid-19 by June 30, 2021.

The estimated Covid-19 mortality can also be expressed as a fraction of the baseline mortality, taken from the 2019 national vital statistics reports (Table S3). The estimated Covid-19 mortality represented an increase over the baseline annual mortality of 10.70% (range 7.91% to 13.21%) in 2020 and 22.40% (range 16.44% to 30.73%) in 2021 (as of August 31). It should be noted that pandemic-related deaths in the final 3 months of 2021 will increase these values.

If the data from Uttar Pradesh are included, then the estimated pandemic-related mortality was 165.3 / 100,000 population through August 31, 2021 (range 122.8 to 217.9 / 100K, Tables 2, S3), corresponding with a mortality of 2.24 million people (range of 1.66 to 2.95 million) during the pandemic in India from Covid-19.

Discussion.

This analysis of excess mortality found that 2.69 million people (range 1.98 to 3.57 million) may have perished in India as a result of the Covid-19 pandemic, as of August 31, 2021.

Data from Uttar Pradesh contained anomalies and had an estimated excess mortality lower than in other regions, in part because Uttar Pradesh data from after April 2021 were not available. However, if the Uttar Pradesh data are included in the model, the estimated pandemic-related mortality in India through August 31, 2021 was 2.24 million people (range 1.66 to 2.95 million).

This mortality level is well above the reported Covid-19 mortality of 438,560 in India as of August 31, 2021. The Institute for Health Metrics and Evaluation (IHME) at the University of Washington currently estimates that the excess mortality in India was 1.23 million persons on August 31, 2021. It should be noted, however, that the IHME model did not look directly at all-cause mortality in India. Rather, the IHME model extrapolated Indian all-cause mortality based on factors such as test positivity rates in India, and all-cause mortality data from other countries, such as Mexico, Brazil, and the
United States,11 Our analysis was based on actual counts of mortality in India, and therefore was a more direct approach to estimation.

One strength of assessing the pandemic impact primarily through excess mortality is the potential to distinguish deaths caused by Covid-19 from “deaths with Covid-19”. Covid-19 patients who likely would have died during the study period due to their comorbidities even if they had never been infected should not result in excess deaths.

Our analysis used the Covid-19 mortality reported by Hopkins University, unless the excess mortality data suggested a higher pandemic-related toll. Our method of determining the expected baseline, by making a projection using linear regression one year (for 2020) or two years (for 2021) into the future, was more conservative than simply using the baseline average mortality, or projecting just one year forward (even for 2021). Thus, our estimates of pandemic-related mortality for various regions are more conservative (i.e. lower) than some other studies and news reports. For instance, Deshmukh and colleagues estimated excess mortality in India of 3.2 million through June 2021 based on Civil Registration System data from 5 states and 5 cities.12 Anand and colleagues estimated excess deaths of 3.4 million through June 2021 based on death registrations from seven states.13 If the number of death registrations increased by a fixed amount every year between 2015 and 2021 in a given state, our study would have reported no excess deaths, while the above studies12,13 would have attributed each annual step increase to the pandemic. Their approach may ultimately prove to generate more accurate estimates, but in the face of uncertainty, we elected to take a more conservative approach. Our definition of the baseline by linear regression was used previously in the World Mortality Dataset.2

Based on mortality data from the online Health Management Information System of the Ministry of Health and Family Welfare, excess deaths in India through June 2021 were estimated to be 2.7 million.12

Survey data can supplement mortality estimates from death registrations. Based on the consumer pyramid household survey (CfHS) produced by the Center for the Monitoring of the Indian Economy (CMIE), Anand estimated excess mortality in India during the pandemic of 4.9 million persons as of April 2021.13 Based on a national telephone survey conducted by Cvoter India OmniBus, the excess deaths in India were estimated to be 3.1 to 3.4 million through June 2021.12 One limitation of this survey is that it included deaths outside the immediate household.12

Seroprevalence data can also help to assess the extent of infection in a population. Based on application of international age-specific infection fatality rates to Indian demography and seroprevalence, the Covid-19 related mortality in India through June 2021 was estimated to be 4.0 million.13 One limitation of this approach is that the infection fatality rates may differ from country to country, depending on the medical system and host factors. The pediatric mortality from Covid-19 in India was higher than in comparison countries in one survey.14 Another limitation of mortality analyses based on seroprevalence is that antibody responses wane over time.15 If seroprevalence is assessed well after the epidemic peak in the study population, overall mortality will be
underestimated. Conversely, if seroprevalence is assessed in the reference population well after the epidemic peak, mortality in the study population could be overestimated.

Guilmoto analyzed Covid-19 mortality in several well-defined Indian populations: deaths in Kerala, elected representatives, Indian Railways personnel, and teachers in Karnataka. Application of these age-specific mortality rates to the Indian population yielded a mortality estimate of 2.2 million persons by late May 2021.

Our analysis has a number of limitations. The data analyzed are still incomplete for many regions and times. There may be delays in registering deaths. In addition, available data obtained from regional government websites, central government compilations, and by reporters through RTI requests are not in complete agreement. Some of these early data may contain errors. All-cause mortality may be higher not only due to infection with the SARS-Cov-2 virus, but also because of health system overload, delays in patients entering the health system for other conditions, or social changes, such as lockdowns. In principle, excess mortality might be observed due to other diseases, war, or environmental factors such as heat waves, though these factors are not known to have played a significant role during the Covid-19 pandemic in India. A number of countries, such as Australia and New Zealand, have experienced lower than normal mortality during the pandemic. Lower mortality rates may occur because there are fewer accidents or homicides, etc. On the other hand, other factors may lead to higher mortality rates during lockdowns in some regions.

Time will tell what the true death toll has been, as the early data are confirmed, additional regions provide more complete mortality data, and data from diverse sources are reconciled. Additional surveys and seroprevalence data can supplement the estimates from death registrations.
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Appendix.

Table S1. Time Series of Mortality from Selected Regions in India.

| Region          | Year   | Period       | Deaths   | Registration Completeness | Reference                  |
|-----------------|--------|--------------|----------|---------------------------|----------------------------|
| Andhra Pradesh  | 2015   | All          | 310,640  | 0.849                     | Vital Statistics           |
| Andhra Pradesh  | 2016   | All          | 313,285  | 0.887                     | Vital Statistics           |
| Andhra Pradesh  | 2017   | All          | 355,546  | 0.944                     | Vital Statistics           |
| Andhra Pradesh  | 2018   | All          | 375,777  | 1.000                     | Vital Statistics           |
| Andhra Pradesh  | 2019   | All          | 401,472  | 1.000                     | Vital Statistics           |
| Andhra Pradesh  | 2018   | All          | 333,275  |                          | Rukmini “AP”               |
| Andhra Pradesh  | 2019   | All          | 363,414  |                          | Rukmini “AP”               |
| Andhra Pradesh  | 2020   | All          | 428,907  |                          | Rukmini “AP”               |
| Andhra Pradesh  | 2018   | Months 1-7   | 193,698  |                          | Banaji (github)            |
| Andhra Pradesh  | 2019   | Months 1-7   | 206,461  |                          |                            |
| Andhra Pradesh  | 2020   | Months 1-7   | 198,030  |                          |                            |
| Andhra Pradesh  | 2021   | Months 1-7   | 385,608  |                          |                            |
| Assam State     | 2015   | All          | 116,778  | 0.511                     | Vital Statistics           |
| Assam State     | 2016   | All          | 130,414  | 0.598                     | Vital Statistics           |
| Assam State     | 2017   | All          | 141,012  | 0.659                     | Vital Statistics           |
| Assam State     | 2018   | All          | 142,605  | 0.669                     | Saikia, Vital St.          |
| Assam State     | 2019   | All          | 163,057  | 0.740                     | Saikia, Vital St.          |
| Assam State     | 2020   | All          | 187,085  |                          | Saikia                     |
| Bihar           | 2015   | All          | 204,093  | 0.319                     | Vital Statist.             |
| Bihar           | 2016   | All          | 177,021  | 0.283                     | Vital Statist.             |
| Bihar           | 2017   | All          | 261,425  | 0.427                     | Vital Statist.             |
| Bihar           | 2018   | All          | 213,989  | 0.346                     | Vital Statist.             |
| Bihar           | 2019   | All          | 359,349  | 0.516                     | Vital Statist.             |
| Bihar           | 2018   | Entire year  | 182,921  |                          | devdatalab                 |
| Bihar           | 2019   | Entire year  | 351,274  |                          | devdatalab                 |
| Bihar           | 2020   | Entire year  | 387,429  |                          | devdatalab                 |
| State     | Year    | Period          | Value     | Source                  |
|-----------|---------|-----------------|-----------|-------------------------|
| Bihar     | 2018    | Jan-May         | 45,487    | devdatalab              |
|           | 2019    | Jan-May         | 133,224   | devdatalab              |
|           | 2020    | Jan-May         | 138,693   | devdatalab              |
|           | 2021    | Jan-May         | 215,746   | devdatalab              |
| Chandigarh| 2015    | Entire year     | 16,203    | Vital Statistics        |
| Chandigarh| 2016    | Entire year     | 16,570    | Vital Statistics        |
| Chandigarh| 2017    | Entire year     | 21,236    | Vital Statistics        |
| Chandigarh| 2018    | Entire year     | 23,330    | Vital Statistics        |
| Chandigarh| 2019    | Entire year     | 23,592    | Vital Statistics        |
| Chandigarh| 2018    | Entire year     | 15,503    | Banaji                  |
| Chandigarh| 2019    | Entire year     | 23,352    | Banaji                  |
| Chandigarh| 2020    | Entire year     | 18,215    | Banaji                  |
| Chandigarh| 2018    | Jan-May         | 9,367     | Banaji                  |
| Chandigarh| 2019    | Jan-May         | 9,748     | Banaji                  |
| Chandigarh| 2020    | Jan-May         | 7,641     | Banaji                  |
| Chandigarh| 2021    | Jan-May         | 9,026     | Banaji                  |
| Chhattisgarh| 2018  | Entire year     | 15,690    | Online portal of the state CRS (devdatalab) |
| Chhattisgarh| 2019  | Entire year     | 15,607    | Online portal of the state CRS (devdatalab) |
| Chhattisgarh| 2020  | Entire year     | 63,237    | Online portal of the state CRS (devdatalab) |
| Chhattisgarh| 2018  | Months 1-5      | 6,802     | Online portal of the state CRS (devdatalab) |
| Chhattisgarh| 2019  | Months 1-5      | 5,623     | Online portal of the state CRS (devdatalab) |
| Chhattisgarh| 2020  | Months 1-5      | 17,497    | Online portal of the state CRS (devdatalab) |
| Chhattisgarh| 2021  | Months 1-5      | 106,832   | Online portal of the state CRS (devdatalab) |
| Chhattisgarh| 2015  | Entire year     | 168,034   | Vital Statistics        |
| Chhattisgarh| 2016  | Entire year     | 182,985   | Vital Statistics        |
| Chhattisgarh| 2017  | Entire year     | 175,035   | Vital Statistics        |
| Chhattisgarh| 2018  | Entire year     | 177,549   | Vital Statistics        |
| Chhattisgarh| 2019  | Entire year     | 188,211   | Vital Statistics        |
| Delhi     | 2015    | All             | 124,516   | Vital Statistics        |
| Delhi     | 2016    | All             | 141,632   | Vital Statistics        |
| Delhi     | 2017    | All             | 136,117   | Vital Statistics        |
| Delhi     | 2018    | All             | 145,533   | Vital Statistics        |
| Delhi     | 2019    | All             | 145,284   | Vital Statistics        |
| Delhi     | 2020    | All             | 145,284   | Vital Statistics        |
| Delhi     | 2018    | Jan-Jun         | 74,063    | Radhakrishnan           |
| Delhi     | 2019    | Jan-Jun         | 74,464    | Radhakrishnan           |
| Delhi     | 2020    | Jan-Jun         | 70,144    | Radhakrishnan           |
| Delhi     | 2021    | Jan-Jun         | 123,176   | Radhakrishnan           |
| Gujarat   | 2015    | All             | 412,322   | Vital Statistics        |
| Gujarat   | 2016    | All             | 417,835   | Vital Statistics        |
| State      | Year  | Period          | Count  | Rate   | Source           |
|------------|-------|-----------------|--------|--------|------------------|
| Gujarat    | 2017  | All             | 388,316| 0.982  | Vital Statistics |
| Gujarat    | 2018  | All             | 433,256| 1.000  | Vital Statistics |
| Gujarat    | 2019  | All             | 462,284| 1.000  | Vital Statistics |
| Gujarat    | 2017  | Jan 1-Nov 30    | 368,000|        | Dave             |
| Gujarat    | 2018  | Jan 1-Nov 30    | 393,000|        | Dave             |
| Gujarat    | 2019  | Jan 1-Nov 30    | 419,000|        | Dave             |
| Gujarat    | 2020  | Jan 1-Nov 30    | 374,000|        | Dave             |
| Gujarat    | 2020  | Mar. 1-May 10   | 58,000 |        | Desai            |
| Gujarat    | 2021  | Mar. 1-May 10   | 123,871|        | Desai            |
| Gujarat: 68 municipalities | 2019  | Entire year     | 33,362 |        | Jalihal          |
| Gujarat    | 2019  | Jan-Apr         | 11,354 |        | Jalihal          |
| Gujarat    | 2020  | Jan-Apr         | 11,364 |        | Jalihal          |
| Gujarat    | 2021  | Jan-Apr         | 21,460 |        | Jalihal          |
| Gujarat: Chorvad, Idar, Khedbrahma | 2019  | May 1-June 10   | 82     |        | wallofgrief.org  |
| Gujarat: Ahmedabad | 2017  | Mar. 1-May 10   | 9,319  |        | Opindia          |
| Gujarat    | 2018  | Mar. 1-May 10   | 9,866  |        | Opindia          |
| Gujarat    | 2019  | Mar. 1-May 10   | 9,950  |        | Opindia          |
| Gujarat    | 2020  | Mar. 1-May 10   | 7,786  |        | Opindia          |
| Gujarat    | 2021  | Mar. 1-May 10   | 13,593 |        | Opindia          |
| Gujarat: Ahmedabad | 2019  | Apr-May         | 5,490  |        | Khanna           |
| Gujarat    | 2020  | Apr-May         | 10,708 |        | Khanna           |
| Haryana    | 2015  | Entire year     | 168,910| 1.000  | Vital Statistics |
| Haryana    | 2016  | Entire year     | 181,138| 1.000  | Vital Statistics |
| Haryana    | 2017  | Entire year     | 174,937| 1.000  | Vital Statistics |
| Haryana    | 2018  | Entire year     | 185,842| 1.000  | Vital Statistics |
| Haryana    | 2019  | Entire year     | 188,910| 1.000  | Vital Statistics |
| Haryana    | 2018  | Entire year     | 178,536|        | Ramani           |
| Haryana    | 2019  | Entire year     | 184,155|        | Ramani           |
| Haryana    | 2020  | Entire year     | 198,223|        | Ramani           |
| Haryana    | 2018  | Jan-May         | 74,816 |        | Ramani           |
| Haryana    | 2019  | Jan-May         | 76,870 |        | Ramani           |
| State       | Year      | Period      | Population | Source   |
|------------|-----------|-------------|------------|----------|
| Himachal Pradesh | 2020      | Jan-May     | 78,030     | Ramani   |
|             | 2021      | Jan-May     | 121,100    | Ramani   |
|             | 2015      | Entire year | 41,462     | 0.882    | Vital statistics |
|             | 2016      | Entire year | 35,819     | 0.734    | Vital statistics |
|             | 2017      | Entire year | 39,114     | 0.821    | Vital statistics |
|             | 2018      | Entire year | 41,833     | 0.834    | Vital statistics |
|             | 2019      | Entire year | 43,633     | 0.864    | Vital statistics |
| Himachal Pradesh | 2018      | Jan-May     | 42,151     | Ramani   |
|             | 2019      | Entire year | 42,989     | Ramani   |
|             | 2020      | Entire year | 44,436     | Ramani   |
| Himachal Pradesh | 2018      | Jan-May     | 17,759     | Ramani   |
|             | 2019      | Jan-May     | 17,515     | Ramani   |
|             | 2020      | Jan-May     | 16,806     | Ramani   |
|             | 2021      | Jan-May     | 21,180     | Ramani   |
| Karnataka: Bengaluru | 2019      | Entire year | 65,019     | devdatalab |
|             | 2020      | Entire year | 75,441     | devdatalab |
| Karnataka: Bengaluru | 2019      | Jan-June    | 31,726     | devdatalab |
|             | 2020      | Jan-June    | 28,830     | devdatalab |
|             | 2021      | Jan 1-June  | 87,082     | Chatterjee |
| Karnataka     | 2015      | All         | 393,731    | 0.962    | Srivat., Vital Statistics, devdatalab (all agree) |
| Karnataka     | 2016      | All         | 420,774    | 1.000    | devdatalab |
| Karnataka     | 2017      | All         | 481,747    | 1.000    | devdatalab |
| Karnataka     | 2018      | All         | 483,511    | 1.000    | devdatalab |
| Karnataka     | 2019      | All         | 508,584    | 1.000    | devdatalab |
| Karnataka     | 2020      | All         | 551,808    | Srivatsa, devdatalab |
| Karnataka     | 2018      | Jan-June    | 224,000    | Chatterjee |
| Karnataka     | 2019      | Jan-June    | 235,000    | Chatterjee |
| Karnataka     | 2021      | Jan-June    | 337,580    | Chatterjee |
| Karnataka     | 2015      | Jan-Aug     | 260,513    | devdatalab |
| Karnataka     | 2016      | Jan-Aug     | 278,351    | devdatalab |
| Karnataka     | 2017      | Jan-Aug     | 309,995    | devdatalab |
| Karnataka     | 2018      | Jan-Aug     | 323,028    | devdatalab |
| Karnataka     | 2019      | Jan-Aug     | 324,531    | devdatalab |
| Karnataka     | 2020      | Jan-Aug     | 327,917    | devdatalab |
| Karnataka     | 2021      | Jan-Aug     | 474,070    | karnataka.gov |
| Kerala        | 2015      | Jan 1-May   | 95,281     | devdatalab |
| Kerala        | 2016      | Jan 1-May   | 98,195     | devdatalab |
| Kerala        | 2017      | Jan 1-May   | 96,534     | devdatalab |
| State          | Year | Period        | Value   | Source       |
|---------------|------|---------------|---------|--------------|
| Kerala        | 2018 | Jan 1-May 31 | 99,473  | devdatalab   |
| Kerala        | 2019 | Jan 1-May 31 | 104,705 | devdatalab   |
| Kerala        | 2020 | Jan 1-May 31 | 95,544  | devdatalab   |
| Kerala        | 2021 | Jan 1-May 31 | 113,372 | devdatalab   |
| Kerala        | 2015 | Entire year  | 235,982 | Rajendran    |
| Kerala        | 2016 | Entire year  | 244,900 | Rajendran    |
| Kerala        | 2017 | Entire year  | 252,103 | Rajendran    |
| Kerala        | 2018 | Entire year  | 255,594 | Rajendran    |
| Kerala        | 2019 | Entire year  | 264,150 | Rajendran    |
| Kerala        | 2020 | Entire year  | 252,421 | Rajendran    |
| Kerala        | 2021 | Jan 1-May 31 | 113,372 | Rajendran    |
| Kerala        | 2015 | All           | 252,576 | 1.000        |
| Kerala        | 2016 | All           | 256,130 | 0.943        |
| Kerala        | 2017 | All           | 263,342 | 1.000        |
| Kerala        | 2018 | All           | 258,530 | 1.000        |
| Kerala        | 2019 | All           | 270,567 | 1.000        |
| Kerala        | 2015 | All           | 236,859 | lsgkerala.gov |
| Kerala        | 2016 | All           | 244,894 | lsgkerala.gov |
| Kerala        | 2017 | All           | 252,097 | lsgkerala.gov |
| Kerala        | 2018 | All           | 255,571 | lsgkerala.gov |
| Kerala        | 2019 | All           | 264,131 | lsgkerala.gov |
| Kerala        | 2020 | All           | 242,910 | lsgkerala.gov |
| Kerala        | 2021 | Jan 1-Aug 31 | 166,514 | lsgkerala.gov |
| Madhya Pradesh| 2015 | All           | 311,411 | 0.538        |
| Madhya Pradesh| 2016 | All           | 338,587 | 0.609        |
| Madhya Pradesh| 2017 | All           | 370,538 | 0.687        |
| Madhya Pradesh| 2018 | All           | 424,527 | 0.788        |
| Madhya Pradesh| 2019 | All           | 493,328 | 0.891        |
| Madhya Pradesh| 2018 | Months 1-12   | 407,172 | LM           |
| Madhya Pradesh| 2019 | Months 1-12   | 449,819 | LM           |
| Madhya Pradesh| 2020 | Months 1-12   | 461,057 | LM           |
| State                  | Year | Period          | Value   | Unit  |
|-----------------------|------|-----------------|---------|-------|
| Madhya Pradesh        | 2018 | Months 1-5      | 152,346 | LM    |
| Madhya Pradesh        | 2019 | Months 1-5      | 167,549 | LM    |
| Madhya Pradesh        | 2020 | Months 1-5      | 164,191 | LM    |
| Madhya Pradesh        | 2021 | Months 1-5      | 348,708 | LM    |
| Madhya Pradesh: urban regions of 25 districts | 2015 | Entire year     | 119,068 | Vital Statistics |
|                       | 2016 | Entire year     | 112,303 | Vital Statistics |
|                       | 2017 | Entire year     | 113,612 | Vital Statistics |
|                       | 2018 | Entire year     | 112,188 | Vital Statistics |
|                       | 2019 | Entire year     | 119,914 | Vital Statistics |
|                       | 2021 | April 1-30      | 21,456  | Datta  |
| Maharashtra           | 2015 | Entire year     | 673,824 | 0.975  |
|                       | 2016 | Entire year     | 666,448 | 0.937  |
|                       | 2017 | Entire year     | 647,161 | 0.931  |
|                       | 2018 | Entire year     | 667,900 | 0.984  |
|                       | 2019 | Entire year     | 693,800 | 1.000  |
| Maharashtra (less 6 districts) | 2018 | Entire year     | 426,489 | Ramani |
|                       | 2019 | Entire year     | 462,028 | Ramani |
|                       | 2020 | Entire year     | 565,180 | Ramani |
|                       | 2018 | Jan-May         | 177,130 | Ramani |
|                       | 2019 | Jan-May         | 186,004 | Ramani |
|                       | 2020 | Jan-May         | 197,676 | Ramani |
|                       | 2021 | Jan-May         | 287,123 | Ramani |
| Maharashtra: Mumbai City | 2017 | Entire year     | 89,037  | WM     |
|                       | 2018 | Entire year     | 88,852  | WM     |
|                       | 2019 | Entire year     | 91,123  | WM     |
|                       | 2020 | Entire year     | 109,398 | WM     |
|                       | 2017 | Jan-May         | 36,166  | WM     |
|                       | 2018 | Jan-May         | 37,173  | WM     |
|                       | 2019 | Jan-May         | 37,363  | WM     |
|                       | 2020 | Jan-May         | 35,914  | WM     |
|                       | 2021 | Jan-May         | 45,163  | WM     |
| Maharashtra: Nagpur City | 2019 | Months 4-12    | 16,238  | WM     |
|                       | 2020 | Months 4-12    | 20,382  | WM     |
| Odisha                | 2015 | All year        | 321,009 | 1.000  |
| Odisha                | 2016 | All year        | 345,527 | 1.000  |
| Odisha                | 2017 | All year        | 322,660 | 1.000  |
| Odisha                | 2018 | All year        | 328,799 | 1.000  |
| Odisha                | 2019 | All year        | 342,947 | 1.000  |
| Odisha                | 2020 | All year        | 362,982 | Mohanty |
| State            | Year  | Period     | Population | Rate | Reference       |
|------------------|-------|------------|------------|------|-----------------|
| Odisha           | 2021  | Jan-Aug    | 286,623    |      | odisha.gov.in   |
| Punjab           | 2015  | Entire year| 199,461    | 1.000| Vital statistics|
| Punjab           | 2016  | Entire year| 213,578    | 1.000| Vital statistics|
| Punjab           | 2017  | Entire year| 210,398    | 1.000| Vital statistics|
| Punjab           | 2018  | Entire year| 213,234    | 1.000| Vital statistics|
| Punjab           | 2019  | Entire year| 215,045    | 1.000| Vital statistics|
| Punjab           | 2015  | Jan-June   | 199,749    |      | Ramani          |
| Punjab           | 2016  | Jan-June   | 210,848    |      | Ramani          |
| Punjab           | 2017  | Jan-June   | 208,005    |      | Ramani          |
| Punjab           | 2018  | Jan-June   | 211,213    |      | Ramani          |
| Punjab           | 2019  | Jan-June   | 213,122    |      | Ramani          |
| Punjab           | 2020  | Jan-June   | 222,136    |      | Ramani          |
| Punjab           | 2015  | Jan-June   | 100,258    |      | Ramani          |
| Punjab           | 2016  | Jan-June   | 101,885    |      | Ramani          |
| Punjab           | 2017  | Jan-June   | 101,688    |      | Ramani          |
| Punjab           | 2018  | Jan-June   | 105,856    |      | Ramani          |
| Punjab           | 2019  | Jan-June   | 107,823    |      | Ramani          |
| Punjab           | 2020  | Jan-June   | 106,371    |      | Ramani          |
| Punjab           | 2021  | Jan-June   | 147,389    |      | Ramani          |
| Rajasthan        | 2015  | Entire year| 409,463    | 0.899| Vital statistics|
| Rajasthan        | 2016  | Entire year| 416,992    | 0.933| Vital statistics|
| Rajasthan        | 2017  | Entire year| 424,763    | 0.953| Vital statistics|
| Rajasthan        | 2018  | Entire year| 443,173    | 0.999| Vital statistics|
| Rajasthan        | 2019  | Entire year| 451,315    | 0.986| Vital statistics|
| Rajasthan        | 2018  | Entire year| 216,370    |      | Ramani          |
| Rajasthan        | 2019  | Entire year| 219,814    |      | Ramani          |
| Rajasthan        | 2020  | Entire year| 229,564    |      | Ramani          |
| Rajasthan        | 2018  | Months 1-5 | 95,484     |      | Ramani          |
| Rajasthan        | 2019  | Months 1-5 | 90,366     |      | Ramani          |
| Rajasthan        | 2020  | Months 1-5 | 94,566     |      | Ramani          |
| Rajasthan        | 2021  | Months 1-5 | 125,863    |      | Ramani          |
| Tamil Nadu, 6 cities: Madurai, Coimbatore, Trichy, Vellore, Karur, Tirupur. | 2019 | Jan-May | 10,587 | Nagar |
| Tamil Nadu: Madurai District. | 2019 | All | 19,735 | Radhakrishnan |
| Tamil Nadu        | 2015  | All year   | 568,271    | 1.000| Vital Statistics|
| Tamil Nadu        | 2016  | All year   | 563,625    | 1.000| Vital Statistics|
| Tamil Nadu        | 2017  | All year   | 580,496    | 1.000| Vital Statistics|
| Tamil Nadu        | 2018  | All year   | 574,006    | 1.000| Vital Statistics|
| Tamil Nadu        | 2019  | All year   | 633,897    | 1.000| Vital Statistics|
| State          | Year | Duration       | Value 1    | Value 2   |
|---------------|------|----------------|------------|-----------|
| Tamil Nadu    | 2018 | Entire year    | 549,209    | crstn.org |
|               | 2019 | Entire year    | 637,270    | crstn.org |
|               | 2020 | Entire year    | 687,488    | crstn.org |
|               | 2021 | Jan-Aug        | 607,307    | crstn.org |
| Tamil Nadu    | 2018 | All year       | 536,192    | LM; Ramani|
|               | 2019 | All year       | 588,221    | LM; Ramani|
|               | 2020 | All year       | 644,291    | LM; Ramani|
|               | 2018 | Jan-Aug        | 363,744    | LM; Ramani|
|               | 2019 | Jan-Aug        | 392,304    | LM; Ramani|
| Tamil Nadu: Chennai | 2015 | Wks 1-52   | 59,875   | LM         |
|               | 2016 | Wks 1-52   | 57,826   | LM         |
|               | 2017 | Wks 1-52   | 63,726   | LM         |
|               | 2018 | Wks 1-52   | 62,793   | LM         |
|               | 2019 | Wks 1-52   | 67,002   | LM         |
|               | 2020 | Wks 1-52   | 73,932   | LM         |
|               | 2015 | Wks 1-30   | 33,691   | Rukmini    |
|               | 2016 | Wks 1-30   | 33,837   | Rukmini    |
|               | 2017 | Wks 1-30   | 36,056   | Rukmini    |
|               | 2018 | Wks 1-30   | 35,927   | Rukmini    |
|               | 2019 | Wks 1-30   | 38,145   | Rukmini    |
|               | 2020 | Wks 1-30   | 40,338   | Rukmini    |
| Tamil Nadu: Chennai | 2021 | Wks 1-30 | 59,129 | Rukmini |
| Telangana     | 2015 |                | 192,857    | 0.819      | Vital Statistics |
|               | 2016 |                | 204,917    | 0.920      | Vital Statistics |
|               | 2017 |                | 178,345    | 0.735      | Vital Statistics |
|               | 2018 |                | 136,528    | 0.585      | Vital Statistics |
|               | 2019 |                | 228,294    | 0.972      | Vital Statistics |
| Telangana: Hyderabad | 2016 | Jan-Dec | 49,523 | LM, Ramani |
|               | 2017 | Jan-Dec | 52,710 | LM, Ramani |
|               | 2018 | Jan-Dec | 55,026 | LM, Ramani |
|               | 2019 | Jan-Dec | 66,131 | LM, Ramani |
|               | 2020 | Jan-Dec | 77,241 | LM, Ramani |
| Telangana: Hyderabad | 2016 | Jan-May | 18,839 | LM, Ramani |
|               | 2017 | Jan-May | 20,645 | LM, Ramani |
|               | 2018 | Jan-May | 21,696 | LM, Ramani |
|               | 2019 | Jan-May | 25,657 | LM, Ramani |
|               | 2020 | Jan-May | 24,884 | LM, Ramani |
|               | 2021 | Jan-May | 36,041 | LM, Ramani |
| Uttar Pradesh | 2015 | Entire year | 687,416 | 0.442 | Vital Statistics |
| Uttar Pradesh | 2016 | Entire year | 608,740 | 0.402 | Vital Statistics |
| Uttar Pradesh | 2017 | Entire year | 571,170 | 0.383 | Vital Statistics |
| Uttar Pradesh | 2018 | Entire year | 906,653 | 0.608 | Vital Statistics |
| Uttar Pradesh | 2019 | Entire year | 944,596 | 0.633 | Vital Statistics |
| Uttar Pradesh | 2019 | Entire year | 773,402 | Bhawan |
| State          | Year | Time Period         | Total Cases | Location |
|---------------|------|---------------------|-------------|----------|
| Uttar Pradesh | 2020 | Entire year         | 793,505     | Bhawan   |
| Uttar Pradesh | 2019 | Jan 1-Apr 30       | 259,316     | Bhawan   |
| Uttar Pradesh | 2020 | Jan 1-Apr 30       | 188,747     | Bhawan   |
| Uttar Pradesh | 2021 | Jan 1-Apr 30       | 333,878     | Bhawan   |
| West Bengal   | 2015 | Entire year         | 403,180     | 0.723    |
| West Bengal   | 2016 | Entire year         | 445,540     | 0.806    |
| West Bengal   | 2017 | Entire year         | 442,995     | 0.797    |
| West Bengal   | 2018 | Entire year         | 490,530     | 0.908    |
| West Bengal   | 2019 | Entire year         | 551,695     | 1.000    |
| West Bengal   | 2018 | Entire year         | 368,477     | Ramani   |
| West Bengal   | 2019 | Entire year         | 410,503     | Ramani   |
| West Bengal   | 2020 | Entire year         | 463,858     | Ramani   |
| West Bengal   | 2018 | Jan-May             | 155,108     | Ramani   |
| West Bengal   | 2019 | Jan-May             | 167,422     | Ramani   |
| West Bengal   | 2020 | Jan-May             | 176,451     | Ramani   |
| West Bengal   | 2021 | Jan-May             | 216,972     | Ramani   |
| West Bengal:  |      |                      |             |          |
| Kolkata       | 2015 | Weeks 1-52          | 62,710      | LM       |
|               | 2016 | Weeks 1-52          | 65,060      | LM       |
|               | 2017 | Weeks 1-52          | 69,910      | LM       |
|               | 2018 | Weeks 1-52          | 68,998      | LM       |
|               | 2019 | Weeks 1-52          | 69,844      | LM       |
|               | 2020 | Weeks 1-52          | 74,841      | LM       |
| West Bengal:  |      |                      |             |          |
| Kolkata       | 2015 | Weeks 1-20          | 25,128      | LM       |
|               | 2016 | Weeks 1-20          | 24,506      | LM       |
|               | 2017 | Weeks 1-20          | 26,980      | LM       |
|               | 2018 | Weeks 1-20          | 25,985      | LM       |
|               | 2019 | Weeks 1-20          | 29,222      | LM       |
|               | 2020 | Weeks 1-20          | 27,674      | LM       |
|               | 2021 | Weeks 1-20          | 33,132      | LM       |
LM = Local Mortality dataset (Karlinsky 2021).

The urban areas in Madhya Pradesh from which funeral counts were tabulated for April 2021 were from the following 25 districts: Barwani, Bhind, Bhopal, Burhanpur, Chhatarpur, Chhindwara, Dewas, Dhar, Gwalior, Indore, Jabalpur, Jhabua, Khandwa, Mandsaur, Morena, Neemuch, Ratlam, Sagar, Satna, Seoni, Shahdol, Shivpuri, Singroli, Tikamgarh, Vidisha (Datta 2021).
**Table S2. Covid-19 Deaths Based on Viral Testing and Clinical Symptoms, as Tabulated by Johns Hopkins University.**

| Region              | Population  | Reported Covid Deaths in 2020 | Deaths/100K in 2020 | Reported Covid deaths by August 31, 2021. | Deaths/100K in 2021 (as of August 31) |
|---------------------|-------------|-------------------------------|---------------------|------------------------------------------|---------------------------------------|
| Andhra Pradesh      | 53,903,393  | 7,104                         | 13.179              | 13,838                                   | 12.493                                |
| Assam               | 35,607,039  | 1,043                         | 2.929               | 5,655                                    | 12.952                                |
| Bihar               | 124,799,930 | 1,393                         | 1.116               | 9,653                                    | 6.619                                 |
| Chandigarh          | 11,584,730  | 316                           | 2.728               | 813                                      | 4.290                                 |
| Delhi               | 18,710,920  | 10,523                        | 56.240              | 25,081                                   | 77.805                                |
| Gujarat             | 63,872,400  | 4,302                         | 6.735               | 10,081                                   | 9.048                                 |
| Haryana             | 28,204,692  | 2,899                         | 10.278              | 9,675                                    | 24.024                                |
| Himachal Pradesh    | 7,451,955   | 931                           | 12.493              | 3,595                                    | 35.749                                |
| Karnataka           | 67,562,700  | 12,081                        | 17.881              | 37,293                                   | 37.316                                |
| Kerala              | 35,699,440  | 3,042                         | 8.521               | 20,673                                   | 49.387                                |
| Madhya Pradesh      | 85,358,970  | 3,595                         | 4.212               | 10,516                                   | 8.108                                 |
| Maharashtra         | 123,144,200 | 49,463                        | 40.167              | 137,209                                  | 71.255                                |
| Odisha              | 46,356,334  | 1,871                         | 4.036               | 7,901                                    | 13.008                                |
| Punjab              | 30,141,373  | 5,331                         | 17.687              | 16,373                                   | 36.634                                |
| Rajasthan           | 81,032,689  | 2,689                         | 3.318               | 8,954                                    | 7.731                                 |
| Tamil Nadu          | 77,841,270  | 12,109                        | 15.556              | 34,899                                   | 29.278                                |
| Telangana           | 39,362,732  | 1,541                         | 3.915               | 3,872                                    | 5.922                                 |
| Uttar Pradesh       | 237,882,725 | 8,352                         | 3.511               | 22,820                                   | 6.082                                 |
| West Bengal         | 99,609,300  | 9,683                         | 9.721               | 18,434                                   | 8.785                                 |
| Total, except Uttar Pradesh | 1,030,244,067 | 129,916              | 12.610              | 374,515                                   | 23.742                                |

**This table lists absolute and per-capita reported Covid-19 deaths, rather than excess deaths.**
### Table S3. Range of Estimated Covid-19 Deaths in India, 2020 through August 2021.

| State            | Population     | Estimate Type. | 2020  | 2021, by August 31 |
|------------------|----------------|----------------|-------|--------------------|
|                  |                |                | Deaths/100K | Deaths/100K | Deaths |
| Andhra Prad.     | 53,903,393     | --             | 121.501 | 65,493           | 321.772 | 173,446 |
| Assam            | 35,607,039     | --             | 42.819  | 15,246           | --      | --     |
| Bihar            | 124,799,930    | --             | 107.567 | 134,244          | 101.272 | 126,388 |
| Chandigarh       | 11,584,730     | --             | 2.728   | 316              | 4.290   | 813    |
| Delhi            | 18,710,920     | --             | 56.240  | --               | 230.342 | 43,099 |
| Gujarat          | 63,872,400     | Low            | 6.735   | 4,302            | 36.417  | 23260  |
|                  |                | High           | 182.464 | 116,544          | 430.389 | 274,900 |
| Haryana          | 28,204,692     | --             | 12.493  | 11,087           | 145.458 | 41,026 |
| Himachal Pradesh | 7,451,955      | --             | 12.493  | 931              | 39.930  | 2,976  |
| Karnataka        | 67,562,700     | Low            | 18.689  | 12,627           | 165.588 | 111,876 |
|                  |                | High           | 77.103  | 52,093           | 648.291 | 438,003 |
| Kerala           | 35,699,440     | --             | 8.521   | 3,042            | 49.387  | 17,631 |
| Madhya Pradesh   | 85,358,970     | Low            | 4.212   | 3,595            | 46.376  | 39,586 |
|                  |                | High           | 4.212   | 3,595            | 212.232 | 181,159 |
| Maharashtra      | 123,144,200    | Low            | 100.540 | 103,152          | 71.255  | 137,209 |
|                  |                | High           | 172.308 | 212,187          | 102.288 | 104,946 |
| Odisha           | 46,356,334     | --             | 43.220  | 20,035           | 71.768  | 59,555 |
| Punjab           | 30,141,373     | --             | 17.687  | 5,331            | 120.255 | 36,247 |
| Rajasthan        | 81,034,689     | --             | 8.181   | 6,629            | 39.874  | 32,311 |
| Tamil Nadu       | 77,841,270     | Low            | 15.556  | 12,109           | 76.508  | 59,555 |
|                  |                | High           | 92.563  | 72,052           | 270.866 | 210,846 |
| Telangana        | 39,362,732     | --             | 88.157  | 34,701           | 71.768  | 28,250 |
| Uttar Pradesh    | 237,882,725    | --             | 3.511   | 8,352            | 20.371  | 48,458 |
| West Bengal      | 99,609,300     | Low            | 46.145  | 45,965           | 49.315  | 49,128 |
|                  |                | High           | 53.564  | 53,355           | 64.514  | 64,262 |
| Total, except    | 1,030,244,067  | Low            | 47.496  | 489,328          | --      | --     |
| Uttar Pradesh    |                | High           | 79.341  | 817,404          | --      | --     |
| Total, except    | 994,637,028    | Low            | --      | --               | 98.632  | 981,033 |
| Uttar Pradesh    |                | High           | --      | --               | 184.443 | 1,834,540 |
| Total            | 1,268,126,792  | Low            | 39.245  | 497,680          | --      | --     |
|                  |                | High           | 65.116  | 825,756          | --      | --     |
|                  | 1,232,519,753  | Low            | --      | --               | 83.527  | 1,029,491 |
|                  |                | High           | --      | --               | 152.776 | 1,882,998 |

All estimates based on excess deaths, except 2020 Delhi, Kerala, and Punjab data, which are based on known Covid-19 mortality as reported by Johns Hopkins University, and Gujarat, West Bengal, Madhya Pradesh, and Tamil Nadu, which included the Hopkins data as the low end of the uncertainty range.
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