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Supplementary Materials for

Epidemiology and transmission dynamics of COVID-19 in two Indian states

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This PDF file includes:

Other supplementary material for this manuscript includes:

MDAR Reproducibility Checklist (PDF)

Materials and Methods

Epidemiological surveillance.

Data for the analyses were generated through public health surveillance activities undertaken by the Health and Family Welfare Department of the Government of Tamil Nadu and the Department of Health, Medical and Family Welfare Department of the Government of Andhra Pradesh, in accordance with national and state policies. In India, COVID-19 surveillance was initiated on 7 February, 2020 with airport-based thermal screening for international travelers from affected countries. Traveler screening was expanded to include thermal screening of maritime passengers and crew members on 10 March, 2020. Intensified health screening at land borders was commenced on 15 March, 2020.

Testing guidelines changed several times during early phases of the epidemic. Beginning on 9 March, 2020, symptomatic individuals developing symptoms 14 days after close contact with a laboratory-confirmed case or travel history to COVID-19 affected countries within 14 days of the onset of symptoms were eligible for testing. Testing was expanded to all symptomatic individuals with international travel history, and to symptomatic healthcare workers managing patients with respiratory distress or severe acute respiratory infection, on 17 March, 2020. As of 20 March, 2020, testing indications were expanded to all symptomatic healthcare workers, all hospitalized patients with severe acute respiratory infection, and all asymptomatic direct and high-risk contacts of confirmed cases, who were recommended to receive one test within 5-14 days of their last reported contact with a confirmed case. Our analyses addressed the results of the most recent test undertaken, if contacts received multiple tests.

Healthcare delivery and public health systems are decentralized in India and states are empowered to implement national programs and guidelines with consideration for local contexts. During the epidemic, states could intensify response measures but were not permitted to dilute or weaken directives from the central government. Tamil Nadu commenced airport-based screening for severe acute respiratory infection among incoming international travelers on 20 January, 2020 and initiated thermal and clinical screening at borders with the states of Kerala, Karnataka, and Andhra Pradesh as of 4 March, 2020. Beginning on 28 March, 2020 in Tamil Nadu, all individuals with travel history were screened for symptoms and kept under home quarantine for 21 days with health monitoring to determine disease onset.

Active house-to-house surveillance for influenza-like-illness was carried out by community health workers in “containment zones” (i.e., areas within 5km radius around case residences) in both Tamil Nadu and Andhra Pradesh beginning on 28 March, 2020. Community health workers visited households to identify suspected cases and identify the contacts of all suspected or confirmed cases. Information on all cases and their contacts was communicated daily to supervisory medical officers. The contacts of all cases were monitored daily for development of symptoms over 28 days in Tamil Nadu and for the longer of either 28 days, or 21 days from the last occurrence of a positive case, in Andhra Pradesh.

Testing was conducted over the study period via reverse-transcriptase polymerase chain reaction (RT-PCR) by both government and private labs, with positive, negative, and indeterminate

results notified directly to the Health and Family Welfare Department of the Government of Tamil Nadu and the Department of Health, Medical and Family Welfare of the Government of Andhra Pradesh. Information reported for each positive case included the laboratory where testing was conducted, dates of sample collection and test results, and the age and sex of the patient. Positive cases were issued unique state-assigned case identification numbers, including in the scenario of posthumous SARS-CoV-2 detection for individuals who died shortly after admission to hospitals, or who died in the community and had specimens collected for SARS-CoV-2 testing. Retrospective medical record reviews were undertaken for fatal cases; consistent with US studies (*34*), comorbidities were considered to include any history of diabetes mellitus, sustained hypertension, coronary artery disease, renal disease, chronic obstructive pulmonary disease, asthma, cancer, pulmonary or extrapulmonary tuberculosis, stroke, or liver disease.

Our analyses are limited to tests performed for the purpose of diagnosis. Tests undertaken to determine recovery after infection (for the purposes of hospital discharge) were not included. For individuals who received multiple tests during the course of the epidemic, our analysis includes all tests conducted up to and including the test yielding a positive result, resulting in the individual being reported as a confirmed COVID-19 case and assigned a unique case identification number.

Reproductive number estimation.

We used the EpiEstim package in R (*23*) to estimate the instantaneous reproduction number R_t. As neither the delay distribution nor its mean were known for either the time from infection to testing or from symptoms onset to testing, we defined R_t for the testing day t, recognizing that this value may thus provide a retrospective view of transmission conditions. Based on maximum-likelihood fits to data from a previous review (*50*), we specified hyperparameters for the mean and standard deviation of the serial interval distribution as $\mathrm{Norm}(\mu_{\mathrm{Mean}} = 3.96,\ \sigma_{\mathrm{Mean}} = 0.22)$ and $\mathrm{Norm}(\mu_{\mathrm{SD}} = 4.76,\ \sigma_{\mathrm{SD}} = 0.16)$, respectively, and estimated R_t over sliding 7-day windows based on vectors of daily case counts.

Inferring risk factors for infection among contacts.

We fit Poisson regression models to data on contacts' recorded infection status and attributes of each contact and their respective index cases to estimate adjusted relative risks for infection of contacts as a function of these exposures. Models that included interactions between case and contact age groups (defined per **Fig. 2** as ages 0-4y, 5-9y, 10-14y, 15-19y, 20-39y, 40-64y, 65-79y, and ≥80y), interactions between the sexes of index cases and their contacts (excluding individuals reporting transgender status due to limited numbers), and state (Tamil Nadu or Andhra Pradesh). Separate models were fitted for high- and low-risk contacts, per definitions in **Table S6**.

Secondary attack rate estimation.

We computed secondary attack rates by dividing the number of positive contacts by the number of contacts traced, overall and for high-risk and low-risk contacts and for each reported exposure setting, where available. We conducted statistical inference using the cluster bootstrap to

resample index cases across 1,000 replicate datasets, summing positive contacts and total contacts among resampled index cases (**Table S7**).

Survival analyses.

We estimated adjusted hazard ratios for the outcome of death on or before 1 August, 2020 using Cox proportional hazards models, accounting for age group, sex, state (Tamil Nadu or Andhra Pradesh), and testing date (grouped as 1 March to 30 April; 1 May to 30 June; or 1 July onward). We defined the 50-64-year-old age group as a reference when estimating hazard ratios for age-specific mortality to maximize statistical power. The day of testing provided the earliest anchoring point in our study due to a lack of information on symptoms onset or exposure dates, and is a close proxy for admission date as all COVID-19 cases were admitted to dedicated COVID-19 facilities, until 5 May (in Tamil Nadu) and 27 April (in Andhra Pradesh) when individuals without symptoms were permitted to isolate at home. We obtained confidence intervals via bootstrap resampling; within bootstrap replicates, we drew from the delay distribution of delays between sample collection and result dates, within the calendar same month, for individuals with missing sample collection dates. We used the same bootstrap resampling approach to generate confidence intervals around case fatality ratio estimates for individuals tested by 1 July, 2020.

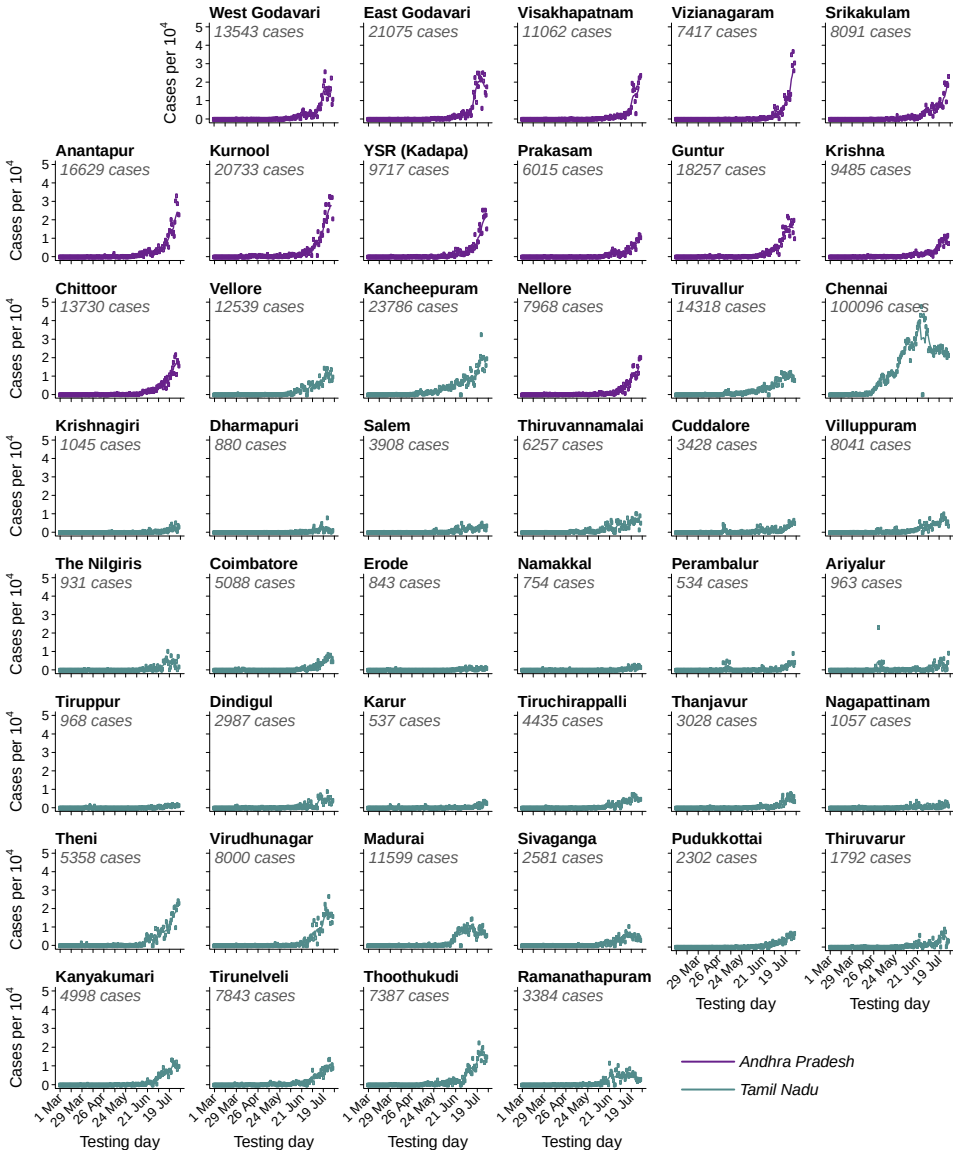

Fig. S1. Incidence, in daily new case detections per 10,000 population (by testing date), for each district. Districts are plotted roughly by their geographic position in relation to one another. Points and lines corresponded to daily counts and 7-day moving averages, respectively.

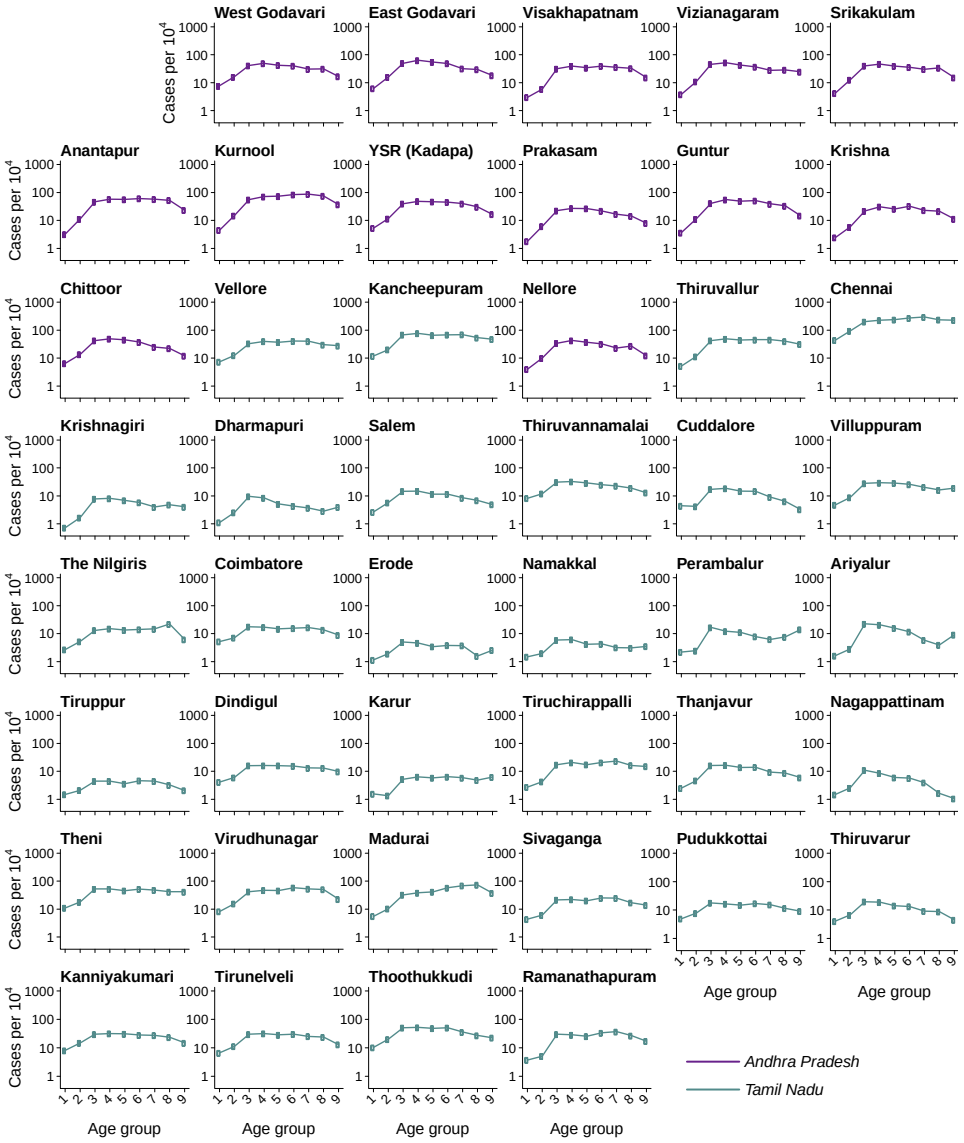

Fig. S2: Cumulative incidence per 10,000 population as of 1 August, 2020, by age group, for each district. Districts are plotted roughly by their geographic position in relation to one another.

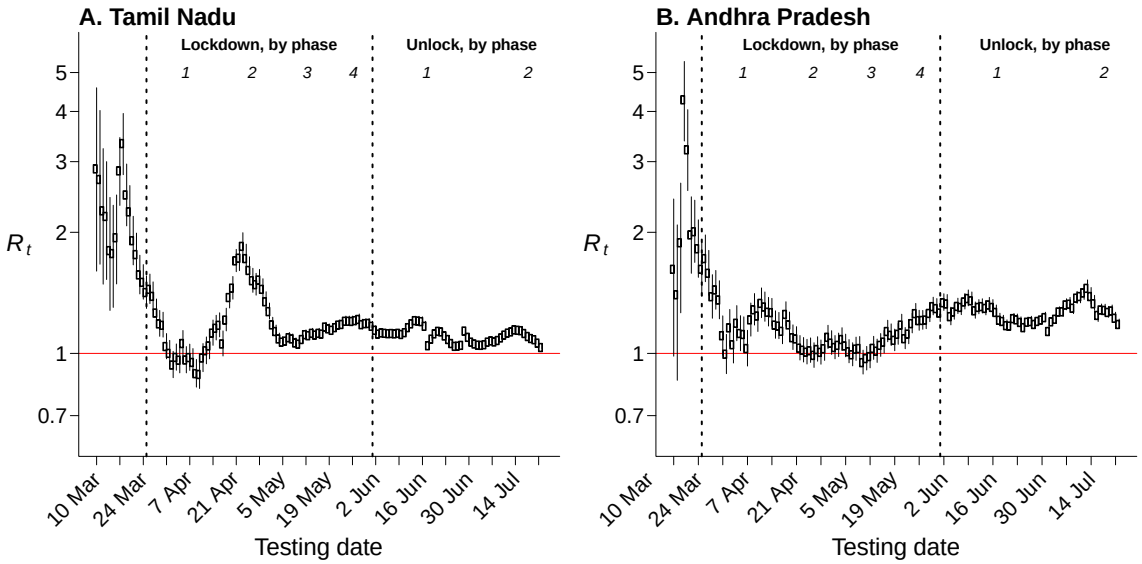

Fig. S3: State-level estimates of the instantaneous reproductive number, R_t, for cases tested on each day t, for (**A**) Tamil Nadu and (**B**) Andhra Pradesh. Lines around point estimates signify 95% credible intervals, estimated according to the method of Cori and colleagues (*23*). Shaded regions correspond to distinct phases of the "Lockdown" and "Unlock" periods (separated from each other and from the pre-intervention period by dashed lines). Phase 1 of the lockdown included restrictions on all activities outside of individuals' homes, including suspension of road, air, and rail transportation and closure of education, industry, hospitality, and non-essential businesses. Phase 2 allowed demarcation of "red", "orange", and "green" zones for localized lockdowns to be imposed, and re-opening of small retail shops. Phase 3 allowed limited movement between districts not classified as "red" zones. Phase 4 allowed local authorities to demarcate "containment" and "buffer" zones within "red" zones for partial relaxation of lockdown measures. Phase 1 of unlocking allowed inter-state travel to resume and re-opening of shopping malls, religious places, hotels, and restaurants, with night curfews and bans on large gatherings remaining in force. Phase 2 allowed relaxation of lockdown measures outside containment zones.

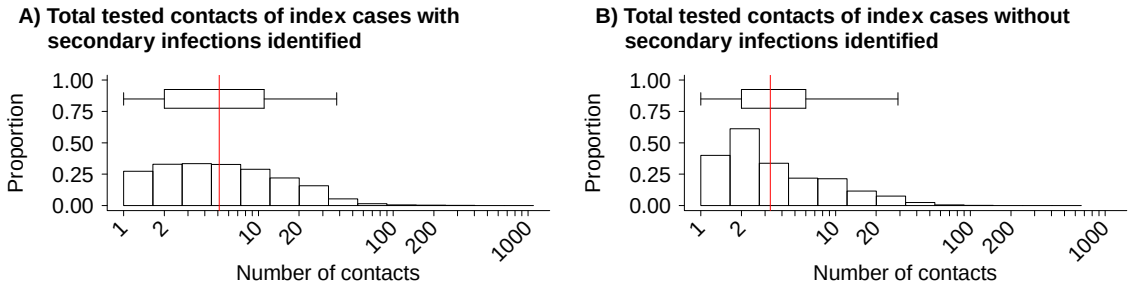

Fig. S4: Distributions of the total number of contacts reported and contacts tested among index cases with and without secondary cases identified. Red lines signify the mean of each distribution; box plots above each histogram indicate the interquartile range, with lines extending to the 2.5%ile and 97.5%ile. (**A**) We illustrate the distribution of the number of all tested contacts among index cases with at least one positive contact identified. (**B**) We illustrate the distribution of the number all tested contacts among index cases without positive contacts identified.

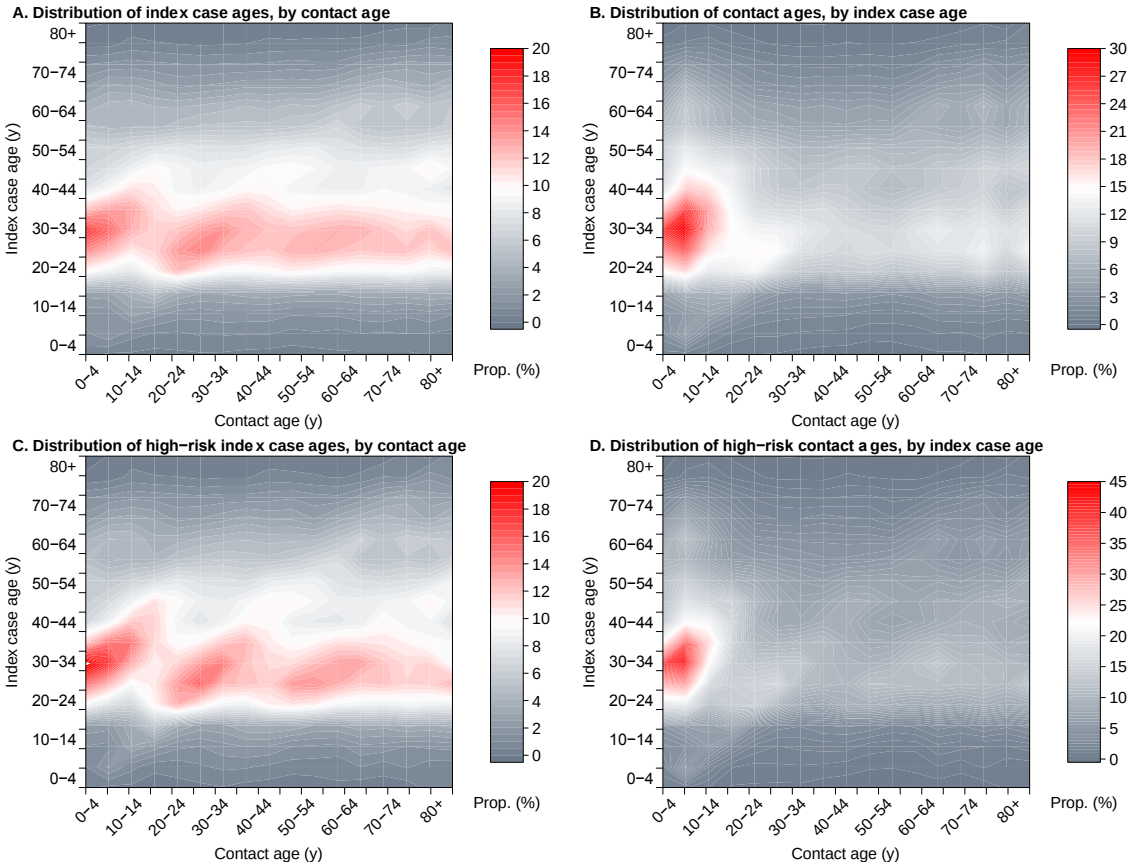

Fig. S5. Distributions of index case and contact ages. Contour plots on the left illustrate the proportion of index cases belonging to each age group on the y-axis, for contacts of ages plotted on the x-axis, for (**A**) all contact pairs and (**B**) high-risk contact pairs. Contour plots on the right indicate the proportion of contacts belonging to each age group on the x-axis, for index cases of ages plotted on the y-axis, for (**A**) all contact pairs and (**B**) high-risk contact pairs.

Table S1: Attributes of reported COVID-19 cases and deaths in Tamil Nadu and Andhra Pradesh.

Attribute		Tamil Nadu, *n* (%)		Andhra Pradesh, *n* (%)	
		Cases	Deaths	Cases	Deaths
Total		263,330	4,247	172,209	1,486
Age					
	0-4 years	3,921 (1)	2 (<1)	1,463 (1)	2 (<1)
	5-17 years	18,233 (7)	11 (<1)	10,889 (6)	2 (<1)
	18-29 years	60,237 (23)	55 (1)	41,566 (24)	32 (2)
	30-39 years	54,538 (21)	176 (4)	39,670 (23)	92 (6)
	40-49 years	47,286 (18)	422 (10)	31,950 (19)	218 (15)
	50-64 years	55,107 (21)	1,476 (35)	33,775 (20)	616 (41)
	65-74 years	17,053 (6)	1,237 (29)	9,857 (6)	337 (23)
	75-84 years	5,740 (2)	680 (16)	2,680 (2)	134 (9)
	≥85 years	1,215 (<1)	182 (4)	359 (<1)	23 (2)
	Unknown	0 (0)	6 (<1)	0 (0)	30 (2)
Sex					
	Male	159,488 (61)	3,023 (71)	108,201 (63)	1,057 (71)
	Female	103,815 (39)	1,224 (29)	63,982 (37)	425 (29)
	Transgender	27 (<1)	0 (0)	26 (<1)	0 (0)
	Unknown	0 (0)	0 (0)	0 (0)	4 (<1)
Testing date					
	Before 1 April, 2020	485 (<1)	2 (<1)	139 (<1)	1 (<1)
	1-15 April, 2020	992 (<1)	16 (<1)	484 (<1)	16 (1)
	16-30 April, 2020	1,546 (1)	16 (<1)	1,087 (1)	27 (2)
	1-15 May, 2020	8,737 (3)	74 (2)	1,147 (10	40 (3)
	16-31 May, 2020	14,362 (5)	263 (6)	1,531 (1)	27 (2)
	1-15 June, 2020	26,568 (10)	489 (12)	4,079 (2)	67 (5)
	16-30 June, 2020	45,582 (17)	832 (20)	12,652 (7)	126 (8)
	1-15 July, 2020	62,203 (24)	1,081 (25)	28,941 (17)	346 (23)
	16 July-1 August, 2020	102,855 (39)	1,474 (35)	122,149 (71)	836 (56)
Ascertained ≥1 day before death					
	Yes	– –	789 (19)	– –	253 (17)
	No	– –	3,458 (81)	– –	1,233 (83)

Values in the table present descriptive attributes of laboratory-confirmed COVID-19 cases and deaths in the two states.

Table S2: Disposition of contacts traced.

Status	Tamil Nadu	Andhra Pradesh
Contacts identified	1,298,406	1,786,479
Contacts tested	1,053,952	789,583
Contacts with known test outcome[1]	999,894	680,950
Line-level result and epidemiological data available[2]	18,812	556,259

[1]Excludes individuals with inconclusive testing outcomes.

[2]Individual-level epidemiological and testing results for all contacts traced were reported by the districts to the Government of Tamil Nadu until 5 June, 2020; thereafter, only aggregate numbers of contacts traced and tested were monitored. Analyses of contact tracing data from Tamil Nadu are therefore limited to the period through 5 June, 2020.

Table S3: Attributes of cases and tested contacts.

Attribute		Tamil Nadu			Andhra Pradesh		
		Index cases with contacts tested, *n* (%)	Tested contacts, *n* (%)	Positive contacts, *n* (%)	Index cases with contacts tested, *n* (%)	Tested contacts, *n* (%)	Positive contacts, *n* (%)
Total included							
Age							
	0-4 years	13 (1)	472 (3)	30 (4)	749 (1)	6,869 (1)	430 (1)
	5-17 years	51 (4)	1,951 (10)	133 (17)	5,250 (6)	48,123 (9)	3,517 (8)
	18-29 years	335 (25)	4,801 (26)	184 (23)	20,320 (24)	147,416 (27)	9,760 (23)
	30-39 years	365 (27)	3,772 (20)	125 (16)	19,554 (23)	120,726 (22)	8,984 (21)
	40-49 years	300 (22)	3,043 (16)	131 (17)	15,557 (19)	90,890 (16)	7,355 (17)
	50-64 years	218 (16)	2,821 (15)	112 (14)	16,133 (19)	92,251 (17)	7,698 (18)
	65-74 years	51 (4)	578 (3)	34 (4)	4,611 (6)	31,883 (6)	2,308 (5)
	75-84 years	12 (1)	173 (1)	6 (1)	1,236 (1)	8,046 (1)	695 (2)
	≥85 years	4 (<1)	41 (<1)	4 (1)	170 (<1)	1,035 (<1)	83 (<1)
	Unknown	2 (<1)	1,159 (6)	30 (4)	34 (<1)	9,020 (2)	1,281 (3)
Sex							
	Male	1,020 (75)	10,150 (54)	401 (51)	52,794 (63)	334,056 (60)	24,759 (59)
	Female	329 (24)	7,701 (41)	382 (48)	30,769 (37)	221,999 (40)	17,333 (41)
	Transgender	0 (0)	0 (0)	0 (0)	17 (<1)	112 (<1)	5 (<1)
	Unknown	2 (<1)	961 (5)	6 (1)	34 (<1)	92 (<1)	14 (<1)

Values in the table present descriptive attributes of laboratory-confirmed COVID-19 cases in the two states for whom contacts were traced and tested, with results available, and descriptive attributes of contacts who were traced and who tested positive via real-time polymerase chain reaction (RT-PCR). Transgender status was recorded for a greater number of individuals in contact-tracing datasets than the case line list (**Table S1**). For contact tracing analyses, we therefore analyzed individuals according to the sex/gender recorded by contact tracers.

Table S4: Comparison of index cases with contacts tested and test-positive contacts.

Attribute		Case population		
		All reported cases, *n* (%)	Reported cases with contacts tested, *n* (%)	Test-positive traced contacts, *n* (%)
Age				
	0-4 years	5,384 (1)	762 (1)	460 (1)
	5-17 years	29,122 (7)	5,301 (6)	3,650 (9)
	18-29 years	101,803 (23)	20,655 (24)	9,944 (23)
	30-39 years	94,208 (22)	19,919 (23)	9,109 (21)
	40-49 years	79,236 (18)	15,857 (19)	7,486 (17)
	50-64 years	88,882 (20)	16,351 (19)	7,810 (18)
	65-74 years	26,910 (6)	4,662 (5)	2,342 (5)
	75-84 years	8,420 (2)	1,248 (1)	701 (2)
	≥85 years	1,574 (<1)	174 (<1)	87 (<1)
	Unknown[1]	0 (0)	35 (<1)	1,311 (3)
Sex				
	Male	267,689 (61)	53,814 (63)	25,160 (59)
	Female	167,797 (39)	31,098 (37)	17,715 (41)
	Transgender	53 (<1)	17 (<1)	5 (<1)
	Unknown[1]	0 (0)	36 (<1)	20 (<1)

Values in the table present descriptive attributes of all laboratory-confirmed COVID-19 cases in the two states; cases for whom contacts were traced and tested, with results available; and test-positive traced contacts. Transgender status was recorded for a greater number of individuals in contact-tracing datasets than the case line list (**Table S1**). For contact tracing analyses, we therefore analyzed individuals according to the sex/gender recorded by contact tracers.

[1]Unknown age/sex of index cases with contacts traced arose where unique case identification numbers were inconsistent between surveillance datasets.

Table S5: Coverage of districts in contact tracing effort.

State	District[1]	Case population			
		Total cases reported	Index cases with contacts tested, *n* (%)	Contacts tested, *n* (%)	Contacts tested per case
Andhra Pradesh					
	Anantapur	17,578 (10)	2,303 (3)	14,169 (3)	6.2
	Chittoor	14,394 (8)	9,701 (12)	43,279 (8)	4.5
	East Godavari	21,997 (13)	10,285 (12)	99,580 (18)	9.7
	Guntur	18,752 (11)	8,153 (10)	59,767 (11)	7.3
	Krishna	9,821 (6)	5,975 (7)	23,367 (4)	3.9
	Kurnool	21,589 (13)	17,710 (21)	126,523 (23)	7.1
	Nellore	8,575 (5)	5,825 (7)	47,977 (9)	8.2
	Prakasam	6,379 (4)	3,104 (4)	21,156 (4)	6.8
	Srikakulam	8,731 (5)	3,815 (5)	23,024 (4)	6.0
	Visakhapatnam	12,104 (7)	2,721 (3)	11,609 (2)	4.3
	Vizianagaram	8,145 (5)	4,960 (6)	27,985 (5)	5.6
	West Godavari	13,978 (8)	5,212 (6)	33,167 (6)	6.4
	YSR (Kadapa)	10,166 (6)	3,817 (5)	24,349 (4)	6.4
	Other[2]	0 (0)	33 (<1)	307 (<1)	9.3
	Total	172,209	83,614	556,259	6.7
Tamil Nadu					
	Ariyalur	1,060 (<1)	2 (<1)	15 (<1)	7.5
	Chengalpattu	14,306 (5)	47 (3)	193 (1)	2.0
	Chennai	102,199 (39)	301 (22)	5,073 (27)	16.9
	Coimbatore	5,501 (2)	62 (5)	277 (1)	4.5
	Cuddalore	3,745 (1)	327 (24)	1,954 (10)	6.0
	Dharmapuri	902 (<1)	0 (0)	0 (0)	– –
	Dindigul	3,157 (1)	21 (2)	139 (1)	6.6
	Erode	892 (<1)	0 (0)	0 (0)	– –
	Kallakurichi	3,920 (1)	11 (1)	180 (1)	16.4
	Kancheepuram	10,967 (4)	22 (2)	119 (1)	5.4
	Kanniyakumari	5,419 (2)	7 (1)	31 (<1)	4.4
	Karur	583 (<1)	11 (1)	82 (<1)	7.5
	Krishnagiri	1,172 (<1)	13 (1)	80 (<1)	6.2
	Madurai	11,893 (5)	9 (1)	119 (1)	13.2
	Nagappattinam	1,107 (<1)	14 (1)	77 (<1)	5.5
	Namakkal	822 (<1)	10 (1)	151 (1)	15.1
	The Nilgiris	987 (<1)	7 (1)	22 (<1)	3.1
	Perambalur	576 (<1)	3 (<1)	49 (<1)	16.3
	Pudukkottai	2,519 (1)	13 (1)	152 (1)	11.7
	Ramanathapuram	3,490 (1)	30 (2)	533 (3)	17.8
	Ranipet	5,200 (2)	30 (2)	315 (2)	10.5
	Salem	4,109 (2)	7 (1)	208 (1)	29.7
	Sivagangai	2,692 (1)	9 (1)	115 (1)	12.8
	Tenkasi	2,175 (1)	30 (2)	526 (3)	17.5
	Thanjavur	3,264 (1)	20 (1)	866 (5)	43.3
	Theni	5,979 (2)	34 (3)	343 (2)	10.1
	Thirupathur	1,440 (1)	7 (1)	82 (<1)	11.7
	Thiruvalur	14,953 (6)	20 (1)	123 (1)	6.2
	Thiruvannamalai	6,606 (3)	52 (4)	314 (2)	6.0
	Thiruvarur	1,858 (1)	21 (2)	442 (2)	21.0
	Thoothukkudi	7,892 (3)	13 (1)	228 (1)	17.5
	Tiruchirappalli	4,676 (2)	32 (2)	775 (4)	24.2
	Tirunelveli	6,126 (2)	99 (7)	3,022 (16)	30.5
	Tiruppur	1,046 (<1)	24 (2)	727 (4)	30.3
	Vellore	6,879 (3)	1 (<1)	2 (<1)	2.0
	Villuppuram	4,411 (2)	15 (1)	170 (1)	11.3
	Virudhunagar	8,683 (3)	25 (2)	974 (5)	39.0
	Other[2]	124 (<1)	0 (0)	0 (0)	– –
	Unknown	0 (0)	2 (<1)	334 (2)	167.0
	Total	263,330	1,351	18,812	13.9

Values in the table include all individuals with contacts traced and all traced contacts, irrespective of results availability by 1 August, 2020.
[1]Districts are defined according to 2020 boundaries in this table; 2019 boundaries are illustrated in **Figure 1**, **Figure S1**, and **Figure S2**.
[2]Other includes airport/railway quarantine cases and cases residing in districts in other states.

Table S6: Contact definitions.

High risk criteria	Low risk criteria
(*a*) Touching bodily fluids of the index case (respiratory tract specimens, blood, vomit, saliva, urine, feces, e.g. being coughed on or touching used paper tissues with a bare hand)	(*g*) Shared the same space (e.g. room) as the index case without meeting the high-risk exposure criteria itemize
(*b*) Direct physical contact with the index case, including physical examinations without personal protective equipment	(*h*) Travelled in the same conveyance (e.g. bus, train, flight, other mode of transit) without meeting the high-risk exposure criteria outlined in (*f*)
(*c*) Touched or cleaned linens, clothes, or dishes of the index case	
(*d*) Living in the same household as the index case	
(*e*) Contact at <1m proximity with the index case without taking precautions	
(*f*) Passengers in a shared conveyance within the same row or within 3 rows in front of or behind the index case for more than six hours	

Table S7: Secondary attack rates by interaction type and setting.

Exposure setting	Any contact			High-risk contact[1]			Low-risk contact[1]		
	Index cases	Total contacts (infected)	SAR (95% CI)	Index cases	Total contacts (infected)	SAR (95% CI)	Index cases	Total contacts (infected)	SAR (95% CI)
Any setting (all cases and contacts)	84,965	575,071 (42,900)	7.5 (7.3, 7.6)	73,064	264,872 (28,415)	10.7 (10.5, 10.9)	62,573	309,958 (14,483)	4.7 (4.6, 4.8)
Any setting (exposure setting recorded)	1,343	18,484 (786)	4.2 (3.3, 5.2)	1,013	4,637 (623)	13.3 (10.3, 16.7)	730	13,808 (163)	1.2 (0.8, 1.6)
Community	597	9,628 (249)	2.6 (1.6, 3.9)	37	406 (108)	27.9 (8.4, 54.7)	568	9,221 (141)	1.6 (1.0, 2.20
Household	998	4,065 (380)	9.0 (7.5, 10.5)	979	3,942 (362)	8.8 (7.3, 10.4)	29	122 (18)	15.3 (5.8, 28.0)
Travel together	9	78 (63)	79.3 (52.9, 97.0)	9	78 (63)	79.3 (52.9, 97.0)	– –	– –	– –
Healthcare	12	210 (2)	1.2 (0.0, 5.1)	6	98 (2)	4.7 (0.0, 40.0)	7	112 (0)	0
Other	152	4,503 (92)	2.1 (0.4, 4.4)	9	113 (88)	77.1 (35.3, 100.0)	145	4,353 (4)	0.1 (0.0, 0.2)

SAR (secondary attack rate) indicates the proportion of all tested contacts, who test positive. We obtain point estimates and confidence intervals via cluster-bootstrap resampling of index cases.
[1]High-risk and low-risk contact criteria are defined in **Table S6.**

Table S8: Characteristics of index cases and their contacts, and infection outcomes.

Variable	Index case attribute	Contact attribute	All contacts		High-risk contacts		Low-risk contacts	
			Total, *N*	Infected, *n* (%)	Total, *N*	Infected, *n* (%)	Total, *N*	Infected, *n* (%)
Age								
	0-4 years							
		0-4 years	89	23 (26)	45	13 (29)	44	10 (23)
		5-17 years	450	21 (5)	224	19 (8)	226	2 (1)
		18-29 years	1,364	74 (5)	562	49 (9)	802	25 (3)
		30-39 years	1,098	81 (7)	494	60 (12)	604	21 (3)
		40-49 years	716	43 (6)	295	28 (9)	421	15 (4)
		50-64 years	820	54 (7)	334	35 (10)	486	19 (4)
		65-74 years	297	15 (5)	106	12 (11)	191	3 (2)
		75-84 years	80	6 (8)	38	4 (11)	42	2 (5)
		≥85 years	15	0 (0)	9	0 (0)	6	0 (0)
	5-17 years							
		0-4 years	431	32 (7)	203	27 (13)	228	5 (2)
		5-17 years	3,419	390 (11)	1,751	308 (18)	1,668	82 (5)
		18-29 years	8,594	489 (6)	3,651	303 (8)	4,943	186 (4)
		30-39 years	7,131	626 (9)	3,321	440 (13)	3,810	186 (5)
		40-49 years	5,188	417 (8)	2,362	273 (12)	2,826	144 (5)
		50-64 years	5,180	401 (8)	2,281	247 (11)	2,899	154 (5)
		65-74 years	1,876	104 (6)	816	61 (7)	1,060	43 (4)
		75-84 years	502	40 (8)	209	22 (11)	293	18 (6)
		≥85 years	67	9 (13)	33	5 (15)	34	4 (12)
	18-29 years							
		0-4 years	1,882	106 (6)	1,056	81 (8)	826	25 (3)
		5-17 years	11,181	667 (6)	5,343	477 (9)	5,838	190 (3)
		18-29 years	41,981	2,958 (7)	19,462	2,025 (10)	22,518	933 (4)
		30-39 years	29,896	1,920 (6)	12,982	1,180 (9)	16,914	740 (4)
		40-49 years	23,127	1,804 (8)	10,835	1,185 (11)	12,292	619 (5)
		50-64 years	22,916	1,678 (7)	10,611	1,130 (11)	12,305	548 (4)
		65-74 years	7,663	472 (6)	3,289	288 (9)	4,374	184 (4)
		75-84 years	1,850	161 (9)	853	100 (12)	997	61 (6)
		≥85 years	228	8 (4)	86	6 (7)	142	2 (1)
	30-39 years							
		0-4 years	2,196	139 (6)	1,319	115 (9)	876	24 (3)
		5-17 years	13,215	950 (7)	7,325	728 (10)	5,883	222 (4)
		18-29 years	35,626	2,101 (6)	15,648	1,336 (9)	19,970	765 (4)
		30-39 years	31,753	2,503 (8)	14,455	1,715 (12)	17,292	788 (5)
		40-49 years	21,777	1,500 (7)	9,219	913 (10)	12,551	587 (5)
		50-64 years	22,542	1,710 (8)	10,354	1,144 (11)	12,184	566 (5)
		65-74 years	7,250	474 (7)	3,260	308 (9)	3,990	166 (4)
		75-84 years	1,796	116 (6)	753	83 (11)	1,043	33 (3)
		≥85 years	226	15 (7)	101	8 (8)	125	7 (6)
	40-49 years							
		0-4 years	1,097	66 (6)	546	53 (10)	547	13 (2)
		5-17 years	9,768	827 (8)	5,257	635 (12)	4,468	190 (4)
		18-29 years	27,687	1,848 (7)	12,475	1,259 (10)	15,182	589 (4)
		30-39 years	23,364	1,701 (7)	10,273	1,044 (10)	13,066	657 (5)
		40-49 years	18,351	1,821 (10)	8,465	1,254 (15)	9,851	567 (6)
		50-64 years	17,159	1,325 (8)	7,581	814 (11)	9,555	511 (5)
		65-74 years	6,040	428 (7)	2,725	280 (10)	3,311	148 (4)
		75-84 years	1,526	141 (9)	688	99 (14)	835	42 (5)
		≥85 years	214	18 (8)	90	14 (16)	123	4 (3)
	50-64 years							
		0-4 years	1,181	74 (6)	647	61 (9)	534	13 (2)
		5-17 years	8,314	510 (6)	4,071	343 (8)	4,234	167 (4)
		18-29 years	27,006	1,805 (7)	12,349	1,225 (10)	14,657	580 (4)
		30-39 years	22,723	1,638 (7)	10,239	998 (10)	12,484	640 (5)
		40-49 years	17,893	1,365 (8)	8,173	901 (11)	9,720	464 (5)
		50-64 years	18,976	2,005 (11)	8,862	1,368 (15)	10,114	637 (6)
		65-74 years	6,173	454 (7)	2,756	290 (11)	3,417	164 (5)
		75-84 years	1,633	121 (7)	742	85 (11)	891	36 (4)
		≥85 years	217	23 (11)	100	21 (21)	117	2 (2)
	65-74 years							
		0-4 years	358	14 (4)	190	11 (6)	168	3 (2)
		5-17 years	2,855	220 (8)	1,552	160 (10)	1,303	60 (5)
		18-29 years	7,480	498 (7)	3,511	309 (9)	3,969	189 (5)

		30-39 years	6,539	504 (8)	3,171	324 (10)	3,368	180 (5)
		40-49 years	5,160	424 (8)	2,465	270 (11)	2,695	154 (6)
		50-64 years	5,695	490 (9)	2,571	300 (12)	3,124	190 (6)
		65-74 years	2,415	322 (13)	1,181	251 (21)	1,234	71 (6)
		75-84 years	597	50 (8)	266	34 (13)	331	16 (5)
		≥85 years	82	8 (10)	44	7 (16)	38	1 (3)
	75-84 years							
		0-4 years	75	3 (4)	29	2 (7)	46	1 (2)
		5-17 years	693	59 (9)	342	43 (13)	351	16 (5)
		18-29 years	2,001	145 (7)	897	94 (10)	1,104	51 (5)
		30-39 years	1,674	116 (7)	723	64 (9)	951	52 (5)
		40-49 years	1,443	101 (7)	697	67 (10)	746	34 (5)
		50-64 years	1,482	129 (9)	633	70 (11)	849	59 (7)
		65-74 years	638	62 (10)	314	47 (15)	324	15 (5)
		75-84 years	211	63 (30)	116	51 (44)	95	12 (13)
		≥85 years	18	1 (6)	10	1 (10)	8	0 (0)
	≥85 years							
		0-4 years	15	0 (0)	7	0 (0)	8	0 (0)
		5-17 years	109	4 (4)	66	2 (3)	43	2 (5)
		18-29 years	282	16 (6)	125	11 (9)	148	5 (3)
		30-39 years	205	14 (7)	84	7 (8)	104	7 (7)
		40-49 years	178	7 (4)	83	5 (6)	87	2 (2)
		50-64 years	212	11 (5)	113	7 (6)	96	4 (4)
		65-74 years	72	8 (11)	36	7 (19)	36	1 (3)
		75-84 years	15	3 (20)	9	3 (33)	6	0 (0)
		≥85 years	7	5 (71)	7	5 (71)	0	0 (Undef.)
Sex/gender								
	Male							
		Male	227,730	16,688 (7)	101,560	10,645 (10)	126,81	6,043 (5)
		Female	147,224	11,182 (8)	70,286	7,785 (11)	76,834	3,397 (4)
		Transgender	68	3 (4)	32	1 (3)	36	2 (6)
	Female							
		Male	115,968	8,453 (7)	53,235	5,428 (10)	62,720	3,024 (5)
		Female	82,133	6,511 (8)	38,708	4,503 (12)	43,414	2,007 (5)
		Transgender	38	0 (0)	11	0 (0)	27	0 (0)
	Transgender							
		Male	151	4 (3)	74	2 (3)	77	2 (3)
		Female	64	2 (3)	35	1 (3)	29	1 (3)
		Transgender	6	2 (33)	5	2 (40)	1	0 (0)

Values in the table include all index cases whose contacts were traced, with results available, as illustrated in **Fig. 2**. Table entries may not sum across rows if high-risk or low-risk determinations for contacts were unavailable.

Table S9: Prevalence of comorbid conditions among fatal COVID-19 cases.

Condition	Sex	Prevalence among decedents, %							
		0-17y	18-29y	30-44y	45-64y	65-74y	75-84y	≥85y	All ages
All individuals included									
	All	17	87	531	2469	1574	814	205	5697
	Males	5	50	379	1764	1119	590	154	4061
	Females	12	37	152	705	455	224	51	1636
Diabetes mellitus									
	All	1 (6)	10 (11)	140 (26)	1136 (46)	799 (51)	395 (49)	81 (40)	2562 (45)
	Males	0 (0)	5 (10)	99 (26)	796 (45)	565 (50)	284 (48)	64 (42)	1813 (45)
	Females	1 (8)	5 (14)	41 (27)	340 (48)	234 (51)	111 (50)	17 (33)	749 (46)
Sustained hypertension									
	All	0 (0)	8 (9)	90 (17)	863 (35)	671 (43)	351 (43)	82 (40)	2065 (36)
	Males	0 (0)	3 (6)	61 (16)	608 (34)	475 (42)	252 (43)	60 (39)	1459 (36)
	Females	0 (0)	5 (14)	29 (19)	255 (36)	196 (43)	99 (44)	22 (43)	606 (37)
Coronary artery disease									
	All	0 (0)	1 (1)	25 (5)	258 (10)	239 (15)	139 (17)	38 (19)	700 (12)
	Males	0 (0)	0 (0)	16 (4)	194 (11)	185 (17)	111 (19)	31 (20)	537 (13)
	Females	0 (0)	1 (3)	9 (6)	64 (9)	54 (12)	28 (12)	7 (14)	163 (10)
Renal disease									
	All	1 (6)	11 (13)	40 (8)	215 (9)	130 (8)	56 (7)	17 (8)	470 (8)
	Males	0 (0)	6 (12)	25 (7)	154 (9)	99 (9)	42 (7)	16 (10)	342 (8)
	Females	1 (8)	5 (14)	15 (10)	61 (9)	31 (7)	14 (6)	1 (2)	128 (8)
Chronic obstructive pulmonary disease									
	All	0 (0)	1 (1)	4 (1)	35 (1)	33 (2)	25 (3)	6 (3)	104 (2)
	Males	0 (0)	1 (2)	4 (1)	25 (1)	29 (3)	18 (3)	6 (4)	83 (2)
	Females	0 (0)	0 (0)	0 (0)	10 (1)	4 (1)	7 (3)	0 (0)	21 (1)
Asthma									
	All	0 (0)	1 (1)	12 (2)	49 (2)	25 (2)	13 (2)	4 (2)	104 (2)
	Males	0 (0)	0 (0)	8 (2)	32 (2)	15 (1)	8 (1)	4 (3)	67 (2)
	Females	0 (0)	1 (3)	4 (3)	17 (2)	10 (2)	5 (2)	0 (0)	37 (2)
Cancer									
	All	0 (0)	1 (1)	7 (1)	20 (1)	15 (1)	8 (1)	5 (2)	56 (1)
	Males	0 (0)	0 (0)	3 (1)	15 (1)	8 (1)	5 (1)	4 (3)	35 (1)
	Females	0 (0)	1 (3)	4 (3)	5 (1)	7 (1)	3 (1)	1 (2)	21 (1)
Pulmonary tuberculosis									
	All	0 (0)	1 (1)	11 (2)	23 (1)	13 (1)	10 (1)	2 (1)	60 (1)
	Males	0 (0)	1 (2)	8 (2)	20 (1)	9 (1)	9 (2)	2 (1)	49 (1)
	Females	0 (0)	0 (0)	3 (2)	3 (0)	4 (1)	1 (<1)	0 (0)	11 (1)
Stroke									
	All	0 (0)	0 (0)	4 (1)	42 (2)	34 (2)	18 (2)	2 (1)	100 (2)
	Males	0 (0)	0 (0)	3 (1)	27 (2)	25 (2)	10 (2)	2 (1)	67 (2)
	Females	0 (0)	0 (0)	1 (1)	15 (2)	9 (2)	8 (4)	0 (0)	33 (2)
Hyperthyroidism or hypothyroidism									
	All	1 (6)	0 (0)	17 (3)	66 (3)	36 (2)	28 (3)	7 (3)	155 (3)
	Males	1 (20)	0 (0)	2 (1)	22 (1)	12 (1)	17 (3)	6 (4)	60 (1)
	Females	0 (0)	0 (0)	15 (10)	44 (6)	24 (5)	11 (5)	1 (2)	95 (6)
Liver disease									
	All	3 (18)	2 (2)	15 (3)	43 (2)	19 (1)	11 (1)	2 (1)	95 (2)
	Males	1 (20)	2 (4)	11 (3)	35 (2)	14 (1)	8 (1)	2 (1)	73 (2)
	Females	2 (17)	0 (0)	4 (3)	8 (1)	5 (1)	3 (1)	0 (0)	22 (1)
Any comorbidity									
	All	6 (35)	28 (32)	247 (47)	1540 (62)	1071 (68)	539 (66)	130 (63)	3561 (63)
	Males	2 (40)	14 (28)	166 944)	1090 (62)	754 (67)	388 (66)	102 (66)	2516 (62)
	Females	4 (33)	14 (38)	81 (53)	450 (64)	317 (70)	151 (67)	28 (55)	1045 (64)
Two or more comorbidities									
	All	0 (0)	7 (8)	92 (17)	867 (35)	656 (42)	352 (43)	84 (41)	2058 (36)
	Males	0 (0)	4 (8)	60 (16)	601 (34)	468 (42)	255 (43)	69 (45)	1457 (36)
	Females	0 (0)	3 (8)	32 (21)	266 (38)	188 (41)	97 (43)	15 (29)	601 (37)
Three or more comorbidities									
	All	0 (0)	1 (1)	25 (5)	287 (12)	248 (16)	134 (16)	30 (15)	725 (13)
	Males	0 (0)	0 (0)	14 (4)	200 (11)	181 (16)	103 (17)	24 (16)	522 (13)
	Females	0 (0)	1 (3)	11 (7)	87 (12)	67 (15)	31 (14)	6 (12)	203 (12)

Values in the table indicate the number and proportion of decedents in each stratum with the listed comorbidities. We exclude 36 individuals with missing sex or age data.

Table S10: Cumulative incidence of COVID-19 cases and mortality in Tamil Nadu, Andhra Pradesh, and the United States.

Setting	Age group	Population at risk *(in thousands)*	Cases	Cumulative incidence *(per 10,000)*	Incidence ratio *(ref. age 65-74y)*	Deaths	Cumulative mortality *(per 10,000)*	Mortality ratio *(ref. age 65-74y)*
Tamil Nadu and Andhra Pradesh								
	0-4 years	8,497	5,384	6.3	0.16	4	0.0047	0.0021
	5-17 years	22,980	29,122	12.7	0.33	13	0.0057	0.0025
	18-29 years	25,987	101,803	39.2	1.01	87	0.033	0.015
	30-39 years	20,784	94,208	45.3	1.17	268	0.13	0.057
	40-49 years	19,154	79,236	41.4	1.06	640	0.33	0.15
	50-64 years	20,533	88,882	43.3	1.11	2,092	1.02	0.45
	65-74 years	6,926	26,910	38.9	1.00	1,574	2.27	1.00
	75-84 years	2,403	8,420	35.0	0.90	814	3.39	1.49
	≥85 years	609	1,574	25.9	0.67	205	3.37	1.48
	Unknown	– –	0	– –	– –	42	– –	– –
United States								
	0-4 years	19,736.0	66,110	33.5	0.34	31	0.016	0.0018
	5-17 years	53,548.4	246,818	46.1	0.46	44	0.008	0.00095
	18-29 years	52,870.6	875,795	165.6	1.67	651	0.12	0.014
	30-39 years	43,375.0	682,207	157.3	1.58	1,701	0.39	0.045
	40-49 years	39,290	628,649	157.4	1.59	4,139	1.04	0.12
	50-64 years	62,110	853,058	137.3	1.38	20,264	3.26	0.38
	65-74 years	31,487	312,648	99.3	1.00	27,226	8.65	1.00
	75-84 years	15,407	181,220	117.6	1.18	33,989	22.06	2.55
	≥85 years	5,893	138,736	235.4	2.37	41,026	69.62	8.05

Values in the table correspond to data plotted in **Fig. 4**; cumulative incidence and mortality are calculated for data up to 1 August, 2020 in Tamil Nadu and Andhra Pradesh, and up to 21 August, 2020 in the United States. We present ratios of age-specific cumulative incidence and cumulative mortality relative to the 65-74 year age group for comparison of patterns across settings.

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56. De-identified data and code for replication of the analyses is available from https://doi.org/10.5281/zenodo.4003365.