

## Notes on Kerala's COVID-19 epidemic

(Murad Banaji, July 21, 2021, some corrections/updates from July 22-23, 2021 **in red.**)

### Summary of key points

- Kerala has been relatively successful at containing its COVID-19 epidemic. First wave spread in the state was below the national average and, ironically, Kerala's long drawn-out first wave is likely an indicator of the [successful slowing](#) of COVID-19 transmission during the first wave.
- During the second wave, infection rates in Kerala have likely not, so far, reached the levels seen in many parts of India. With the highly transmissible delta variant of SARS-CoV-2 dominant in the state, and mobility rising back towards baseline levels, the state probably **remains vulnerable** to further surges, even in the short term.
- We can estimate that the **infection rate** in the state by mid-July could be around **37-50%**. There is high uncertainty in this figure, but we arrive at broadly similar estimates from tracking cases, recorded COVID-19 fatalities, or all cause mortality data. [Update (23/07/21): On July 23, 2021 [The Times of India](#) reported that 44.4% of those surveyed in Kerala's districts as part of the Third National Serosurvey had antibodies to SARS-CoV-2. No detail was given about vaccination status.]
- Kerala's all cause mortality data suggests that during the pandemic, upto the end of May, 2021, there had been **excess mortality** of around **0.1%** (1 excess death per 1000 population). The data is incomplete and excess mortality has likely risen substantially since then. There is **high uncertainty** associated with possible shifts in baseline mortality and/or death registration. However, even in more pessimistic scenarios, Kerala remains one of the least hard-hit states in India in terms of excess mortality.
- Kerala has shown **relatively good surveillance** of COVID-19 infections and deaths. Estimates from the third national serosurvey suggest the state was **capturing around 18% of its infections** through testing: many times higher than the national average.
- Estimates based on all cause mortality data suggest that the state could be **capturing around 25-30% of its COVID-19 deaths** - a higher fraction than in most states. Again, these estimates come with high uncertainty. We also don't know to what extent excess mortality reflects COVID-19 deaths, and how non-COVID deaths might have been affected in the state during the pandemic and lockdowns.
- Kerala's COVID-19 **infection fatality rate** (IFR) estimated from excess mortality data is around **0.33%**. [Update (23/07/21): using a [Kerala government serosurvey](#) gives estimates of **0.41% or higher** - see later.] These values are roughly 3.5 to 4 times the naive value using recorded fatalities as the **numerator**, and **on the lower end of values** expected from meta-analyses given the state's relatively elderly population **if we assume even spread across age groups**. It is possible that spread was limited amongst those vulnerable to severe disease during the first wave [Update (23/07/21): **this hypothesis is corroborated by the Kerala government serosurvey**]; and that vaccination has played a part in bringing down IFR during the second wave.
- Kerala's COVID-19 epidemic is very likely not over.

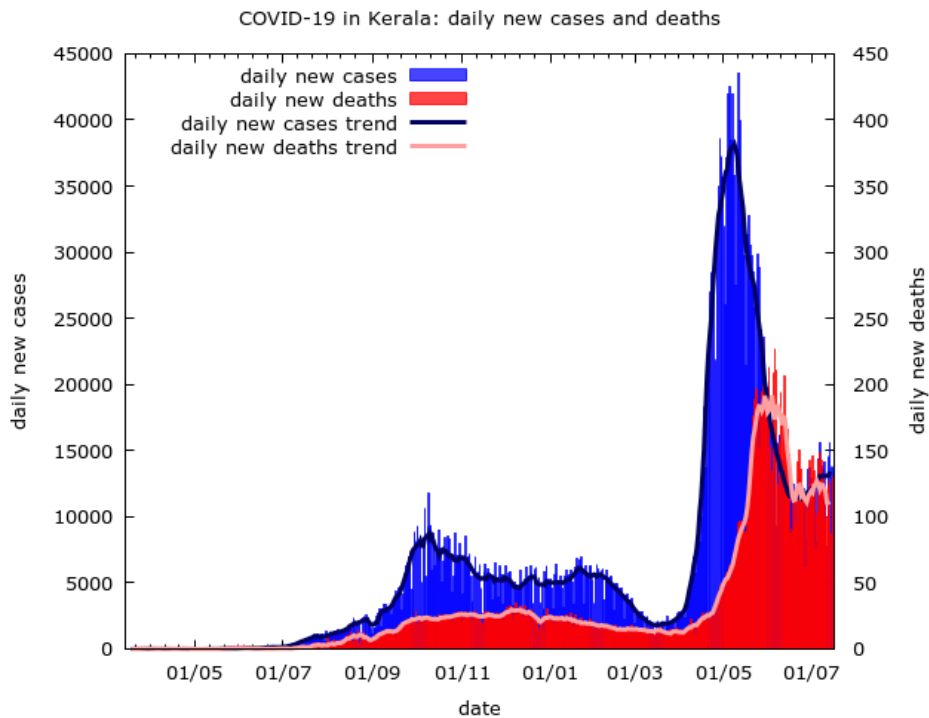
## Early days of the epidemic

Although Kerala recorded the country's first cases of COVID-19, its epidemic took off relatively slowly. By mid-July, 2020, Kerala had officially recorded just 36 COVID-19 deaths, less than 0.25% of the total one year later.

The slow start to Kerala's epidemic was confirmed in the **second national serosurvey** carried out in August and September, 2020. The survey [reported only 0.8% seropositivity](#) in the three districts surveyed in Kerala (Ernakulam, Palakkad, and Thrissur) as against [national unweighted seroprevalence](#) of 10.8% and weighted seroprevalence (adjusted for test performance) of 6.6%.

The surveyed districts in Kerala hold around 28% of the state's population (as of the 2011 census) but had reported only 20% of the state's total cases by the end of August 2020. Even factoring in the possibility that these districts were less affected than the state average, it is clear that COVID-19 had spread less widely in Kerala by August than in many other states.

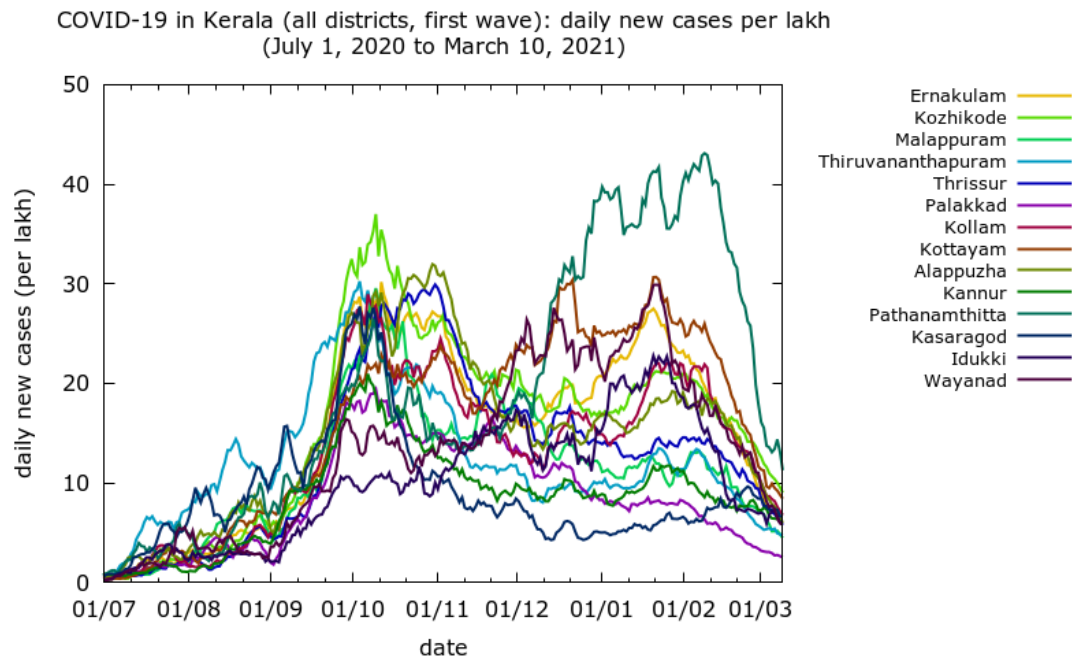
While daily cases peaked *nationally* around the middle of September 2020, Kerala's cases rose more slowly. They reached a daily average of 8728 during the week beginning on October 7, and subsided a little, but remained on a **high plateau** close to or above 5000 until February, 2021. They then dipped briefly during late February and March before surging again in April. The much larger scale of the second wave which followed is clearly visible in both case and fatality data.



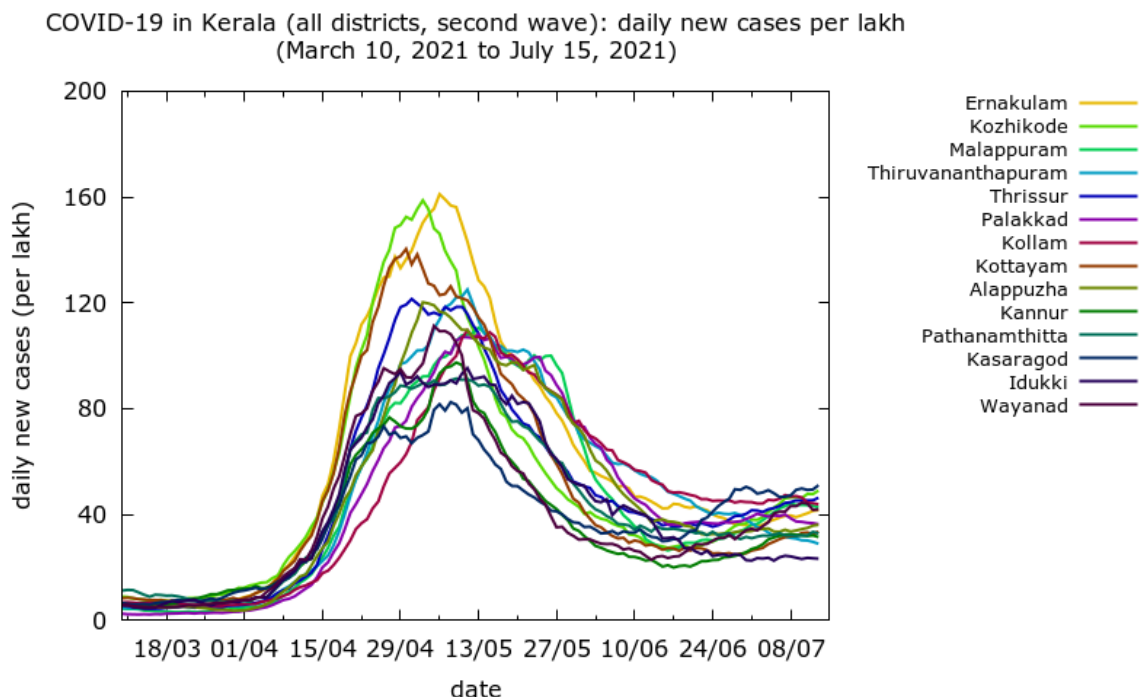
## First and second waves in district-level data

If we look at district-level case data, we see some ingredients of an explanation for Kerala's plateau in daily cases in late 2020 and early 2021. Firstly, many districts repeated the pattern of protracted spread seen at state-level. Moreover, even where there were clear peaks, districts peaked at different times: as cases were gradually coming down in some districts towards the end of 2020 (e.g., Thiruvananthapuram), they were rising in others well into early 2021 (e.g., Pathanamthitta).

The protracted first wave likely reflects **network effects** seen in agent-based modelling: reductions in mobility slow transmission, but nevertheless disease is able to "leak" between localities. Because of relatively successful mitigation, herd effects do *not* occur locally, and so infection continues to spread, albeit at a relatively slow speed. The gradual **increase in mobility** as the first wave progressed helped prolong this trend.



At district level, the second wave has quite a different pattern from the first: district-level epidemics all followed a much more similar path. The much higher peak in daily cases during the second wave was mirrored in recorded fatalities, and excess mortality, as we will see later.



## 2020 estimates based on the third national serosurvey

By the end of 2020, Kerala had officially recorded just 3073 COVID-19 deaths in an estimated population of 35 million. Reporting delays meant that this figure rose, but not substantially; as of July 19, 2021, according to the [state COVID-19 dashboard](#) (which reports fatalities both by date of occurrence and date of recording) 3175 official COVID-19 deaths had occurred in 2020.

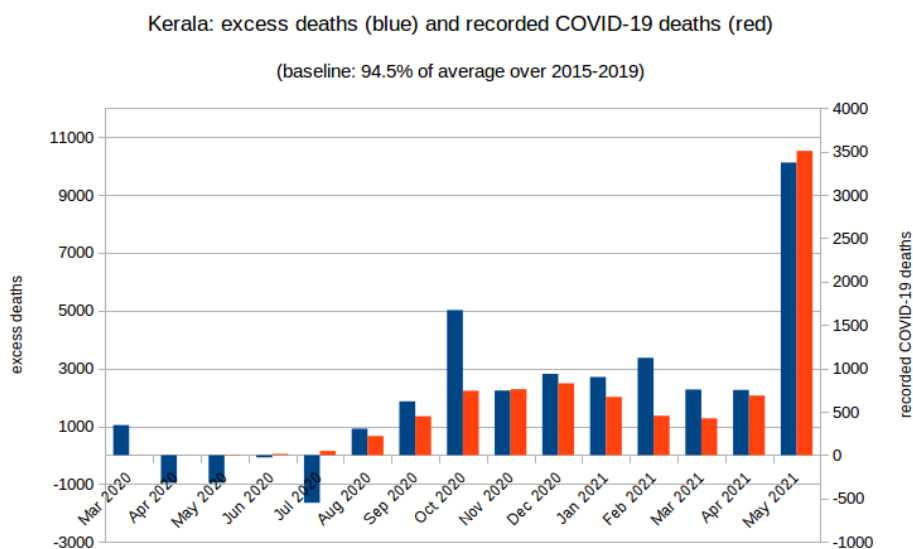
In December 2020, the three districts surveyed in the second national serosurvey were surveyed again as part of the third national serosurvey. The survey found around **11.6% seropositivity** in these districts. This compares to a national estimate of over 20% prior infection from this survey. Disease spread in Kerala had "caught up" somewhat, but was still well below national levels.

11.6% prior infection in Ernakulam, Palakkad, and Thrissur would amount, at face value, to around 1.1 million infections in these districts. By the end of the year, around 206,000 cases had been reported from these districts, suggesting that roughly **18% of infections were being captured** in testing. This compares well to the national estimate of around 3-4% at the time of the [third](#) and [fourth](#) national serosurveys.

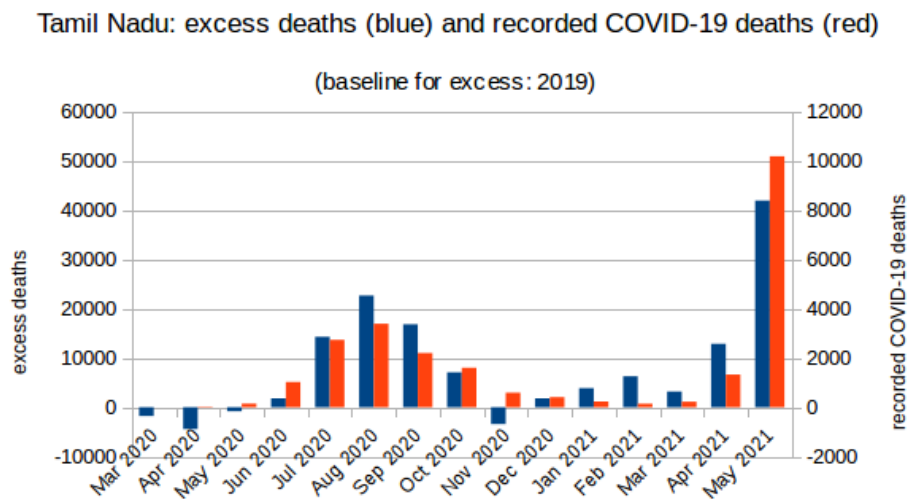
Meanwhile, the surveyed districts had recorded 768 official COVID-19 deaths by the end of 2020. Taking this as the numerator gives a **naive infection fatality rate of 0.07%** in these districts. If we assume prior infection of 11.6% across the whole state and take the 3175 official COVID-19 deaths in 2020 as the numerator, this gives a naive IFR or 0.08% in the state as a whole.

## All cause mortality data from the civil registration system

Recall that COVID-19 did not really surge in Kerala until July-August 2020. In fact, during January-July 2020, according to [data reported by The Hindu](#) (archived [here on github](#)), Kerala **registered 5.5% fewer deaths than the previous 5-year average** over this period. Whether this reflects a [drop in registration coverage](#) as a consequence of national lockdown, or a drop in mortality, for the purposes of calculating excess mortality during the pandemic period we take expected death registrations in any given months to be 0.945 times the average of the monthly deaths during this month in 2015-2019.



There are major uncertainties around this choice of baseline, and hence around these calculations of excess deaths. However, we note that with this baseline, **excess registered deaths approximately track COVID-19 deaths** from August 2020 to May, 2021. This trend is seen in several other states, including neighbouring Tamil Nadu whose data is shown for comparison:



The qualitative match in the time-course of COVID-19 deaths and excess registrations in Kerala provides some confidence in the choice to use a scaled average of the previous five years' deaths as a baseline.

To be more quantitative, we can examine the association between monthly recorded COVID-19 deaths and excess deaths using either 2019 registrations or our rescaled five-year average as a baseline. Over March, 2020 to April, 2021, the former choice leads to a correlation coefficient of 0.52, while the latter choice gives a correlation of 0.84. (We omit May, 2021 because it is a strong outlier in both data-sets; including it would increase the values to 0.87 and 0.92 respectively.)

If the drop in baseline actually reflects an approximately 5.5% drop in registration coverage, then we might, in fact, expect total excess deaths during the pandemic to be around 6% higher than excess registered deaths. (This assumes the increase in unregistered deaths tracks the increase in registered deaths over time.) This correction is fairly minor, and estimates based on it are given in brackets after the estimates based on excess registrations alone.

Acknowledging all the caveats around the choice of baseline, we find a total of 12,835 (13,588) excess deaths in Kerala during August to December, 2020. This gives a **ratio of excess deaths to recorded COVID-19 deaths of 4 to 1** (4.3 to 1) during 2020. This ratio is lower than estimates from most other states from where all cause mortality data has so far emerged.

Taking the 12,835 (13,588) excess deaths as the numerator and assuming prior infection in 11.6% of the population of the state gives an **excess deaths-based IFR estimate of 0.31%** (0.33%) at the end of 2020. This compares to **expectations based on Kerala's age-structure of 0.38%** from the meta-analysis of [O'Driscoll et al](#), and **0.66%** from the meta-analysis in [Levin et al](#).

Both of these estimates are on the assumption that disease spread equally in different age-groups - the fact that Kerala's IFR based on estimated excess deaths was lower than these estimates could reflect lower spread amongst the elderly in the state. For context it is worth noting that estimates of

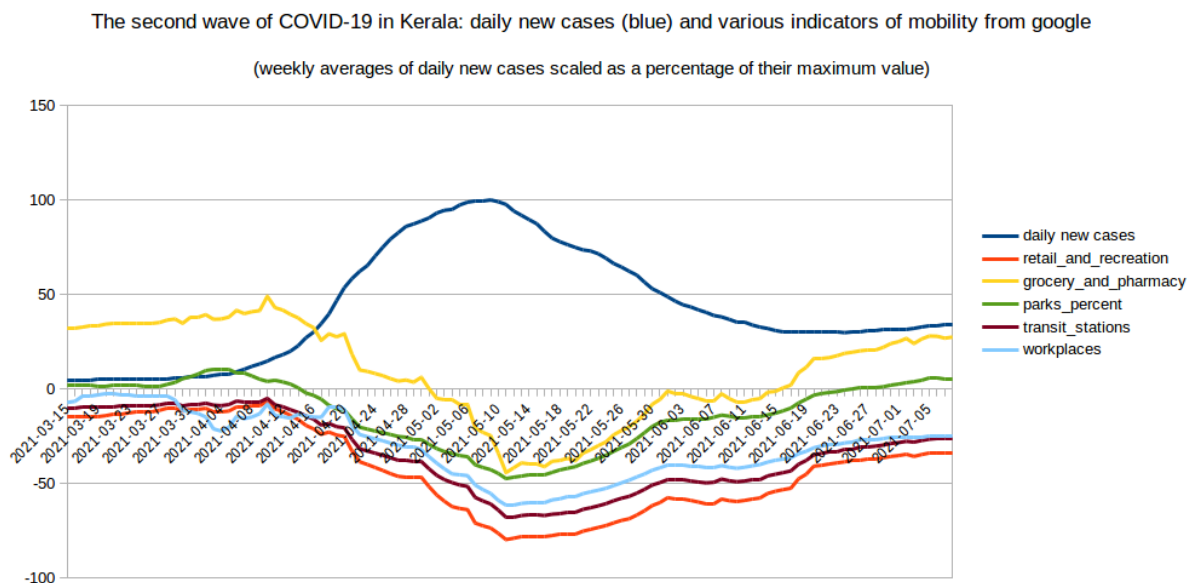
IFR based on excess deaths data are close to, or above, estimates based on meta-analyses in several Indian states examined so far.

[Update (23/07/21): Another larger serosurvey in Kerala took place in February 2021 and found 10.8% seroprevalence amongst those surveyed, close to the estimate from the third national serosurvey. But, importantly, seroprevalence was lower in older groups. Using excess deaths from August 2020 to Jan 2021 (15,538) and the seroprevalence of 10.8, given an excess-deaths based estimate of first-wave IFR of **0.41%**. If we include excess deaths from February this goes up to **0.50%**. Correcting for the uneven spread by age, we find that expected first-wave IFR is **0.33%** from the meta-analysis of [O'Driscoll \*et al.\*](#), and **0.58%** from the meta-analysis in [Levin \*et al.\*](#) Using the new data, Kerala's first wave IFR estimates now lies well within the range from meta-analyses.]

## The second wave

Kerala's epidemic had hardly wound down before surging again. It is likely that new variants of SARS-CoV-2 contributed to the rapid surge in April 2021: data from the [Phylovis surveillance dashboard](#) shows the delta variant rapidly coming to dominate in the state during April and May 2021.

Second wave **daily cases peaked at an average of 38,143** during the week beginning May 6, 2021. By the end of that week, the state had recorded around 1.9 million cases. Cases then declined fairly steadily. [Google mobility data](#) indicates a sharp drop in various indicators of mobility in Kerala as second wave cases rose. This likely played an important part in stabilising transmission. However, as cases declined, mobility moved gradually back towards baseline levels, raising worries about a new surge. At the time of writing, 'R' is above 1.



As of July 19, the state had recorded 3.16 million cases, four times the number at the end of 2020, and equivalent to 9% of the state's [estimated current population](#) of 35 million. Official COVID-19 deaths stood at 15,350, almost five times the value at the end of 2020.

From August 2020 to May 2021, taking baseline mortality as described earlier (94.5% of the pre-pandemic average), we get a **total of 33,546 (35,515) excess deaths** in the state. This estimate is based on deaths which had occurred during this period and had been reported by the time the data was obtained by the Hindu in late June: reporting delays mean that it is likely to rise.

If we assume that excess-deaths based IFR remained fixed, then this would give us an excess-deaths based estimate of around 10.7 million infections in the state to the end of May, amounting to an **infection rate of around 30%**. This is consistent with the rise in cases in the state upto May and the assumption that surveillance of infections remained roughly constant.

Update (23/07/2021): if we assume excess-deaths based IFR of 0.41% from the Kerala government survey, we find an estimated 8.5 million infections by the end of May: an infection rate of around **24%**. If we assume excess-deaths based IFR of 0.5%, we find an estimated 7M infections by the end of May: an infection rate of around **20%**.

If, instead of excess deaths we use the rise in recorded COVID-19 deaths (by date of death) from 3822 at the end of Jan to 10,025 by the end of May as the basis for extrapolation, we get 28% prior infection by the end of May. If we use the rise in recorded COVID-19 deaths from 4292 at the end of Feb to 10,025 by the end of May as the basis for extrapolation, we get 25% prior infection by the end of May.

Given uncertainties about possible changes in IFR during the second wave, if we use the rise in cases from the end of Jan, 2021 (9.3M) to end May (25.2) as the basis for extrapolation, we get around 29% prior infection by the end of May. If we use the rise in cases from the end of Feb, 2021 (10.6M) to the end of May (25.2) as the basis for extrapolation, we get around 26% prior infection by the end of May.

Thus the great majority of approaches give an estimate of 25-30% prior infection by the end of May. The estimates based on extrapolation from cases or recorded deaths give a range of excess-deaths based IFR estimates of 0.33-0.40% by the end of May, somewhat lower than the estimates of 0.41-0.50% from the Kerala government serosurvey.

33,546 (35,515) excess deaths amounts to **excess mortality of 0.095% (0.1%)**, namely 0.95 (1.0) excess deaths per 1000 population by the end of May. This would place Kerala as one of the least affected states in India in terms of excess mortality during the pandemic: it compares to very provisional excess mortality estimates of around 0.18% in Tamil Nadu, 0.21% in Karnataka, 0.20% in Haryana, 0.22% in Bihar, and 0.42% in Andhra Pradesh [corrected: 22/07/21] by May. Note, however, that recorded COVID-19 deaths in Kerala increased by 50% from the end of May to mid-July, 2021. A proportionate scaling of excess mortality would take excess mortality close to 0.15% during the pandemic in Kerala to date.

Taking deaths as reported by date of occurrence from the state dashboard, we find that by the end of May 10,025 official COVID-19 deaths had occurred in the state. The data thus suggests a **ratio of excess deaths to recorded COVID-19 deaths of 3.3 to 1** (3.5 to 1), an apparent improvement over the estimate from the end of 2020 of 4 to 1 (4.3 to 1).

Given delays and multiple uncertainties, we cannot be very confident about this, but it seems possible that surveillance of COVID-19 deaths has improved in Kerala during the second wave. This would be fairly remarkable given the scale of the surge. We know that COVID-19 death undercounting results from a mixture of "structural" factors (the extent of testing, health seeking behaviours, likelihood of reaching hospital before death, etc.), and government policies, for example around death audit committees. It is possible that after [reports of systematic undercounting](#) last year, the state government improved surveillance.

## Conclusions: what next?

It is worth noting that around 5,200 COVID-19 deaths have already been reported to have occurred in June and July 2021 so far, consistent with the large number of cases which came after the May peak, and amounting to one third of the state's official COVID-19 deaths to date. Scaling up estimated infections proportionately would take the likely total infection rate to around 45-50%. This would be consistent with the state's 3.16 million recorded cases if around 18-20% of all its infections were being captured in testing (as estimated at the time of the third national serosurvey).

[Update (23/07/21): if we take the range of estimates of 25-30% prior infection by the end of May - based on extrapolation from the Kerala government serosurvey using either cases or recorded fatalities - then we would get prior infection of around 37-45% by mid-July.]

Of course, these estimates are based on very limited data; but estimates based on deaths and cases are fairly consistent in implying that around 45-50% of the state's population could have been infected with SARS-CoV-2 to date. This places Kerala's infection rate below national estimates from the [fourth national serosurvey](#) in which 62% of unvaccinated individuals were found to be seropositive.

[Update (23/07/21): On July 23, 2021 [The Times of India](#) reported results from Kerala's districts surveyed in the fourth national serosurvey: 44.4% of those surveyed had antibodies to SARS-CoV-2, close to the estimate here. This figure was not broken down according to how many of these were vaccinated, so it is possible that prior infection is somewhat lower. Note that the estimates of prior infection of 36-50% based on extrapolation are broadly consistent with this data.]

How could vaccination affect the picture? By mid-May [around 54% of over-60s in Kerala](#) had had at least one vaccine dose, and there were signs of a drop in the share of official COVID-19 deaths amongst the elderly, a likely vaccine effect.

According to the [state COVID-19 dashboard](#) around 34% of the state's population had received at least one vaccine dose by July 19, 2021. This rose to around 70% amongst the over-45s. Given the highly transmissible nature of the delta variant, we should not expect around 36-50% prior infection and 34% (partial) vaccination to be sufficient to halt the epidemic. For a start we don't know the overlap amongst those who have been infected, and those who have been vaccinated.

However, we would expect increasing levels of prior infection and vaccination to significantly reduce hospitalisations and COVID-19 deaths, particularly as vaccination coverage is high in the groups most vulnerable to severe disease. In the most optimistic scenario, continued vaccination sufficiently reduce transmission to offset the likely increase in transmission that comes from increased mobility and prevent a further surge. But this is far from certain.

## Summary of point estimates for Kerala

### IFR

- *Naive COVID-19 IFR based on the third national serosurvey: 0.07-0.08% [Update (23/07/21): 0.10-0.11% based on a Kerala government serosurvey]*
- *First wave IFR based on excess deaths and third national serosurvey: 0.31-0.33% [Update (23/07/21): 0.41-0.50% based on a Kerala government serosurvey] (moderate uncertainty)*



- *Expected first wave IFR based on meta-analyses: 0.38-0.66%* [**Update (23/07/21): these values were under the assumption of even spread. Given [age-wise seroprevalence data from the Kerala govt serosurvey](#), these would become 0.33-0.58%.**]

### **Excess deaths**

- *Excess deaths by the end of 2020: around 13,000 (0.4 per 1000, moderate uncertainty)*
- *Excess deaths by the end of May, 2021: around 35,000 (1.0 per 1000, moderate uncertainty)*

### **Infections**

- *Infection rate by the end of 2020: 11.6% (based on third national serosurvey), [**Update: (23/07/21) 10.8% by Feb, 2021 based on a Kerala government serosurvey.**]*
- *Infection rate by the end of May, 2021: 30% (based on third national serosurvey) [**Update: 25-30% using a variety of extrapolations based on the Kerala government serosurvey.**]*
- *Infection rate by mid-July, 2021: 45-50% (extrapolated: high uncertainty, **but corroborated roughly by [fourth national serosurvey data](#).**)*

### **Surveillance of infections and deaths**

- *Infections captured in testing: around 20% (based on third national serosurvey, **or a Kerala government serosurvey**)*
- *Recorded deaths as a fraction of excess deaths: 25-30% (high uncertainty)*