BMJ Open

Secondary attack rate of COVID-19 among contacts and risk factors, Tamil Nadu, April-May 2020: A retrospective Cohort Study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-051491
Article Type:	Original research
Date Submitted by the Author:	22-Mar-2021
Complete List of Authors:	Karumanagoundar, Kolandaswamy; Directorate of Public Health and Preventive Medicine Raju, Mohankumar; National Institute of Epidemiology Ponnaiah, Manickam; National Institute of Epidemiology Kaur, P; National Institute of Epidemiology viswanathan, Vidhya; National Institute of Epidemiology Rubeshkumar, Polani; National Institute of Epidemiology Sakthivel, Manikandanesan; National Institute of Epidemiology Shanmugiah, Porchelvan; National Institute of Epidemiology Ganeshkumar, P; National Institute of Epidemiology Muthusamy, Santhosh Kumar ; National Institute of Epidemiology Sendhilkumar, Muthappan ; National Institute of Epidemiology, Epidemilogy Venkatasamy, Vettrichelvan; National Institute of Epidemiology Sambath, Irene; National Institute of Epidemiology, Epidemiology Ilangovan, Kumaravel; National Institute of Epidemiology, Epidemiology M, Jagadeesan; Greater Chennai Corporation Govindarajan, Rameshkumar; Directorate of Public Health and Preventive Medicine Shanmugam, Soundammal; Directorate of Public Health and Preventive Medicine Rajarathinam, Selvakumar; Directorate of Public Health and Preventive Medicine Suresh, KST; Directorate of Public Health and Preventive Medicine Varadharajan, M; Directorate of Public Health and Preventive Medicine Thiagarajan, Manivannan; Directorate of Public Health and Preventive Medicine Jagadeeshkumar, K; Directorate of Public Health and Preventive Medicine Ganesh, Velmurugan; Directorate of Public Health and Preventive Medicine Kumar, Sateesh; Directorate of Public Health and Preventive Medicine Venkatesan, Prakash; Directorate of Public Health and Preventive Medicine Nallathambi, Yogananth; Directorate of Public Health and Preventive Medicine Palani, Sampath; Directorate of Public Health and Preventive Medicine Selvavinayagam, TS; Directorate of Public Health and Preventive Medicine Reddy, Madhusudhan; Greater Chennai Corporation

	Rajesh, Beela; Government of Tamil Nadu, Health and Family Welfare Department Murhekar, Manoj; National Institute of Epidemiology
Keywords:	COVID-19, Epidemiology < INFECTIOUS DISEASES, Infection control < INFECTIOUS DISEASES, Public health < INFECTIOUS DISEASES

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Secondary attack rate of COVID-19 among contacts and risk factors, Tamil Nadu, April-May 2020: A retrospective Cohort Study

Kolandaswamy Karumanagoundar[1], Raju Mohankumar[2*], Manickam Ponnaiah[2], Prabhdeep Kaur[2], Vidhya viswanathan[2], Polani Rubeshkumar[2], Manikandanesan Sakthivel[2], Porchelvan Shanmugiah[1,2], Parasuraman Ganeshkumar[2], Muthusamy Santoshkumar[2], Muthappan Sendhilkumar[2], Vettrichelvan Venkatasamy[2], Irene Sambath[2], Kumaravel Ilangovan[2], Jagadeesan M[3], Rameshkumar Govindarajan[1], Soundammal Shanmugam[1], Selvakumar Rajarathinam[1], Suresh KST[1], Varadharajan M[1], Manivannan Thiagarajan[1], Jagadeeshkumar K[1], Velmurugan Ganesh[1], Sateesh Kumar[1], Prakash Venkatesan[1], Yogananth Nallathambi[1], Sampath Palani[1], Selvavinayagam TS[1], Madhusudhan Reddy[3], Beela Rajesh[4], Manoj Murhekar[2]

[1]Directorate of Public Health and Preventive Medicine, Tamil Nadu

[2]ICMR National Institute of Epidemiology, Chennai

[3]Greater Chennai Corporation, Chennai

[4]Health and Family Welfare Department, Government of Tamil Nadu

*Corresponding author:

Dr Raju Mohankumar, Consultant, ICMR-National Institute of Epidemiology, TNHB, Ayappakam, Chennai, India, PIN- 600077. Email: mohankumar@nieicmr.org.in, Phone: +914426136333

Word count: 3527

Keywords: Secondary Attack Rate, COVID-19, Contact investigation, Disease transmission, Cluster

Abstract:

Objective: To describe the characteristics of contacts of COVID-19 case-patients in terms of time, place, and person, to calculate the secondary attack rate and factors associated with COVID-19 infection among contacts

Design: Retrospective cohort study

Setting and participants: Contacts of cases identified by the health department from March 14 to May 5, 2020, in nine of 38 administrative districts of Tamil Nadu

Outcome measure: Attack rate among the contacts and factors associated with COVID-19 positivity.

Results:

We listed 15,702 contacts of 931 primary cases. Of the contacts, 89% (n=14002) were tested for COVID-19. The overall SAR was 4% (599/14002), with higher among the household contacts (13%) than the community contacts (1%). SAR among the contacts of primary cases with congregation exposure were five times higher than the contacts of non-congregation primary cases (10% Vs 2%). Being a household contact of a primary case with congregation exposure had a four-fold increased risk of getting COVID-19 (RR=16.4; 95%CI:13-20) than contact of primary case without congregation exposure. Among the symptomatic primary cases, household contacts of congregation primaries had higher RR than household contacts of other cases [(RR=25.3; 95%CI:10.2-63) Vs (RR=14.6; 95%CI:5.7-37.7)]. Among asymptomatic primary case, RR was increased among household contacts (RR=16.5; 95%CI:13.2–20.7) of congregation primaries compared to others

Conclusion:

Our study showed an increase in disease transmission among household contacts than community contacts. Also, symptomatic primary cases and primary cases with exposure to the congregation had more secondary cases than others.

Strengths and Limitations:

- **Strengths**
    - We documented the secondary attack rate of COVID-19 in a large cohort of more than 15,000 contacts in India.

- Majority of the contacts were tested with RT-PCR, therefore the estimates of secondary attack rate were reliable.
- We documented high transmission among household contacts and contacts of symptomatic primary cases which guided the testing policy early in the pandemic in Tamil Nadu, India.

- **Limitations:**
  - We did not have confirmation of the COVID-19 status of 11% of the contacts,
  - Contact tracing was prioritised for household contacts during lockdown as the community interactions were limited.

Background

The novel coronavirus outbreak due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection reported from China in December 2019 was declared a Public Health Emergency of International Concern (PHEIC) by WHO on January 30, 2020[1]. At the early stages of COVID-19, international travel was the most common exposure. Subsequently, clusters emerged in various settings, including community gatherings, hospital settings, and commercial gatherings. Investigating such clusters provided clues for disease transmission and guided intervention strategies for pandemic response[2]. Contact tracing is one of the key strategies to interrupt the chain of transmission of SARS-CoV-2. The aim of the contact tracing strategy is to reduce secondary cases of COVID-19. In this context, the secondary attack rate of SARS-CoV-2 denotes the probability that infection occurs among susceptible contacts within a reasonable incubation period following contact with the infectious person(s) or that of the source[3] and represents infectiousness of the agent. The secondary attack rate among contacts thus is a useful indicator to track the viral transmission potential[4] and thereby guides control strategies. The secondary attack rate of SARS-CoV-2 differs from the nature of the setting and that of the symptomatic status of the primary cases.[5 6 7 8] Understanding the dynamics of transmission of COVID-19 for specific settings will help in preventing the spread of the infection[9].

India reported the first laboratory-confirmed case on January 30, 2020, from a Southern state Kerala. In early March, most reported cases had a history of international travel or contact with the traveller[10]. Tamil Nadu, the southern State of India, reported the first case of COVID-19 on March 18 2020[11]. At the initial stages, COVID-19 cases were reported among international travellers and subsequently among travellers from other states. On March 13, the media reported a cluster of cases linked to a religious congregation in New Delhi.[12 13] According to the reports, the event started on February 9, 2020, with more than 4000 participants from various Indian states and abroad gathered in groups to attend the meeting.[14] As the participants returned to their respective states, clusters emerged in several states. [15] People from Tamil Nadu also participated in the meeting, predominantly during 21-23 March, 2020[16]. After returning from the event, attendees travelled to many parts

of the State. Public health authorities initiated a massive search for potential cases and their contact in various districts.

Due to the novelty of the pandemic, the transmission dynamics of the diseases were not fully understood. In the early phase, knowledge on the spread of the disease in various settings and in different geographical was not known. Knowing this information was crucial in preventing the disease's spread from the primary case to the contacts. In this context, we conducted a study to estimate the secondary attack rate in terms of time, place, and person and determined risk factors for COVID-19 infection among contacts during March-May 2020 in Tamil Nadu, India.

Methods:

Study design

We conducted a retrospective cohort study of all contacts of COVID-19 cases between March 14 to May 5, 2020, of Tamil Nadu, Southern India.

Study setting and the COVID-19 context:

We studied nine of 38 administrative districts reporting maximum cases during the study period (Figure 1). The study districts varied in a population density ranging from 28,553 persons per square Kilometre in the State capital city of Chennai to 367 in Erode district, located southwest of Chennai (Table 1). The average family size was similar (3.5 to 4.3 persons per family) across these study districts.

The COVID-19 response strategies implemented by the State included surveillance for case identification, confirmation with Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) test for COVID-19, contact tracing, isolation, and quarantine, in addition to community-based interventions. The district officials hospitalised the COVID-19 patients, and quarantined COVID-19 tested negatives at home or facility. By contact tracing, the officials identified the household and the community contacts and tested them for COVID-19. We included all COVID-19 confirmed cases in the study period from these districts.

Sampling and sample size

We listed all the identified confirmed COVID-19 cases in the study districts from March 1 to May 30, 2020. We included all the contacts of the identified COVID-19 positive individuals.

Operational definitions:

Primary case: We defined a primary case as any person with a laboratory-confirmed COVID-19 case with no established contact history.

Confirmed Case: Any person who is positive for COVID-19 using RT-PCR

Contact: Contact is any person exposed to COVID-19 positive individuals[17].

Household contact: It is defined as any person living in the same household and comes in contact with the COVID-19 case

Community contact: It is defined as any person other than living in the same household and comes in contact with the COVID-19 case

Cluster: An unusual aggregation of health events grouped in time and space and reported to a health agency[18]

Secondary attack rate: The secondary attack rate is the proportion of COVID-19 positive individuals among the tested contacts minus the primary cases of the contacts.

Data collection and analysis:

We collected data from district surveillance records and classified the contacts as household and community contacts. We abstracted the information on sociodemographic characteristics, residence location, symptom status and congregation exposure of the primary case from the district surveillance records.

We described the total number of contacts and the median number of contacts per case by the district. We calculated the overall secondary attack rate (SAR) for COVID-19 and by age, gender, symptom status and congregation exposure of the primary case. We estimated the SAR by symptom status and congregation exposure of the primary case in two subgroups, namely household and community contacts. We determined the risk factors associated with COVID-19 infection among contacts based on the household vs community exposure, congregation vs non-congregation exposure of primary case and symptom status of the primary case. We estimated the unadjusted and age/sex-adjusted relative risk (RR) and 95% confidence intervals

(CI) for the four categories of contacts. The community contacts of the non-congregation primary case were the reference category. The other categories were community contacts of congregation primary, household contacts of non-congregation and household contacts of congregation primary cases. We also estimated the unadjusted and age/sex-adjusted RR and 95% CI after stratifying the four categories by symptom status of the primary case.

Human participation protection:

We obtained the approval of the Institutional Ethics Committee of the ICMR-National Institute of Epidemiology. No primary information was collected from the participants. We maintained complete confidentiality and anonymity of the participants during data abstraction.

Results:

Description of the cases and contacts

We identified 931 COVID-19 primary cases and 15,702 contacts during the study period. The median number of contacts identified per COVID-19 case was 17 (IQR: 9, 18) in the selected nine districts. The duration, from the reporting of the first COVID-19 case to the time of data abstraction, ranged from 51 days for Chennai and 15 days in the Karur district. (Table 1).

Of the identified 15,702 contacts, 14,002 (89%) contacts were tested for COVID-19. Apart from household contacts, most community contacts (98%) were cab-drivers, vegetable sellers, co-workers, or co-passengers in public transport. The majority of the household contacts (99%) were tested. There is no difference between tested and not-tested by age and gender (data not shown).

Information on age was available for 99.7% (13,969/14,002) of the contacts (Table 2). The contacts were predominantly aged 21-40 years (41%) and 41 to 59 years (27%). Over half of the contacts were males (53%). About one-fourth (28%) of the contacts were traced from primary cases with congregation exposure, and 25% of the contacts had household COVID-19 exposure. Healthcare providers contributed to less than 1% of the contacts identified for the primary cases.

Secondary attack rate by selected characteristics

Among tested contacts (n=14002), 599 (4.3%) tested positive for COVID-19 based on RT PCR. The overall secondary attack rate was 4% (599 of 14,002). The secondary attack rate was similar across the age groups and gender, ranging from 4% to 5%. The secondary attack rate among the contacts of primary cases with congregation exposure was five times higher (10%) than contacts of non-congregation primary cases (2%). Of the 598 contacts who tested positive, more than three-fourths (78%) were household contacts.

The overall secondary attack rate was 4%, with 13% among the household contacts compared to 1% among the community contacts. The secondary attack among household contacts of primary cases with exposure to congregation was higher (21%) than the contacts of primary cases without congregation exposure (6%) (Table 3). The primary cases' symptomatic status was available for 95% (13,338) of the tested contacts. The overall secondary attack among contacts of the primary cases with COVID -19 symptoms was 6% compared to 4% among the contacts of asymptomatic cases. The household contacts exposed to the symptomatic primary case had two times higher attack rate as compared to contacts of asymptomatic primary cases (25% vs 12%). Secondary attack among the community contacts was similar irrespective of the symptomatic status of the primary case.

Risk factors for secondary cases

We estimated the risk of acquiring infection for contacts by type of contact and congregation participation of the primary cases. There was no significant risk among the community contacts of the primary cases irrespective of the participation in the congregation. The relative risk of household contacts of primary cases with congregation participation was four times higher (RR=16.4; 95% CI: 13.3 to 20.2) in getting COVID-19 compared to household contacts of other primary cases (RR=4.9; 95% CI: 3.81 to 6.38). The association did not change even after adjusting for age and gender. (Table 4)

We estimated the RR stratified by the symptomatic status of the primary cases. In the strata where the primary case was symptomatic, there was an eight-fold increase in RR for household contacts of congregation participants when compared to the household contacts of other cases [RR=25.3,95% CI: 10.2 to 63) vs RR= 14.6, 95% CI: 5.7 to 37.7)]. If the primary case was asymptomatic, there was no increase in RR for community contacts of congregation participants, but RR was increased among

household contacts of primary cases with congregation exposure. The change in RR among household contacts of the symptomatic primary case was several folds higher as compared to household contacts of the asymptomatic primary case (Table 5).

Discussion:

Our study showed an increase in disease transmission among household contacts than community contacts. The transmission was further accentuated if the primary case had symptoms or exposure to a congregation. The high risk of infection among family members was consistent with the pooled analysis of 43 studies which estimated an SAR of 18% among household contacts[19]. We observed very low SAR (1%) among non-household contacts, possibly due to the State's lockdown situation during the study period.

Contact tracing is one of the core public health strategies for COVID-19 control, and our study assessed if districts implemented this strategy. Although the median number of contacts per case was 17, there was a high variation between districts due to limiting the contact tracing to only household contacts in several cases. A study in the UK measuring the efficacy of contact tracing for COVID-19 suggested an average of 36 contacts must be traced per case[20]. Another study in the Republic of Korea shows a range of 15-649 contacts traced per case[21]. Once the number of cases increases, extensive contact tracing may not be feasible unless we deploy dedicated human resources and train the contact tracers. There was limited capacity in the initial phase of the epidemic; however, the public health department added human resources, especially in the capital city of Chennai, to sustain the contact tracing as cases started increasing.

We observed a higher attack rate among household contacts (25%) of symptomatic primary cases when compared to asymptomatic. Our observations were similar to a pooled analysis of three studies from Wei et al.[22], Part et al.[23], Chaw et al.[24], which reported 20% SAR among household contacts of symptomatic primary cases[25]. This observation guided the testing policy in the context of limited resources at the peak of the pandemic. We prioritised the testing of household contacts of symptomatic primary cases. Although the attack rate was lower among contacts of asymptomatic primary, the transmission did take place especially in the household setting. Our

findings support the rationale of isolation of all cases irrespective of the symptoms and testing of all household contacts to break the chain of transmission[26].

The congregation clusters were one of the sources which led to COVID-19 transmission in various communities[27]. Similar to our setting, many countries experienced clusters emerging from congregation settings. In South Korea, an explosive outbreak happened following a social event held at a Church and is attributable to 84% of the total confirmed cases of South Korea reported till mid-March[28]. Another study in Jordan among the wedding attendees reported a higher attack rate of 22%[29]. Similar clusters had been reported in different parts of South Korea[30] , and in the USA, a secondary attack of 53.3% was estimated among one such event attendees[31]. Avoiding any type of gathering is one of the essential mitigation measures to be followed strictly. Government actions to ban mass gatherings are essential, as are good diagnostic facilities and remotely accesses health advice, together with specialised treatment for people with severe disease[32].

Our study has several limitations. We did not have confirmation of the COVID-19 status of 11% of the contacts, who were mostly community contacts. Hence, this may have over-estimated the overall secondary attack rate by 0.3%. Contact tracing was prioritised for household contacts due to restricted mobility and limited interactions at the community level. Therefore, secondary attack among non-household contacts may not reflect the real transmission potential. Information regarding symptoms was retrieved from district surveillance records. The symptom status was collected at the time of diagnosis. We could not verify if the primary case developed symptoms later in the course of illness. Hence, there was a chance of misclassification of symptom status.

We conclude that COVID-19 transmission was higher among household contacts, contacts of symptomatic primary case, and contacts of primary cases exposed to the congregation. Based on the findings, we informed the testing policy and contact tracing strategy in the early stages of the COVID-19 epidemic in Tamil Nadu. We recommend testing all household contacts irrespective of the symptoms and extensive contact tracing and testing in case of super spreader events. In resource-constrained settings, all contacts of symptomatic primary cases should be prioritised for testing. The gatherings should be restricted to prevent significant clusters.

Author Contributions: KK, RM, MP, and PK designed the study, supervised fieldwork, did primary data collection, planned data analysis and wrote the first draft of the manuscript. VV, PR, MS, PS, PG and MS did primary data collection and did data analysis. VV, IS, and KI supervised fieldwork and data management. JM, RG, SS, SR, SKST, VM, MT, JK, VG, and SK supervised fieldwork and supported data collection. PV, YN, SP, STS, MR, BR and MM conceptualised the study and gave critical comments in finalising the manuscript. All authors approved the final manuscript

Funding:

This work was supported by ICMR-National Institute of Chennai intramural funds.

Award/Grant number: Not applicable

Competing interests: None declared

Patient consent for publication: Not required

Ethics approval: Institutional Ethics Committee of ICMR-National Institute of Epidemiology, Chennai, approved the study. Written consent was not required for this study

Provenance and peer review: Not commissioned; externally peer-reviewed.

Data availability statement: Data are available upon reasonable request

Patient and Public Involvement in research: Not involved in the conduct of research

Trial registration: Not applicable

Figure 1: Map of Tamil Nadu included in the epidemiological study of COVID-19. There are nine of the 38 districts included in the study.

Table 1: Frequency of contacts traced per COVID-19 primary case by district, Tamil Nadu, India, April-May, 2020

District	Demographic characteristics		# Primary Cases	Frequency of contacts		Days since reporting of the first case in the district
	Population density (Per Sq KM)*	Family size*		# Contacts identified	Median (Range) contacts per Primary case	
Chennai	26553	3.9	530	9731	18 (1 to151)	51
Coimbatore	731	3.9	151	3257	22 (1 to 274)	33
Erode	391	3.5	56	1032	18 (3 to 141)	46
Karur	367	3.7	42	416	10 (1 to 86)	15
Ranipet	648	4.3	29	273	9 (1 to 68)	25
Tirunelveli	460	3.8	35	166	5 (1 to 21)	23
Tirupathur	648	4.3	12	312	26 (1 to 100)	20
Tiruppur	478	3.6	66	279	5 (1 to 10)	24
Vellore	648	4.3	10	236	24 (6 to 79)	23
Overall			931	15,702	17(5 to 26)	

*- Census 2011

Table 2: Secondary Attack Rate (%) by selected characteristics among the contacts traced per COVID-19 primary case, Tamil Nadu, India, April- May 2020

Selected characteristics		Number of contacts (%)	# COVID-19 Positive	Secondary attack rate (%)
Overall		14002(100%)	599	4
Age in Years (N=13,379)	≤20	3203 (24%)	138	4
	21-40	5511 (41%)	237	4
	41-59	3364 (25%)	155	5
	60+	1301 (10%)	65	5
Gender (N=13,969)	Male	7443 (53%)	280	4
	Female	6526 (47%)	318	5
Congregation exposure of primary case (N=14,002)	Yes	3884 (28%)	377	10
	No	10,118 (72%)	222	2
Contact type (N=14,002)	Household	3474 (25%)	464	13
	Community	10,417 (74%)	134	1
	Healthcare personnel	111 (1%)	0	0
Symptom status of Primary case (N=13338)	Symptomatic	607(5%)	37	6
	Asymptomatic	12,731(95%)	464	4

Table 3: Secondary Attack Rate among household and non-household contacts of COVID-19 individuals by type of exposure and symptom status of primary cases, Tamil Nadu, April-May, 2020 (N=14002)

Type of exposure or symptom status of the primary case	The secondary attack rate (%) (# cases / # contacts of the case)		
	Household	Community contacts	Overall
N = 14,002			
Congregation	**21%** *(352/1686)*	**1%** *(25/2198)*	**10%** *(377/3884)*
No congregation	**6%** *(112/1788)*	**1%** *(110/8330)*	**2%** *(222/10118)*
N= 13,338			
Symptomatic	**25%** (26/104)	**2%** (11/503)	**6%** (37/607)
Asymptomatic	**12%** (341/2930)	**1%** (123/9801)	**4%** (464/12731)

Table 4: Factors associated with COVID-19 among the contacts of Tamil Nadu, India April – May 2020

Risk factors	Crude RR (95% CI)	RR with age-adjusted (95% CI)	RR with age and sex-adjusted (95% CI)
Community contacts of non-congregation Primary cases	Ref	Ref	Ref
Community contact of Congregation Primary cases	1.0 (0.7-1.5)	0.9 (0.6-1.4)	0.9 (0.6-1.4)
Household contacts of non-congregation Primary cases	4.9 (3.8-6.4)	4.7 (3.7 – 6.2)	4.7 (36.4-6.1)
Household contacts of Congregation Primary cases	16.4 (13.3–20.2)	16.2 (13.1-20.0)	16.1 (13.0-20.0)

Table 5: Factors associated with COVID-19 among the contacts stratified by the symptomatic status of the primary cases of Tamil Nadu, India April – May 2020

Symptomatic Primary	Type of contacts	Crude RR (95% CI)	Adjusted RR with Age and Sex (95% CI)
Yes	Community contacts of non-congregation Primary cases	Ref	Ref
	Community contact of Congregation Primary cases	10.5 (6.0-33.0)	8.6 (2.6 – 29.1)
	Household contacts of non-congregation Primary cases	15.5 (6.0-39.8)	14.6 (5.7 – 37.7)
	Household contacts of Congregation Primary cases	26.7 (10.8-65.9)	25.3 (10.2 – 63.0)
No	Community contacts of non-congregation Primary cases	Ref	Ref
	Community contact of Congregation Primary cases	0.9 (0.6-1.4)	0.9 (0.5 – 1.3)
	Household contacts of non-congregation Primary cases	4.6 (3.5-6.0)	4.4 (3.4 – 5. 8)
	Household contacts of Congregation Primary cases	16.48 (13.17-20.63)	16.52 (13.16 – 20.74)

Reference:

[1], World Health Organization. Statement on the second meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV). https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov) (2020).

[2] WHO; Coronavirus disease (COVID-19): Contact tracing 2020 [Available from: https://www.who.int/news-room/q-a-detail/coronavirus-disease-covid-19-contact-tracing.

[3] Halloran ME. Secondary Attack Rate. In: Peter A, Theodore C, editors. Encyclopedia of Biostatistics. New York: John Wiley & Sons Ltd; 2005

[4] Li W, Zhang B, Lu J, Liu S, Chang Z, Cao P, et al. The characteristics of household transmission of COVID-19. Clinical Infectious Diseases. 2020.

[5] Liu Y, Eggo RM, Kucharski AJ. Secondary attack rate and superspreading events for SARS-CoV-2. The Lancet. 2020 Mar 14;395(10227):e47

[6] Luo L, Liu D, Liao X, Wu X, Jing Q, Zheng J, Liu F, Yang S, Bi H, Li Z, Liu J. Contact settings and risk for transmission in 3410 close contacts of patients with COVID-19 in Guangzhou, China: a prospective cohort study. Annals of internal medicine. 2020 Aug 13

[7] Yang J, Zheng Y, Gou X, Pu K, Chen Z, Guo Q, et al. Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. International Journal of Infectious Diseases. 2020; 94:91-5

[8] Cheng HY, Jian SW, Liu DP, Ng TC, Huang WT, Lin HH. High transmissibility of COVID-19 near symptom onset. medRxiv. 2020 Jan 1

[9] Wilder-Smith A, Chiew CJ, Lee VJ. Can we contain the COVID-19 outbreak with the same measures as for SARS?. The Lancet Infectious Diseases. 2020 Mar 5

[10] Jahan N, Rubeshkumar P, Karuppiah M, Sambath I, Sendhilkumar M, Ilangovan K, et al. Entry and initial spread of COVID-19 in India: Epidemiological analysis of media surveillance data, India, 2020. Clinical Epidemiology and Global Health. 2020.

[11] MediaBulletin180320COVID19.pdf [Internet]. [cited 2020 May 31]. Available from: https://stopcorona.tn.gov.in/wp-content/uploads/files/MediaBulletin180320COVID19.pdf

[12] Ali, A. (2020, April 1). Coronavirus was a test of secular nationalism. Then Tablighi Jamaat became the scapegoat. *The Print*. https://theprint.in/opinion/coronavirus-test-of-secular-nationalism-tablighi-jamaat-became-scapegoat/392764/

[13] Gathering at Nizamuddin a highly irresponsible act, says Kejriwal. (2020, March 31). *The Hindu*. https://www.thehindu.com/news/cities/Delhi/gathering-at-nizamuddin-a-highly-irresponsible-act-says-kejriwal/article31221982.ece

[14] Chandna, H. (2020, April 18). 30% of India's Covid-19 positive caseload linked to Tablighi Jamaat meet, says govt. *The Print*. https://theprint.in/health/30-of-indias-covid-19-positive-caseload-linked-to-tablighi-jamaat-meet-says-govt/404426/

[15] Of 14,378 total Covid-19 cases in India, 4,291 linked to Delhi's Markaz event: Health ministry. (2020, April 18). *India Today*. https://www.indiatoday.in/india/story/coronavirus-india-total-cases-linked-tablighi-jamaat-markaz-nizamuddin-event-health-ministry-1668456-2020-04-18

[16] NDTV. 1,023 COVID-19 Cases Linked To Mosque Event, Tamil Nadu Leads: 10 Points: NDTV; [Available from: https://www.ndtv.com/india-news/coronavirus-tablighi-jamaat-1-023-of-2-902-covid-19-cases-linked-to-mosque-event-tamil-nadu-leads-2206193

[17] National Centre for Disease Control Directorate General of Health Services MoH&FW, GOI, New Delhi The updated case definitions and contact-categorisation [internet]. [citied 2020 Jun 2]. Available from https://nirth.res.in/virology/Revised_case_definitions_for_COVID_19.pdf

[18] US Department of Health and Human Services. Guidelines for investigating clusters of health events. Mort Morb Wkly Rep. 1990;39:1-23.

[19] Koh WC, Naing L, Chaw L, Rosledzana MA, Alikhan MF, et al. (2020) What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLOS ONE 15(10): e0240205. https://doi.org/10.1371/journal.pone.0240205

[20] Keeling MJ, Hollingsworth TD, Read JM. The Efficacy of Contact Tracing for the Containment of the 2019 Novel Coronavirus (COVID-19). medRxiv. 2020.

[21] COVID-19 National Emergency Response Center Epidemiology and case management team, Korea Centers for disease Control and prevention. Coronavirus disease-19: summary of 2,370 contact investigations of the first 30 cases in the Republic of Korea. Public Health Res Perspect. 2020;11(2):81–84. doi: 10.24171/j.phrp.2020.11.2.04

[22] Wei L, Lv Q, Wen Y, Feng S, Gao W, Chen Z, Cao B, Wu X, Lu Y, Zhao J, Zou X. Household transmission of COVID-19, Shenzhen, January-February 2020. medRxiv. 2020 Jan 1

[23] Park SY, Kim YM, Yi S, Lee S, Na BJ, Kim CB, Kim JI, Kim HS, Kim YB, Park Y, Huh IS. Coronavirus disease outbreak in call center, South Korea. Emerging infectious diseases. 2020 Aug;26(8):1666.

[24] Chaw, L., Koh, W., Jamaludin, S., Naing, L., Alikhan, M., & Wong, J. (2020). Analysis of SARS-CoV-2 Transmission in Different Settings, Brunei. *Emerging Infectious Diseases*, *26*(11), 2598-2606. https://dx.doi.org/10.3201/eid2611.202263

[25] Koh WC, Naing L, Chaw L, Rosledzana MA, Alikhan MF, et al. (2020) What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLOS ONE 15(10): e0240205. https://doi.org/10.1371/journal.pone.0240205

[26] MOHFW. Revised guidelines for Home Isolation of very mild/pre-symptomatic/asymptomatic COVID-19 cases. MOHFW 2020 July 2 [Available from RevisedHomeIsolationGuidelines.pdf (mohfw.gov.in)]

[27] Quadri SA. COVID-19 and religious congregations: Implications for spread of novel pathogens. International Journal of Infectious Diseases. 2020 Jul 1;96:219-21.

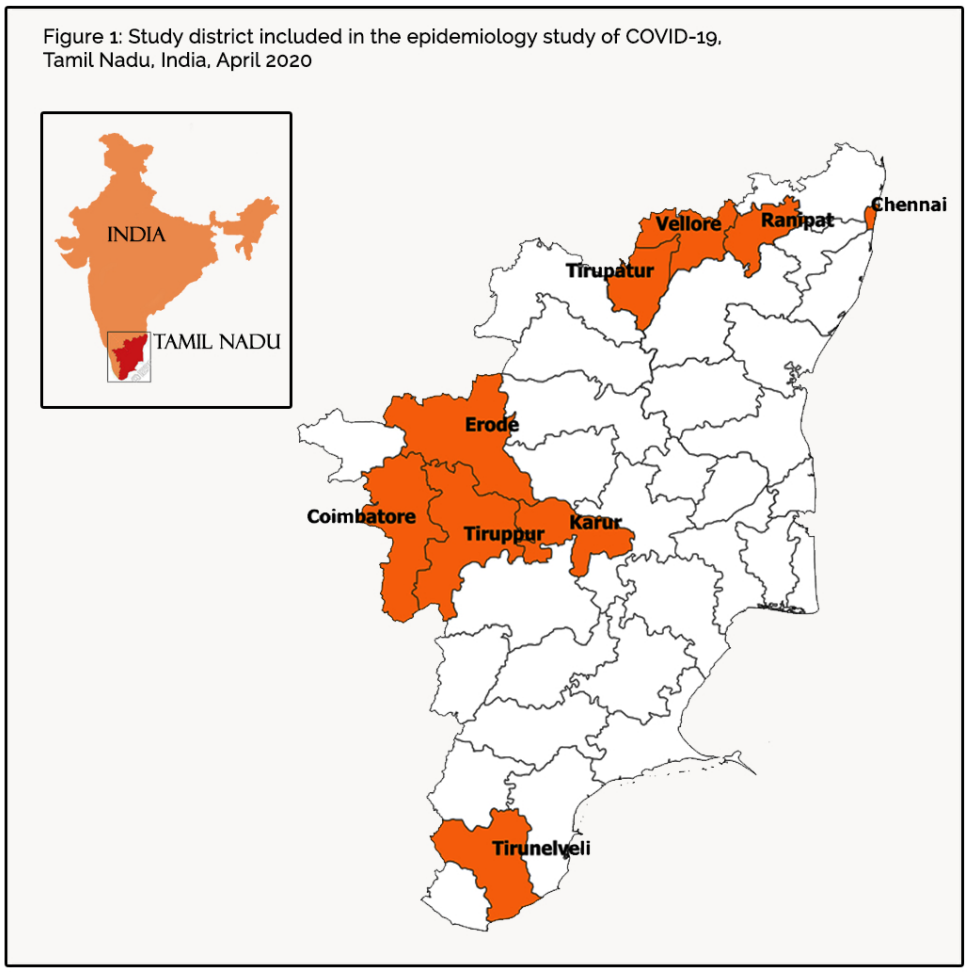
[28] Choi JY. COVID-19 in South Korea. Postgraduate Medical Journal. 2020;96(1137):399-402.

[29] Yusef D, Hayajneh W, Awad S, Momany S, Khassawneh B, Samrah S, Obeidat B, Raffee L, Al-Faouri I, Issa AB, Al Zamel H. Large outbreak of coronavirus disease among wedding attendees, Jordan. Emerging infectious diseases. 2020 Sep;26(9):2165.

[30] Shim E, Tariq A, Choi W, Lee Y, Chowell G. Transmission potential and severity of COVID-19 in South Korea. International Journal of Infectious Diseases. 2020;93:339-44.

[31] Hamner L, Dubbel P, Capron I, Ross A, Jordan A, Lee J, et al. High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice - Skagit County, Washington, March 2020. MMWR Morbidity and mortality weekly report. 2020;69(19):606-10

[32] The Times of India; Avoid mass gatherings, says govt as corona cases hit 31: [Available from: http://timesofindia.indiatimes.com/articleshow/74520610.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst]



Map of Tamil Nadu included in the epidemiological study of COVID-19. There are nine of the 38 districts included in the study.

90x90mm (300 x 300 DPI)

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohortreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1

Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	4
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnosti4c criteria, if applicable	5
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is	5

		more than one group. Give information separately for for exposed and unexposed groups if applicable.	
Bias	#9	Describe any efforts to address potential sources of bias	n/a
Study size	#10	Explain how the study size was arrived at	4
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	5
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	n/a
Statistical methods	#12c	Explain how missing data were addressed	n/a
Statistical methods	#12d	If applicable, explain how loss to follow-up was addressed	n/a
Statistical methods	#12e	Describe any sensitivity analyses	n/a
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-	5

		up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	n/a
Participants	#13c	Consider use of a flow diagram	n/a
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	5
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	5
Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	6
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6
Main results	#16b	Report category boundaries when continuous variables were categorized	n/a
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a

Other analyses	#17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6
Discussion			
Key results	#18	Summarise key results with reference to study objectives	7
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	8
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	8
Generalisability	#21	Discuss the generalisability (external validity) of the study results	n/a
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

BMJ Open

Secondary attack rate of COVID-19 among contacts and risk factors, Tamil Nadu, March-May 2020: A retrospective Cohort Study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-051491.R1
Article Type:	Original research
Date Submitted by the Author:	02-Sep-2021
Complete List of Authors:	Karumanagoundar, Kolandaswamy; Directorate of Public Health and Preventive Medicine Raju, Mohankumar; National Institute of Epidemiology Ponnaiah, Manickam; National Institute of Epidemiology Kaur, P; National Institute of Epidemiology viswanathan, Vidhya; National Institute of Epidemiology Rubeshkumar, Polani; National Institute of Epidemiology Sakthivel, Manikandanesan; National Institute of Epidemiology Shanmugiah, Porchelvan; National Institute of Epidemiology Ganeshkumar, Parasuraman; National Institute of Epidemiology Muthusamy, Santhosh Kumar ; National Institute of Epidemiology Sendhilkumar, Muthappan ; National Institute of Epidemiology Venkatasamy, Vettrichelvan; National Institute of Epidemiology Sambath, Irene; National Institute of Epidemiology Ilangovan, Kumaravel; National Institute of Epidemiology M, Jagadeesan; Greater Chennai Corporation Govindarajan, Rameshkumar; Directorate of Public Health and Preventive Medicine Shanmugam, Soundammal; Directorate of Public Health and Preventive Medicine Rajarathinam, Selvakumar; Directorate of Public Health and Preventive Medicine Suresh, KST; Directorate of Public Health and Preventive Medicine Varadharajan, M; Directorate of Public Health and Preventive Medicine Thiagarajan, Manivannan; Directorate of Public Health and Preventive Medicine Jagadeeshkumar, K; Directorate of Public Health and Preventive Medicine Ganesh, Velmurugan; Directorate of Public Health and Preventive Medicine Kumar, Sateesh; Directorate of Public Health and Preventive Medicine Venkatesan, Prakash; Directorate of Public Health and Preventive Medicine Nallathambi, Yogananth; Directorate of Public Health and Preventive Medicine Palani, Sampath; Directorate of Public Health and Preventive Medicine Selvavinayagam, TS; Directorate of Public Health and Preventive Medicine Reddy, Madhusudhan; Greater Chennai Corporation Rajesh, Beela; Government of Tamil Nadu, Health and Family Welfare

	Department Murhekar, Manoj; National Institute of Epidemiology
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	COVID-19, Epidemiology < INFECTIOUS DISEASES, Infection control < INFECTIOUS DISEASES, Public health < INFECTIOUS DISEASES

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Secondary attack rate of COVID-19 among contacts and risk factors, Tamil Nadu, March-May 2020: A retrospective Cohort Study

Kolandaswamy Karumanagoundar[1], Raju Mohankumar[2*], Manickam Ponnaiah[2], Prabhdeep Kaur[2], Vidhya viswanathan[2], Polani Rubeshkumar[2], Manikandanesan Sakthivel[2], Porchelvan Shanmugiah[1,2], Parasuraman Ganeshkumar[2], Muthusamy Santhosh kumar[2], Muthappan Sendhilkumar[2], Vettrichelvan Venkatasamy[2], Irene Sambath[2], Kumaravel Ilangovan[2], Jagadeesan M[3], Rameshkumar Govindarajan[1], Soundammal Shanmugam[1], Selvakumar Rajarathinam[1], Suresh KST[1], Varadharajan M[1], Manivannan Thiagarajan[1], Jagadeeshkumar K[1], Velmurugan Ganesh[1], Sateesh Kumar[1], Prakash Venkatesan[1], Yogananth Nallathambi[1], Sampath Palani[1], Selvavinayagam TS[1], Madhusudhan Reddy[3], Beela Rajesh[4], Manoj Murhekar[2]

[1]Directorate of Public Health and Preventive Medicine, Tamil Nadu

[2]ICMR National Institute of Epidemiology, Chennai

[3]Greater Chennai Corporation, Chennai

[4]Health and Family Welfare Department, Government of Tamil Nadu

*Corresponding author:

Dr Raju Mohankumar, Consultant, ICMR-National Institute of Epidemiology, TNHB, Ayappakam, Chennai, India, PIN- 600077. Email: mohankumar@nieicmr.org.in, Phone: +914426136333

Word count: 4235

Keywords: Secondary Attack Rate, COVID-19, Contact investigation, Disease transmission, Cluster

Abstract:

Objective: To describe the characteristics of contacts of COVID-19 case-patients in terms of time, place, and person, to calculate the secondary attack rate and factors associated with COVID-19 infection among contacts

Design: Retrospective cohort study

Setting and participants: Contacts of cases identified by the health department from March 14 to May 30, 2020, in nine of 38 administrative districts of Tamil Nadu. Significant proportion of cases attended a religious congregation.

Outcome measure: Attack rate among the contacts and factors associated with COVID-19 positivity.

Results: We listed 15,702 contacts of 931 primary cases. Of the contacts, 89% (n=14002) were tested for COVID-19. The overall SAR was 4% (599/14002), with higher among the household contacts (13%) than the community contacts (1%). SAR among the contacts of primary cases with congregation exposure were five times higher than the contacts of non-congregation primary cases (10% Vs 2%). Being a household contact of a primary case with congregation exposure had a four-fold increased risk of getting COVID-19 (RR=16.4; 95%CI:13-20) than contact of primary case without congregation exposure. Among the symptomatic primary cases, household contacts of congregation primaries had higher RR than household contacts of other cases [(RR=25.3; 95%CI:10.2-63) Vs (RR=14.6; 95%CI:5.7-37.7)]. Among asymptomatic primary case, RR was increased among household contacts (RR=16.5; 95%CI:13.2–20.7) of congregation primaries compared to others

Conclusion: Our study showed an increase in disease transmission among household contacts than community contacts. Also, symptomatic primary cases and primary cases with exposure to the congregation had more secondary cases than others.

Strengths and Limitations:

- **Strengths**
  - We documented the secondary attack rate of COVID-19 in a large cohort of more than 15,000 contacts in India
  - All the contacts were tested with RT-PCR, therefore the estimates of secondary attack rate were reliable.
  - We documented high transmission among household contacts and contacts of symptomatic primary cases which guided the testing policy of the state in the early phase of the pandemic,
- **Limitations:**
  - We did not have confirmation of the COVID-19 status of 11% of the contacts
  - Contact tracing was prioritised for household contacts during lockdown as the community interactions were limited

Background

The novel coronavirus outbreak due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection reported from China in December 2019 was declared a Public Health Emergency of International Concern (PHEIC) by WHO on January 30, 2020[1]. At the early stages of COVID-19, international travel was the most common exposure. Subsequently, clusters emerged in various settings, including community gatherings, hospital settings, and commercial gatherings. Investigating such clusters provided clues for disease transmission and guided intervention strategies for pandemic response[2]. Contact tracing is one of the key strategies to interrupt the chain of transmission of SARS-CoV-2. The aim of the contact tracing strategy is to reduce secondary cases of COVID-19. In this context, the secondary attack rate of SARS-CoV-2 denotes the probability that infection occurs among susceptible contacts within a reasonable incubation period following contact with the infectious person(s) or that of the source[3] and represents infectiousness of the agent. The secondary attack rate among contacts thus is a useful indicator to track the viral transmission potential[4] and thereby guides control strategies. The secondary attack rate of SARS-CoV-2 differs from the nature of the setting and that of the symptomatic status of the primary cases.[5 6 7 8] Understanding the dynamics of transmission of COVID-19 for specific settings will help in preventing the spread of the infection[9].

India reported the first laboratory-confirmed case on January 30, 2020, from a Southern state Kerala. In early March, most reported cases had a history of international travel or contact with the traveller[10]. Tamil Nadu, the southern State of India, reported the first case of COVID-19 on March 18 2020[11]. At the initial stages, COVID-19 cases were reported among international travellers and subsequently among travellers from other states. On March 13, the media reported a cluster of cases linked to a religious congregation in New Delhi.[12 13] According to the reports, the event started on February 9, 2020, with more than 4000 participants from various Indian states and abroad gathered in groups to attend the meeting.[14] As the participants returned to their respective states, clusters emerged in several states. [15] People from Tamil Nadu also participated in the meeting, predominantly during 21-23 March, 2020[16]. After returning from the event, attendees travelled to many parts

of the State. Public health authorities initiated a massive search for potential cases and their contact in various districts.

From February 2020, the health department of Tamil Nadu state practised testing and quarantine of international travellers and enhanced the voluntary testing of symptomatic individuals with h/o travel or h/o contact with a traveller. When the congregation cluster was reported, all the persons who attended the congregation were traced, quarantined and tested. The persons tested for COVID-19 were isolated and treated. The persons who tested negative were quarantined for 14 days. Also, the COVID-19 test was repeated after 5th day of the first testing. The household members of the attendees were immediately tested for COVID-19, if any person is tested positive.

After the information of COVID outbreak in the Delhi congregation setting, Govt of Tamil Nadu collected the line list of participants from the appropriate authority involved in the outbreak control in the congregation. The district collected additional information from the local leaders.

At the time this investigation was undertaken, there was no wide spread community transmission. Most of the infection were among travelers and health care workers, and they did not mingle with the community due to restrictions. Unlike international travelers, congregation participants travelled with other local travelers and after attending the congregation, all resumed social and work-related activities after arrival. Therefore, they are more likely to transmit to the community.

Due to the novelty of the pandemic, the transmission dynamics of the diseases were not fully understood. In the early phase, knowledge on the spread of the disease in various settings and in different geographical was not known. Also, the contribution of the congregation cluster in driving the pandemic is not known. Knowing this information was crucial in preventing the disease's spread from the primary case to the contacts. In this context, we conducted a study to estimate the secondary attack rate in terms of time, place, and person and determined risk factors for COVID-19 infection among contacts during March-May 2020 in Tamil Nadu, India.

Methods:

Study design

We conducted a retrospective cohort study of all contacts of COVID-19 cases between March 14 to May 30, 2020, of Tamil Nadu, Southern India.

Study setting and the COVID-19 context:

We studied nine of 38 administrative districts reporting maximum cases during the study period (Figure 1). The study districts varied in a population density ranging from 28,553 persons per square Kilometre in the State capital city of Chennai to 367 in Erode district, located southwest of Chennai. The average family size was similar (3.5 to 4.3 persons per family) across these study districts.

The COVID-19 response strategies implemented by the State included surveillance for case identification, confirmation with Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) test for COVID-19, contact tracing, isolation, and quarantine, in addition to community-based interventions. The confirmation with RT-PCR was done by identifying two or more target genes (E / RdRp / ORF1ab / N / S) using multiplex PCR kits The district officials hospitalised the COVID-19 patients, and quarantined COVID-19 tested negatives at home or facility. By contact tracing, the officials identified the household and the community contacts and tested them for COVID-19. We included all COVID-19 confirmed cases in the study period from these districts.

Sampling and sample size

We listed all the identified confirmed COVID-19 cases in the study districts from March 1 to May 30, 2020. We included all the contacts of the identified COVID-19 positive individuals.

Operational definitions:

Primary case: Any individual with a laboratory-confirmed COVID-19 case with no reported history of contact with COVID-19 case

Symptomatic Cases: Any individual with H/O Fever, cough, Sore throat or breathlessness from 5 days before the date of testing

Confirmed Case: Any individual who is tested positive for COVID-19 using RT-PCR

Contact: Any individual comes in proximity with COVID-19 positive individuals[17]. High risk contacts is defined as any person who was in proximity with COVID-19

positive individual within 2 metres of proximity for 15 minutes. Low risk contact is defined as any person who was in proximity with COVID-19 positive individual and sharing same environment but not having high exposure.

Household contact: Any individual living in the same household and comes in proximity with the COVID-19 confirmed individual

Community contact: Any individual other than living in the same household and comes in proximity with the COVID-19 confirmed individual

Cluster: An unusual aggregation of two are more COVID-19 cases grouped in time and space and reported to a health agency[18]

Congregation exposure: Individual wo have attended the religious congregation event held during February and March 2020 (News paper reference)

Secondary attack rate: The secondary attack rate is the proportion of COVID-19 positive individuals among the tested contacts.

Data collection and analysis:

We collected data from district surveillance records and classified the contacts as household and community contacts. We abstracted the information on sociodemographic characteristics, residence location, symptom status and congregation exposure of the primary case from the district surveillance records.

We described the total number of contacts and the median number of contacts per case by the district. We calculated the overall secondary attack rate (SAR) for COVID-19 and by age, gender, symptom status and congregation exposure of the primary case. We estimated the SAR by symptom status and congregation exposure of the primary case in two subgroups, namely household and community contacts. We determined the risk factors associated with COVID-19 infection among contacts based on the household vs community exposure, congregation vs non-congregation exposure of primary case and symptom status of the primary case. We estimated the unadjusted and age/sex-adjusted relative risk (RR) and 95% confidence intervals (CI) for the four categories of contacts. The community contacts of the non-congregation primary case were the reference category. The other categories were community contacts of congregation primary, household contacts of non-

congregation and household contacts of congregation primary cases. We also estimated the unadjusted and age/sex-adjusted RR and 95% CI after stratifying the four categories by symptom status of the primary case.

Human participation protection:

We obtained the approval of the Institutional Ethics Committee of the ICMR-National Institute of Epidemiology. No primary information was collected from the participants. We maintained complete confidentiality and anonymity of the participants during data abstraction.

Patient and Public Involvement in research: Not involved in the conduct of research

Results:

Description of the cases and contacts

We identified 931 COVID-19 primary cases and 15,702 contacts during the study period. The median number of contacts identified per COVID-19 case was 17 (IQR: 9, 18) in the selected nine districts. Around 11% (n=102) of the cases did not have household contacts. The duration from the reporting of the first COVID-19 case to the time of data abstraction ranged from 51 days for Chennai and 15 days for Karur district. (Table 1).

Of the identified 15,702 contacts, 14,002 (89%) contacts were tested for COVID-19. Apart from household contacts, most community contacts (98%) were cab-drivers, vegetable sellers, co-workers, or co-passengers in public transport. The majority of the household contacts (99%) were tested. There is no difference between tested and not-tested by age and gender (data not shown).

Information on age was available for 99.7% (13,969/14,002) of the contacts (Table 2). The contacts were predominantly aged 21-40 years (41%) and 41 to 59 years (27%). Over half of the contacts were males (53%). About one-fourth (28%) of the contacts were traced from primary cases with congregation exposure, and 25% of the contacts had household COVID-19 exposure. Healthcare providers contributed to less than 1% of the contacts identified for the primary cases.

Secondary attack rate by selected characteristics

Among tested contacts (n=14002), 599 (4.3%) tested positive for COVID-19 based on RT PCR. The overall secondary attack rate was 4% (599 of 14,002). The secondary attack rate was similar across the age groups and gender, ranging from 4% to 5%. The secondary attack rate among the contacts of primary cases with congregation exposure was five times higher (10%) than contacts of non-congregation primary cases (2%). Of the 599 contacts who tested positive, more than three-fourths (78%) were household contacts.

The overall secondary attack rate was 4%, with 13% among the household contacts compared to 1% among the community contacts. The secondary attack among household contacts of primary cases with exposure to congregation was higher (21%) than the contacts of primary cases without congregation exposure (6%) (Table 3). The primary cases' symptomatic status was available for 95% (13,338) of the tested contacts. The overall secondary attack among contacts of the primary cases with COVID -19 symptoms was 6% compared to 4% among the contacts of asymptomatic cases. The household contacts exposed to the symptomatic primary case had two times higher attack rate as compared to contacts of asymptomatic primary cases (25% vs 12%). Secondary attack among the community contacts was similar irrespective of the symptomatic status of the primary case.

Risk factors for secondary cases

We estimated the risk of acquiring infection for contacts by type of contact and congregation participation of the primary cases. There was no significant risk among the community contacts of the primary cases irrespective of the participation in the congregation. The relative risk of household contacts of primary cases with congregation participation was four times higher (RR=16.4; 95% CI: 13.3 to 20.2) in getting COVID-19 compared to household contacts of other primary cases (RR=4.9; 95% CI: 3.81 to 6.38). The association did not change even after adjusting for age and gender. (Table 4)

We estimated the RR stratified by the symptomatic status of the primary cases. In the strata where the primary case was symptomatic, there was an eight-fold increase in RR for household contacts of congregation participants when compared to the household contacts of other cases [RR=25.3,95% CI: 10.2 to 63) vs RR= 14.6, 95% CI: 5.7 to 37.7)]. If the primary case was asymptomatic, there was no increase in RR for community contacts of congregation participants, but RR was increased among

household contacts of primary cases with congregation exposure. The change in RR among household contacts of the symptomatic primary case was several folds higher as compared to household contacts of the asymptomatic primary case (Table 5).

Discussion:

Our study showed an increase in disease transmission among household contacts than community contacts. The transmission was further accentuated if the primary case had symptoms or exposure to a congregation. The high risk of infection among family members was consistent with the pooled analysis of 43 studies which estimated an SAR of 18% among household contacts[19]. Other systematic reviews demonstrated a secondary attack rate of 16.6%[20] and 27%[21] compared to our study. This may probably due to the timeline of our study in early part of the pandemic. We also observed very low SAR (1%) among non-household contacts, possibly due to the State's lockdown situation during the study period. Contact tracing is one of the core public health strategies for COVID-19 control, and our study assessed if districts implemented this strategy. Although the median number of contacts per case was 17, there was a high variation between districts due to limiting the contact tracing to only household contacts in several cases. A study in the UK measuring the efficacy of contact tracing for COVID-19 suggested an average of 36 contacts must be traced per case[22]. Another study in the Republic of Korea shows a range of 15-649 contacts traced per case[23]. Once the number of cases increases, extensive contact tracing may not be feasible unless we deploy dedicated human resources and train the contact tracers. There was limited capacity in the initial phase of the epidemic; however, the public health department added human resources, especially in the capital city of Chennai, to sustain the contact tracing as cases started increasing.

We observed a higher attack rate among household contacts (25%) of symptomatic primary cases when compared to asymptomatic. Our observations were similar to a pooled analysis of three studies from Wei et al.[24], Part et al.[25], Chaw et al.[26], which reported 20% SAR among household contacts of symptomatic primary cases[27]. This observation guided the testing policy in the context of limited resources at the peak of the pandemic. We prioritised the testing of household contacts of symptomatic primary cases in the subsequent phases of pandemic at times of resource

constraints. Although the attack rate was lower among contacts of asymptomatic primary, the transmission did take place especially in the household setting. Our findings support the rationale of isolation of all cases irrespective of the symptoms and testing of all household contacts to break the chain of transmission[28].

The congregation clusters were one of the sources which led to COVID-19 transmission in various communities[29]. Similar to our setting, many countries experienced clusters emerging from congregation settings. In South Korea, an explosive outbreak happened following a social event held at a Church and is attributable to 84% of the total confirmed cases of South Korea reported till mid-March[30]. Another study in Jordan among the wedding attendees reported a higher attack rate of 22%[31]. Similar clusters had been reported in different parts of South Korea[32] , and in the USA, a secondary attack of 53.3% was estimated among one such event attendees[33]. In addition to the effect of disease spread within the cluster, the attendees returned from the congregation involved themselves in the routine duties and social activities, which led to further spread of the disease in the community. Avoiding any type of gathering is one of the essential mitigation measures to be followed strictly. Government actions to ban mass gatherings are essential, as are good diagnostic facilities and remotely accesses health advice, together with specialised treatment for people with severe disease[34].

Our study has several limitations. We did not have confirmation of the COVID-19 status of 11% of the contacts, who were mostly community contacts. Hence, this may have over-estimated the overall secondary attack rate by 0.3%. Contact tracing was prioritised for household contacts due to restricted mobility and limited interactions at the community level. Therefore, secondary attack among non-household contacts may not reflect the real transmission potential. Information regarding symptoms was retrieved from district surveillance records. The symptom status was collected at the time of diagnosis. We could not verify if the primary case developed symptoms later in the course of illness. Hence, there was a chance of misclassification of symptom status.

We conclude that COVID-19 transmission was higher among household contacts, contacts of symptomatic primary case, and contacts of primary cases exposed to the congregation. Based on the findings, we informed the testing policy and contact tracing strategy in the early stages of the COVID-19 epidemic in Tamil Nadu. We

recommend testing all household contacts irrespective of the symptoms and extensive contact tracing and testing in case of super spreader events. In resource-constrained settings, all contacts of symptomatic primary cases should be prioritised for testing. The gatherings should be restricted to prevent significant clusters.

Author Contributions: KK, RMK, MP, and PK designed the study, supervised fieldwork, did primary data collection, planned data analysis and wrote the first draft of the manuscript. VV, PRK, MS, PS, PG and MSK did primary data collection and did data analysis. SM, VV, IS, and KI supervised fieldwork and data management. JM, RG, SS, SR, SKST, VM, MT, JK, VG, and SK supervised fieldwork and supported data collection. PV, YN, SP, STS, MR, BR and MM conceptualised the study and gave critical comments in finalising the manuscript. All authors approved the final manuscript

Funding:

This work was supported by ICMR-National Institute of Chennai intramural funds.

Award/Grant number: Not applicable

Competing interests: None declared

Patient consent for publication: Not required

Ethics approval: Institutional Ethics Committee of ICMR-National Institute of Epidemiology, Chennai, approved the study. Written consent was not required for this study

Provenance and peer review: Not commissioned; externally peer-reviewed.

Data availability statement: Data are available upon reasonable request

Trial registration: Not applicable

Figure 1: Map of Tamil Nadu included in the epidemiological study of COVID-19

Table 1: Frequency of contacts traced per COVID-19 primary case by district, Tamil Nadu, India, March-May, 2020

District	Days since reporting of the first case in the district	# Primary Cases	Frequency of contacts				No. of contacts tested	No of contacts tested positive	SAR
			# Contacts identified	Household contacts	Community Contacts	Median (Range) contacts per Primary case			
Chennai	51	530	9731	1795	7936	18 (1 to151)	9724	261	3 (2.4-3.0)
Coimbatore	33	151	3257	570	2687	22 (1 to 274)	1585	151	10(8.2-11.1)
Erode	46	56	1032	246	786	18 (3 to 141)	1032	38	4 (2.7-5.0)
Karur	15	42	416	271	145	10 (1 to 86)	416	18	4(2.8-6.7)
Ranipet	25	29	273	153	120	9 (1 to 68)	273	11	4(2.3-7.1)
Tirunelveli	23	35	166	157	9	5 (1 to 21)	145	20	14(9.1-20.0)
Tirupathur	20	12	312	61	251	26 (1 to 100)	312	5	2(0.7-3.7)
Tiruppur	24	66	279	241	38	5 (1 to 10)	279	80	29(23.7-34.0)
Vellore	23	10	236	51	185	24 (6 to 79)	236	15	6(3.9-10.0)
Overall		931	15,702	3545	12157	17(5 to 26)	14002	599	4(4.0-4.6)

Table 2: Secondary Attack Rate (%) by selected characteristics among the contacts traced per COVID-19 primary case, Tamil Nadu, India, March- May 2020

Selected characteristics		Number of contacts (%)	# COVID-19 Positive	Secondary attack rate % (95% CI)
Overall		**14002(100%)**	**599**	**4 (4.0-4.6)**
Age in Years (N=13,379)	≤20	3203 (24%)	138	4 (3.7-5.1)
	21-40	5511 (41%)	237	4(3.8-4.9)
	41-59	3364 (25%)	155	5(4.0-5.4)
	60+	1301 (10%)	65	5 (4.0-6.4)
Gender (N=13,969)	Male	7443 (53%)	280	4 (3.4-4.2)
	Female	6526 (47%)	318	5 (4.4-5.4)
Congregation exposure of primary case (N=14,002)	Yes	3884 (28%)	377	10 (8.8-10.7)
	No	10,118 (72%)	222	2 (1.9-2.5)
Contact type (N=14,002)	Household	3474 (25%)	464	13 (12.3-14.5)
	Community	10,417 (74%)	135	1 (1.0 – 1.5)
	Healthcare personnel	111 (1%)	0	0
Symptom status of Primary case (N=13338)	Symptomatic	607(5%)	37	6 (4.5-8.3)
	Asymptomatic	12,731(95%)	464	4 (3.3-4.0)

Table 3: Secondary Attack Rate among household and non-household contacts of COVID-19 individuals by type of exposure and symptom status of primary cases, Tamil Nadu, March-May, 2020 (N=14002)

Type of exposure or symptom status of the primary case	The secondary attack rate (%) (95% CI) (# cases / # contacts of the case)		
	Household	Community contacts	Overall
N = 14,002	**21 (19.0 – 22.9)**	**1 (0.6-1.5)**	**10 (8.8-10.7)**
Congregation	*(352/1686)*	*(25/2198)*	*(377/3884)*
No congregation	**6 (5.2-7.5)**	**1 (1.0-1.6)**	**2 (1.9-2.5)**
	(112/1788)	*(110/8330)*	*(222/10118)*
N= 13,338	**25 (17.6-34.1)**	**2 (1.2-3.9)**	**6 (4.5-8.3)**
Symptomatic	(26/104)	(11/503)	(37/607)
Asymptomatic	**12 (10.5-12.9)**	**1 (1.0-1.5)**	**4 (3.3-4)**
	(341/2930)	(123/9801)	(464/12731)

Table 4: Factors associated with COVID-19 among the contacts of Tamil Nadu, India March – May 2020

Risk factors	Crude RR (95% CI)	RR with age-adjusted (95% CI)	RR with age and sex-adjusted (95% CI)
Community contacts of non-congregation Primary cases	Ref	Ref	Ref
Community contact of Congregation Primary cases	1.0 (0.7-1.5)	0.9 (0.6-1.4)	0.9 (0.6-1.4)
Household contacts of non-congregation Primary cases	4.9 (3.8-6.4)	4.7 (3.7 – 6.2)	4.7 (36.4-6.1)
Household contacts of Congregation Primary cases	16.4 (13.3–20.2)	16.2 (13.1-20.0)	16.1 (13.0-20.0)

Table 5: Factors associated with COVID-19 among the contacts stratified by the symptomatic status of the primary cases of Tamil Nadu, India March – May 2020

Symptomatic Primary	Type of contacts	Crude RR (95% CI)	Adjusted RR with Age and Sex (95% CI)
Yes	Community contacts of non-congregation Primary cases	Ref	Ref
	Community contact of Congregation Primary cases	10.5 (6.0-33.0)	8.6 (2.6 – 29.1)
	Household contacts of non-congregation Primary cases	15.5 (6.0-39.8)	14.6 (5.7 – 37.7)
	Household contacts of Congregation Primary cases	26.7 (10.8-65.9)	25.3 (10.2 – 63.0)
No	Community contacts of non-congregation Primary cases	Ref	Ref
	Community contact of Congregation Primary cases	0.9 (0.6-1.4)	0.9 (0.5 – 1.3)
	Household contacts of non-congregation Primary cases	4.6 (3.5-6.0)	4.4 (3.4 – 5. 8)
	Household contacts of Congregation Primary cases	16.48 (13.17-20.63)	16.52 (13.16 – 20.74)

Reference:

[1] World Health Organization. Statement on the second meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV). https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov) (2020).

[2] WHO; Coronavirus disease (COVID-19): Contact tracing 2020 [Available from: https://www.who.int/news-room/q-a-detail/coronavirus-disease-covid-19-contact-tracing.

[3] Halloran ME. Secondary Attack Rate. In: Peter A, Theodore C, editors. Encyclopedia of Biostatistics. New York: John Wiley & Sons Ltd; 2005

[4] Li W, Zhang B, Lu J, Liu S, Chang Z, Cao P, et al. The characteristics of household transmission of COVID-19. Clinical Infectious Diseases. 2020.

[5] Liu Y, Eggo RM, Kucharski AJ. Secondary attack rate and superspreading events for SARS-CoV-2. The Lancet. 2020 Mar 14;395(10227):e47

[6] Luo L, Liu D, Liao X, Wu X, Jing Q, Zheng J, Liu F, Yang S, Bi H, Li Z, Liu J. Contact settings and risk for transmission in 3410 close contacts of patients with COVID-19 in Guangzhou, China: a prospective cohort study. Annals of internal medicine. 2020 Aug 13

[7] Yang J, Zheng Y, Gou X, Pu K, Chen Z, Guo Q, et al. Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. International Journal of Infectious Diseases. 2020; 94:91-5

[8] Cheng HY, Jian SW, Liu DP, Ng TC, Huang WT, Lin HH. High transmissibility of COVID-19 near symptom onset. medRxiv. 2020 Jan 1

[9] Wilder-Smith A, Chiew CJ, Lee VJ. Can we contain the COVID-19 outbreak with the same measures as for SARS?. The Lancet Infectious Diseases. 2020 Mar 5

[10] Jahan N, Rubeshkumar P, Karuppiah M, Sambath I, Sendhilkumar M, Ilangovan K, et al. Entry and initial spread of COVID-19 in India: Epidemiological analysis of media surveillance data, India, 2020. Clinical Epidemiology and Global Health. 2020.

[11] MediaBulletin180320COVID19.pdf [Internet]. [cited 2020 May 31]. Available from: https://stopcorona.tn.gov.in/wp-content/uploads/files/MediaBulletin180320COVID19.pdf

[12] Ali, A. (2020, April 1). Coronavirus was a test of secular nationalism. Then Tablighi Jamaat became the scapegoat. *The Print*. https://theprint.in/opinion/coronavirus-test-of-secular-nationalism-tablighi-jamaat-became-scapegoat/392764/

[13] Gathering at Nizamuddin a highly irresponsible act, says Kejriwal. (2020, March 31). *The Hindu*. https://www.thehindu.com/news/cities/Delhi/gathering-at-nizamuddin-a-highly-irresponsible-act-says-kejriwal/article31221982.ece

[14] Chandna, H. (2020, April 18). 30% of India's Covid-19 positive caseload linked to Tablighi Jamaat meet, says govt. *The Print*. https://theprint.in/health/30-of-indias-covid-19-positive-caseload-linked-to-tablighi-jamaat-meet-says-govt/404426/

[15] Of 14,378 total Covid-19 cases in India, 4,291 linked to Delhi's Markaz event: Health ministry. (2020, April 18). *India Today*. https://www.indiatoday.in/india/story/coronavirus-india-total-cases-linked-tablighi-jamaat-markaz-nizamuddin-event-health-ministry-1668456-2020-04-18

[16] NDTV. 1,023 COVID-19 Cases Linked To Mosque Event, Tamil Nadu Leads: 10 Points: NDTV; [Available from: https://www.ndtv.com/india-news/coronavirus-tablighi-jamaat-1-023-of-2-902-covid-19-cases-linked-to-mosque-event-tamil-nadu-leads-2206193

[17] National Centre for Disease Control Directorate General of Health Services MoH&FW, GOI, New Delhi The updated case definitions and contact-categorisation [internet]. [citied 2020 Jun 2]. Available from https://nirth.res.in/virology/Revised_case_definitions_for_COVID_19.pdf

[18] Guidelines for investigating clusters of health events. MMWR Recomm Rep. 1990 Jul 27;39(RR-11):1-23. PMID: 2117247. .

[19] Koh WC, Naing L, Chaw L, Rosledzana MA, Alikhan MF, et al. (2020) What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLOS ONE 15(10): e0240205. https://doi.org/10.1371/journal.pone.0240205

[20] Madewell ZJ, Yang Y, Longini IM Jr, Halloran ME, Dean NE. Household Transmission of SARS-CoV-2: A Systematic Review and Meta-analysis. JAMA Netw Open. 2020 Dec 1;3(12):e2031756. doi: 10.1001/jamanetworkopen.2020.31756. PMID: 33315116; PMCID: PMC7737089.

[21] Lei H, Xu X, Xiao S, Wu X, Shu Y. Household transmission of COVID-19-a systematic review and meta-analysis. *J Infect*. 2020;81(6):979-997. doi:10.1016/j.jinf.2020.08.033

[22] Keeling MJ, Hollingsworth TD, Read JM. The Efficacy of Contact Tracing for the Containment of the 2019 Novel Coronavirus (COVID-19). medRxiv. 2020.

[23] COVID-19 National Emergency Response Center Epidemiology and case management team, Korea Centers for disease Control and prevention. Coronavirus disease-19: summary of 2,370 contact investigations of the first 30 cases in the Republic of Korea. Public Health Res Perspect. 2020;11(2):81–84. doi: 10.24171/j.phrp.2020.11.2.04

[24] Wei L, Lv Q, Wen Y, Feng S, Gao W, Chen Z, Cao B, Wu X, Lu Y, Zhao J, Zou X. Household transmission of COVID-19, Shenzhen, January-February 2020. medRxiv. 2020 Jan 1

[25] Park SY, Kim YM, Yi S, Lee S, Na BJ, Kim CB, Kim JI, Kim HS, Kim YB, Park Y, Huh IS. Coronavirus disease outbreak in call center, South Korea. Emerging infectious diseases. 2020 Aug;26(8):1666.

[26] Chaw, L., Koh, W., Jamaludin, S., Naing, L., Alikhan, M., & Wong, J. (2020). Analysis of SARS-CoV-2 Transmission in Different Settings, Brunei. *Emerging Infectious Diseases*, *26*(11), 2598-2606. https://dx.doi.org/10.3201/eid2611.202263

[27] Koh WC, Naing L, Chaw L, Rosledzana MA, Alikhan MF, et al. (2020) What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLOS ONE 15(10): e0240205. https://doi.org/10.1371/journal.pone.0240205

[28] MOHFW. Revised guidelines for Home Isolation of very mild/pre-symptomatic/asymptomatic COVID-19 cases. MOHFW 2020 July 2 [Available from RevisedHomeIsolationGuidelines.pdf (mohfw.gov.in)]

[29] Quadri SA. COVID-19 and religious congregations: Implications for spread of novel pathogens. International Journal of Infectious Diseases. 2020 Jul 1;96:219-21.

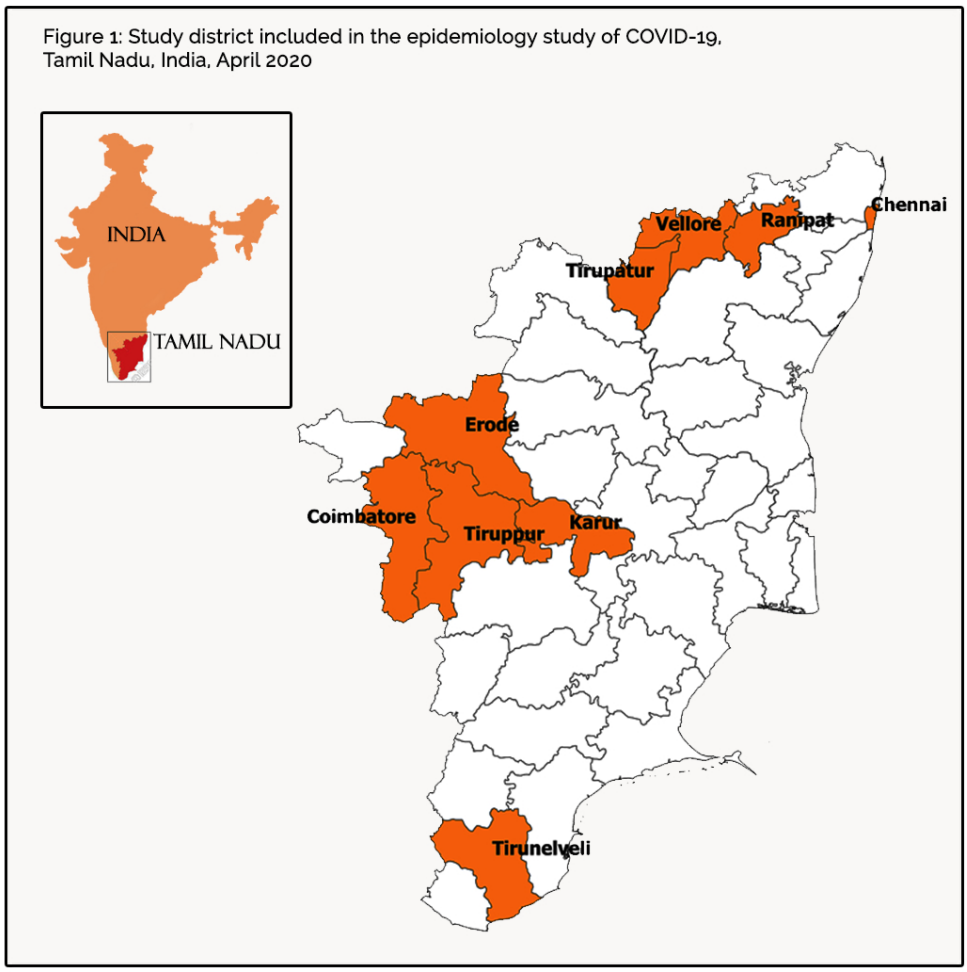
[30] Choi JY. COVID-19 in South Korea. Postgraduate Medical Journal. 2020;96(1137):399-402.

[31] Yusef D, Hayajneh W, Awad S, Momany S, Khassawneh B, Samrah S, Obeidat B, Raffee L, Al-Faouri I, Issa AB, Al Zamel H. Large outbreak of coronavirus disease among wedding attendees, Jordan. Emerging infectious diseases. 2020 Sep;26(9):2165.

[32] Shim E, Tariq A, Choi W, Lee Y, Chowell G. Transmission potential and severity of COVID-19 in South Korea. International Journal of Infectious Diseases. 2020;93:339-44.

[33] Hamner L, Dubbel P, Capron I, Ross A, Jordan A, Lee J, et al. High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice - Skagit County, Washington, March 2020. MMWR Morbidity and mortality weekly report. 2020;69(19):606-10

[34] The Times of India; Avoid mass gatherings, says govt as corona cases hit 31: [Available from: http://timesofindia.indiatimes.com/articleshow/74520610.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst]



Map of Tamil Nadu included in the epidemiological study of COVID-19. There are nine of the 38 districts included in the study.

90x90mm (300 x 300 DPI)

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohortreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1

Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	4
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnosti4c criteria, if applicable	5
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is	5

		more than one group. Give information separately for for exposed and unexposed groups if applicable.	
Bias	#9	Describe any efforts to address potential sources of bias	n/a
Study size	#10	Explain how the study size was arrived at	4
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	5
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	n/a
Statistical methods	#12c	Explain how missing data were addressed	n/a
Statistical methods	#12d	If applicable, explain how loss to follow-up was addressed	n/a
Statistical methods	#12e	Describe any sensitivity analyses	n/a
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-	5

		up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	n/a
Participants	#13c	Consider use of a flow diagram	n/a
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	5
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	5
Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	6
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6
Main results	#16b	Report category boundaries when continuous variables were categorized	n/a
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a

Other analyses	#17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6
Discussion			
Key results	#18	Summarise key results with reference to study objectives	7
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	8
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	8
Generalisability	#21	Discuss the generalisability (external validity) of the study results	n/a
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10

BMJ Open

Secondary attack rate of COVID-19 among contacts and risk factors, Tamil Nadu, March-May 2020: A retrospective Cohort Study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-051491.R2
Article Type:	Original research
Date Submitted by the Author:	13-Oct-2021
Complete List of Authors:	Karumanagoundar, Kolandaswamy; Directorate of Public Health and Preventive Medicine Raju, Mohankumar; National Institute of Epidemiology Ponnaiah, Manickam; National Institute of Epidemiology Kaur, P; National Institute of Epidemiology viswanathan, Vidhya; National Institute of Epidemiology Rubeshkumar, Polani; National Institute of Epidemiology Sakthivel, Manikandanesan; National Institute of Epidemiology Shanmugiah, Porchelvan; National Institute of Epidemiology Ganeshkumar, Parasuraman; National Institute of Epidemiology Muthusamy, Santhosh Kumar ; National Institute of Epidemiology Sendhilkumar, Muthappan ; National Institute of Epidemiology Venkatasamy, Vettrichelvan; National Institute of Epidemiology Sambath, Irene; National Institute of Epidemiology Ilangovan, Kumaravel; National Institute of Epidemiology M, Jagadeesan; Greater Chennai Corporation Govindarajan, Rameshkumar; Directorate of Public Health and Preventive Medicine Shanmugam, Soundammal; Directorate of Public Health and Preventive Medicine Rajarathinam, Selvakumar; Directorate of Public Health and Preventive Medicine Suresh, KST; Directorate of Public Health and Preventive Medicine Varadharajan, M; Directorate of Public Health and Preventive Medicine Thiagarajan, Manivannan; Directorate of Public Health and Preventive Medicine Jagadeeshkumar, K; Directorate of Public Health and Preventive Medicine Ganesh, Velmurugan; Directorate of Public Health and Preventive Medicine Kumar, Sateesh; Directorate of Public Health and Preventive Medicine Venkatesan, Prakash; Directorate of Public Health and Preventive Medicine Nallathambi, Yogananth; Directorate of Public Health and Preventive Medicine Palani, Sampath; Directorate of Public Health and Preventive Medicine Selvavinayagam, TS; Directorate of Public Health and Preventive Medicine Reddy, Madhusudhan; Greater Chennai Corporation Rajesh, Beela; Government of Tamil Nadu, Health and Family Welfare

	Department Murhekar, Manoj; National Institute of Epidemiology
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	COVID-19, Epidemiology < INFECTIOUS DISEASES, Infection control < INFECTIOUS DISEASES, Public health < INFECTIOUS DISEASES

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Secondary attack rate of COVID-19 among contacts and risk factors, Tamil Nadu, March-May 2020: A retrospective Cohort Study

Kolandaswamy Karumanagoundar[1], Raju Mohankumar[2*], Manickam Ponnaiah[2], Prabhdeep Kaur[2], Vidhya viswanathan[2], Polani Rubeshkumar[2], Manikandanesan Sakthivel[2], Porchelvan Shanmugiah[1,2], Parasuraman Ganeshkumar[2], Muthusamy Santhosh kumar[2], Muthappan Sendhilkumar[2], Vettrichelvan Venkatasamy[2], Irene Sambath[2], Kumaravel Ilangovan[2], Jagadeesan M[3], Rameshkumar Govindarajan[1], Soundammal Shanmugam[1], Selvakumar Rajarathinam[1], Suresh KST[1], Varadharajan M[1], Manivannan Thiagarajan[1], Jagadeeshkumar K[1], Velmurugan Ganesh[1], Sateesh Kumar[1], Prakash Venkatesan[1], Yogananth Nallathambi[1], Sampath Palani[1], Selvavinayagam TS[1], Madhusudhan Reddy[3], Beela Rajesh[4], Manoj Murhekar[2]

[1]Directorate of Public Health and Preventive Medicine, Tamil Nadu

[2]ICMR National Institute of Epidemiology, Chennai

[3]Greater Chennai Corporation, Chennai

[4]Health and Family Welfare Department, Government of Tamil Nadu

*Corresponding author:

Dr Raju Mohankumar, Consultant, ICMR-National Institute of Epidemiology, TNHB, Ayappakam, Chennai, India, PIN- 600077. Email: mohankumar@nieicmr.org.in, Phone: +914426136333

Word count: 4389

Keywords: Secondary Attack Rate, COVID-19, Contact investigation, Disease transmission, Cluster

Abstract:

Objective: To describe the characteristics of contacts of COVID-19 case-patients in terms of time, place, and person, to calculate the secondary attack rate and factors associated with COVID-19 infection among contacts

Design: Retrospective cohort study

Setting and participants: Contacts of cases identified by the health department from March 14 to May 30, 2020, in nine of 38 administrative districts of Tamil Nadu. Significant proportion of cases attended a religious congregation.

Outcome measure: Attack rate among the contacts and factors associated with COVID-19 positivity.

Results: We listed 15,702 contacts of 931 primary cases. Of the contacts, 89% (n=14002) were tested for COVID-19. The overall SAR was 4% (599/14002), with higher among the household contacts (13%) than the community contacts (1%). SAR among the contacts of primary cases with congregation exposure were five times higher than the contacts of non-congregation primary cases (10% Vs 2%). Being a household contact of a primary case with congregation exposure had a four-fold increased risk of getting COVID-19 (RR=16.4; 95%CI:13-20) than contact of primary case without congregation exposure. Among the symptomatic primary cases, household contacts of congregation primaries had higher RR than household contacts of other cases [(RR=25.3; 95%CI:10.2-63) Vs (RR=14.6; 95%CI:5.7-37.7)]. Among asymptomatic primary case, RR was increased among household contacts (RR=16.5; 95%CI:13.2–20.7) of congregation primaries compared to others

Conclusion: Our study showed an increase in disease transmission among household contacts than community contacts. Also, symptomatic primary cases and primary cases with exposure to the congregation had more secondary cases than others.

Strengths and Limitations:

- **Strengths**
  - We documented the secondary attack rate of COVID-19 in a large cohort of more than 15,000 contacts in India
  - All the contacts were tested with RT-PCR; therefore, the estimates of secondary attack rate were reliable.
  - The state updated the testing poliy in the early phase of this pandemic based on the findings from this study.
- **Limitations:**
  - We did not have confirmation of the COVID-19 status of 11% of the contacts
  - Contact tracing was prioritised for household contacts during lockdown as the community interactions were limited

Background

The novel coronavirus outbreak due to Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) infection reported from China in December 2019 was declared a Public Health Emergency of International Concern (PHEIC) by WHO on January 30, 2020[1]. At the early stages of COVID-19, international travel was the most common exposure. Subsequently, clusters emerged in various settings, including community gatherings, hospital settings, and commercial gatherings. Investigating such clusters provided clues for disease transmission and guided intervention strategies for pandemic response[2]. Contact tracing is one of the key strategies to interrupt the chain of transmission of SARS-CoV-2. The aim of the contact tracing strategy is to reduce secondary cases of COVID-19. In this context, the secondary attack rate of SARS-CoV-2 denotes the probability that infection occurs among susceptible contacts within a reasonable incubation period following contact with the infectious person(s) or that of the source[3] and represents infectiousness of the agent. The secondary attack rate among contacts thus is a useful indicator to track the viral transmission potential[4] and thereby guides control strategies. The secondary attack rate of SARS-CoV-2 differs from the nature of the setting and that of the symptomatic status of the primary cases.[5 6 7 8] Understanding the dynamics of transmission of COVID-19 for specific settings will help in preventing the spread of the infection[9].

India reported the first laboratory-confirmed case on January 30, 2020, from a Southern state Kerala. In early March, most reported cases had a history of international travel or contact with the traveller[10]. Tamil Nadu, the southern State of India, reported the first case of COVID-19 on March 18 2020[11]. At the initial stages, COVID-19 cases were reported among international travellers and subsequently among travellers from other states. On March 13, the media reported a cluster of cases linked to a religious congregation in New Delhi.[12 13] According to the reports, the event started on February 9, 2020, with more than 4000 participants from various Indian states and abroad gathered in groups to attend the meeting.[14] As the participants returned to their respective states, clusters emerged in several states. [15] People from Tamil Nadu also participated in the meeting, predominantly during 21-23 March, 2020[16]. After returning from the event, attendees travelled to many parts

of the State. Public health authorities initiated a massive search for potential cases and their contact in various districts.

From February 2020, the health department of Tamil Nadu state practised testing and quarantine of international travellers and enhanced the voluntary testing of symptomatic individuals with h/o travel or h/o contact with a traveller. When the congregation cluster was reported, all the persons who attended the congregation were traced, quarantined and tested. The persons tested for COVID-19 were isolated and treated. The persons who tested negative were quarantined for 14 days. Also, the COVID-19 test was repeated after 5th day of the first testing. The household members of the attendees were immediately tested for COVID-19, if any person is tested positive.

After the information of COVID outbreak in the Delhi congregation setting, Govt of Tamil Nadu collected the line list of participants from the appropriate authority involved in the outbreak control in the congregation. The district collected additional information from the local leaders.

At the time this investigation was undertaken, there was no wide spread community transmission. Most of the infection were among travelers and health care workers, and they did not mingle with the community due to restrictions. Unlike international travelers, congregation participants travelled with other local travelers and after attending the congregation, all resumed social and work-related activities after arrival. Therefore, they are more likely to transmit to the community.

Due to the novelty of the pandemic, the transmission dynamics of the diseases were not fully understood. In the early phase, knowledge on the spread of the disease in various settings and in different geographical was not known. Also, the contribution of the congregation cluster in driving the pandemic is not known. Knowing this information was crucial in preventing the disease's spread from the primary case to the contacts. In this context, we conducted a study to estimate the secondary attack rate in terms of time, place, and person and determined risk factors for COVID-19 infection among contacts during March-May 2020 in Tamil Nadu, India.

Methods:

Study design

We conducted a retrospective cohort study of all contacts of COVID-19 cases between March 14 to May 30, 2020, of Tamil Nadu, Southern India.

Study setting and the COVID-19 context:

We studied nine of 38 administrative districts reporting maximum cases during the study period (Figure 1). These nine districts reported higher number of cases during the study period. The study districts varied in a population density ranging from 28,553 persons per square Kilometre in the State capital city of Chennai to 367 in Erode district, located southwest of Chennai. The average family size was similar (3.5 to 4.3 persons per family) across these study districts.

The COVID-19 response strategies implemented by the State included surveillance for case identification, confirmation with Reverse Transcriptase-Polymerase Chain Reaction (RT-PCR) test for COVID-19, contact tracing, isolation, and quarantine, in addition to community-based interventions. The confirmation with RT-PCR was done by identifying two or more target genes (E / RdRp / ORF1ab / N / S) using multiplex PCR kits The district officials hospitalised the COVID-19 patients, and quarantined COVID-19 tested negatives at home or facility. By contact tracing, the officials identified the household and the community contacts and tested them for COVID-19. We included all COVID-19 confirmed cases in the study period from these districts.

Sampling and sample size

We listed all the identified confirmed COVID-19 cases in the study districts from March 1 to May 30, 2020. We included all the contacts of the identified COVID-19 positive individuals.

Operational definitions:

Primary case: Any individual with a laboratory-confirmed COVID-19 case with no reported history of contact with COVID-19 case

Symptomatic Cases: Any individual with H/O Fever, cough, Sore throat or breathlessness from 5 days before the date of testingConfirmed Case: Any individual who is tested positive for COVID-19 using RT-PCR

Contact: Any individual comes in proximity with COVID-19 positive individuals[17]. High risk contacts is defined as any person who was in proximity with COVID-19

positive individual within 2 metres of proximity for 15 minutes. Low risk contact is defined as any person who was in proximity with COVID-19 positive individual and sharing same environment but not having high exposure.

Household contact: Any individual living in the same household and comes in proximity with the COVID-19 confirmed individual

Community contact: Any individual other than living in the same household and comes in proximity with the COVID-19 confirmed individual

Cluster: An unusual aggregation of two are more COVID-19 cases grouped in time and space and reported to a health agency[18]

Congregation exposure: Individual wo have attended the religious congregation event held during February and March 2020 (News paper reference)

Secondary attack rate: The secondary attack rate is the proportion of COVID-19 positive individuals among the tested contacts.

Data collection and analysis:

We collected data from district surveillance records and classified the contacts as household and community contacts. We abstracted the information on sociodemographic characteristics, residence location, symptom status and congregation exposure of the primary case from the district surveillance records.

The analysis is based on the information from nine identified districts. We described the total number of contacts and the median number of contacts per case by the district. We calculated the overall secondary attack rate (SAR) for COVID-19 and by age, gender, symptom status and congregation exposure of the primary case. We estimated the SAR by symptom status and congregation exposure of the primary case in two subgroups, namely household and community contacts. We determined the risk factors associated with COVID-19 infection among contacts based on the household vs community exposure, congregation vs non-congregation exposure of primary case and symptom status of the primary case. We estimated the unadjusted and age/sex-adjusted relative risk (RR) and 95% confidence intervals (CI) for the four categories of contacts. The community contacts of the non-congregation primary case were the reference category. The other categories were community contacts of

congregation primary, household contacts of non-congregation and household contacts of congregation primary cases. We also estimated the unadjusted and age/sex-adjusted RR and 95% CI after stratifying the four categories by symptom status of the primary case.

Human participation protection:

We obtained the approval of the Institutional Ethics Committee of the ICMR-National Institute of Epidemiology. No primary information was collected from the participants. We maintained complete confidentiality and anonymity of the participants during data abstraction.

Patient and Public Involvement in research: Not involved in the conduct of research

Results:

Description of the cases and contacts

We identified 931 COVID-19 primary cases and 15,702 contacts during the study period. The median number of contacts identified per COVID-19 case was 17 (IQR: 9, 18) in the selected nine districts. Around 11% (n=102) of the cases did not have household contacts. The duration from the reporting of the first COVID-19 case to the time of data abstraction ranged from 51 days for Chennai and 15 days for Karur district. (Table 1). This is because the reporting of the first case varies across the districts and the data collection was done in the same period across these districts and hence the duration of the data collection period varies.

Of the identified 15,702 contacts, 14,002 (89%) contacts were tested for COVID-19. Apart from household contacts, most community contacts (98%) were cab-drivers, vegetable sellers, co-workers, or co-passengers in public transport. The majority of the household contacts (99%) were tested. There is no difference between tested and not-tested by age and gender (data not shown).

Information on age was available for 99.7% (13,969/14,002) of the contacts (Table 2). The contacts were predominantly aged 21-40 years (41%) and 41 to 59 years (27%). Over half of the contacts were males (53%). About one-fourth (28%) of the contacts were traced from primary cases with congregation exposure, and 25% of

the contacts had household COVID-19 exposure. Healthcare providers contributed to less than 1% of the contacts identified for the primary cases.

Secondary attack rate by selected characteristics

Among tested contacts (n=14002), 599 (4.3%) tested positive for COVID-19 based on RT PCR. The overall secondary attack rate was 4% (599 of 14,002). The secondary attack rate was similar across the age groups and gender, ranging from 4% to 5%. The secondary attack rate among the contacts of primary cases with congregation exposure was five times higher (10%) than contacts of non-congregation primary cases (2%). Of the 599 contacts who tested positive, more than three-fourths (78%) were household contacts.

The overall secondary attack rate was 4%, with 13% among the household contacts compared to 1% among the community contacts. The secondary attack among household contacts of primary cases with exposure to congregation was higher (21%) than the contacts of primary cases without congregation exposure (6%) (Table 3). The primary cases' symptomatic status was available for 95% (13,338) of the tested contacts. The overall secondary attack among contacts of the primary cases with COVID -19 symptoms was 6% compared to 4% among the contacts of asymptomatic cases. The household contacts exposed to the symptomatic primary case had two times higher attack rate as compared to contacts of asymptomatic primary cases (25% vs 12%). Secondary attack among the community contacts was similar irrespective of the symptomatic status of the primary case.

Risk factors for secondary cases

We estimated the risk of acquiring infection for contacts by type of contact and congregation participation of the primary cases. There was no significant risk among the community contacts of the primary cases irrespective of the participation in the congregation. The relative risk of household contacts of primary cases with congregation participation was four times higher (RR=16.4; 95% CI: 13.3 to 20.2) in getting COVID-19 compared to household contacts of other primary cases (RR=4.9; 95% CI: 3.81 to 6.38). The association did not change even after adjusting for age and gender. (Table 4)

We estimated the RR stratified by the symptomatic status of the primary cases. In the strata where the primary case was symptomatic, there was an eight-fold increase

in RR for household contacts of congregation participants when compared to the household contacts of other cases [RR=25.3,95% CI: 10.2 to 63) vs RR= 14.6, 95% CI: 5.7 to 37.7)]. If the primary case was asymptomatic, there was no increase in RR for community contacts of congregation participants, but RR was increased among household contacts of primary cases with congregation exposure. The change in RR among household contacts of the symptomatic primary case was several folds higher as compared to household contacts of the asymptomatic primary case (Table 5).

Discussion:

Our study showed an increase in disease transmission among household contacts than community contacts. The transmission was further accentuated if the primary case had symptoms or exposure to a congregation. The high risk of infection among family members was consistent with the pooled analysis of 43 studies which estimated an SAR of 18% among household contacts[19]. Other systematic reviews demonstrated a secondary attack rate of 16.6%[20] and 27%[21] compared to our study. This may probably due to the timeline of our study in early part of the pandemic. We also observed very low SAR (1%) among non-household contacts, possibly due to the State's lockdown situation during the study period. Contact tracing is one of the core public health strategies for COVID-19 control, and our study assessed if districts implemented this strategy. Although the median number of contacts per case was 17, there was a high variation between districts due to limiting the contact tracing to only household contacts in several cases. A study in the UK measuring the efficacy of contact tracing for COVID-19 suggested an average of 36 contacts must be traced per case[22]. Another study in the Republic of Korea shows a range of 15-649 contacts traced per case[23]. Once the number of cases increases, extensive contact tracing may not be feasible unless we deploy dedicated human resources and train the contact tracers. There was limited capacity in the initial phase of the epidemic; however, the public health department added human resources, especially in the capital city of Chennai, to sustain the contact tracing as cases started increasing.

Initially, testing was done among the individuals reported with symptoms. But due to the clustering of cases among the congregation attendees, all the congregation attendees were tested irrespective of symptom status, as there was lot of panic in

the initial phase of the pandemic. It posed high risk of big outbreak. Similarly, all international travelers were tested irrespective of the symptom status. We observed a higher attack rate among household contacts (25%) of symptomatic primary cases when compared to asymptomatic. Our observations were similar to a pooled analysis of three studies from Wei et al.[24], Part et al.[25], Chaw et al.[26], which reported 20% SAR among household contacts of symptomatic primary cases[27]. This observation guided the testing policy in the context of limited resources at the peak of the pandemic. We prioritised the testing of household contacts of symptomatic primary cases in the subsequent phases of pandemic at times of resource constraints. Although the attack rate was lower among contacts of asymptomatic primary, the transmission did take place especially in the household setting. Our findings support the rationale of isolation of all cases irrespective of the symptoms and testing of all household contacts to break the chain of transmission[28].

At the time when this investigation was undertaken, there was no widespread community transmission. Most of the infection were among international travellers and health care workers, and they were separated from the community, due to isolation and quarantine protocols. Unlike international travellers, congregation participants travelled with local people. After attending the congregation, all resumed their routine work and social activities after arrival. This posed threat to transmit to diseases in the community, as the congregation occurred before the lockdown.

The congregation clusters were one of the sources which led to COVID-19 transmission in various communities[29]. Similar to our setting, many countries experienced clusters emerging from congregation settings. In South Korea, an explosive outbreak happened following a social event held at a Church and is attributable to 84% of the total confirmed cases of South Korea reported till mid-March[30]. Another study in Jordan among the wedding attendees reported a higher attack rate of 22%[31]. Similar clusters had been reported in different parts of South Korea[32] , and in the USA, a secondary attack of 53.3% was estimated among one such event attendees[33]. In addition to the effect of disease spread within the cluster, the attendees returned from the congregation involved themselves in the routine duties and social activities, which led to further spread of the disease in the community. Avoiding any type of gathering is one of the essential mitigation measures to be followed strictly. Government actions to ban mass gatherings are essential, as are good diagnostic facilities and remotely accesses health advice, together with specialised treatment for people with severe disease[34].

Our study has several limitations. We did not have confirmation of the COVID-19 status of 11% of the contacts, who were mostly community contacts. Hence, this may have over-estimated the overall secondary attack rate by 0.3%. Contact tracing was prioritised for household contacts due to restricted mobility and limited interactions at the community level. Therefore, secondary attack among non-household contacts may not reflect the real transmission potential. Information regarding symptoms was retrieved from district surveillance records. The symptom status was collected at the time of diagnosis. We could not verify if the primary case developed symptoms later in the course of illness. Hence, there was a chance of misclassification of symptom status. We abstracted the information from the records of the district surveillance units. The information on the date of exposure and the date of sample taken are not available for all the contacts. Hence we could not calculate the time taken for the contacts to be tested from the date of contact.

We conclude that COVID-19 transmission was higher among household contacts, contacts of symptomatic primary case, and contacts of primary cases exposed to the congregation. Based on the findings, we informed the testing policy and contact tracing strategy in the early stages of the COVID-19 epidemic in Tamil Nadu. We recommend testing all household contacts irrespective of the symptoms and extensive contact tracing and testing in case of super spreader events. In resource-constrained settings, all contacts of symptomatic primary cases should be prioritised for testing. The gatherings should be restricted to prevent significant clusters.

Author Contributions: KK, RMK, MP, and PK designed the study, supervised fieldwork, did primary data collection, planned data analysis and wrote the first draft of the manuscript. VV, PRK, MNS, PS, PG and MSK did primary data collection and did data analysis. MS, VV, IS, and KI supervised fieldwork and data management. JM, RG, SS, SR, SKST, VM, MT, JK, VG, and SK supervised fieldwork and supported data collection. PV, YN, SP, STS, MR, BR and MM conceptualised the study and gave critical comments in finalising the manuscript. All authors approved the final manuscript

Funding:

This work was supported by ICMR-National Institute of Chennai intramural funds.

Award/Grant number: Not applicable

Competing interests: None declared

Patient consent for publication: Not required

Ethics approval: Institutional Ethics Committee of ICMR-National Institute of Epidemiology, Chennai, approved the study. Written consent was not required for this study

Provenance and peer review: Not commissioned; externally peer-reviewed.

Data availability statement: Data are available upon reasonable request

Trial registration: Not applicable

Figure 1: Map of Tamil Nadu included in the epidemiological study of COVID-19

Table 1: Frequency of contacts traced per COVID-19 primary case by district, Tamil Nadu, India, March-May, 2020

District	Days since reporting of the first case in the district	# Primary Cases	Frequency of contacts				No. of contacts tested	No of contacts tested positive	SAR
			# Contacts identified	Household contacts	Community Contacts	Median (Range) contacts per Primary case			
Chennai	51	530	9731	1795	7936	18 (1 to151)	9724	261	3 (2.4-3.0)
Coimbatore	33	151	3257	570	2687	22 (1 to 274)	1585	151	10(8.2-11.1)
Erode	46	56	1032	246	786	18 (3 to 141)	1032	38	4 (2.7-5.0)
Karur	15	42	416	271	145	10 (1 to 86)	416	18	4(2.8-6.7)
Ranipet	25	29	273	153	120	9 (1 to 68)	273	11	4(2.3-7.1)
Tirunelveli	23	35	166	157	9	5 (1 to 21)	145	20	14(9.1-20.0)
Tirupathur	20	12	312	61	251	26 (1 to 100)	312	5	2(0.7-3.7)
Tiruppur	24	66	279	241	38	5 (1 to 10)	279	80	29(23.7-34.0)
Vellore	23	10	236	51	185	24 (6 to 79)	236	15	6(3.9-10.0)
Overall		931	15,702	3545	12157	17(5 to 26)	14002	599	4(4.0-4.6)

Table 2: Secondary Attack Rate (%) by selected characteristics among the contacts traced per COVID-19 primary case, Tamil Nadu, India, March- May 2020

Selected characteristics		Number of contacts (%)	# COVID-19 Positive	Secondary attack rate % (95% CI)
Overall		**14002(100%)**	**599**	**4 (4.0-4.6)**
Age in Years (N=13,379)	≤20	3203 (24%)	138	4 (3.7-5.1)
	21-40	5511 (41%)	237	4(3.8-4.9)
	41-59	3364 (25%)	155	5(4.0-5.4)
	60+	1301 (10%)	65	5 (4.0-6.4)
Gender (N=13,969)	Male	7443 (53%)	280	4 (3.4-4.2)
	Female	6526 (47%)	318	5 (4.4-5.4)
Congregation exposure of primary case (N=14,002)	Yes	3884 (28%)	377	10 (8.8-10.7)
	No	10,118 (72%)	222	2 (1.9-2.5)
Contact type (N=14,002)	Household	3474 (25%)	464	13 (12.3-14.5)
	Community	10,417 (74%)	135	1 (1.0 – 1.5)
	Healthcare personnel	111 (1%)	0	0
Symptom status of Primary case (N=13338)	Symptomatic	607(5%)	37	6 (4.5-8.3)
	Asymptomatic	12,731(95%)	464	4 (3.3-4.0)

Table 3: Secondary Attack Rate among household and non-household contacts of COVID-19 individuals by type of exposure and symptom status of primary cases, Tamil Nadu, March-May, 2020 (N=14002)

Type of exposure or symptom status of the primary case	The secondary attack rate (%) (95% CI) (# cases / # contacts of the case)		
	Household	Community contacts	Overall
N = 14,002	**21 (19.0 – 22.9)**	**1 (0.6-1.5)**	**10 (8.8-10.7)**
Congregation	*(352/1686)*	*(25/2198)*	*(377/3884)*
No congregation	**6 (5.2-7.5)**	**1 (1.0-1.6)**	**2 (1.9-2.5)**
	(112/1788)	*(110/8330)*	*(222/10118)*
N= 13,338	**25 (17.6-34.1)**	**2 (1.2-3.9)**	**6 (4.5-8.3)**
Symptomatic	(26/104)	(11/503)	(37/607)
Asymptomatic	**12 (10.5-12.9)**	**1 (1.0-1.5)**	**4 (3.3-4)**
	(341/2930)	(123/9801)	(464/12731)

Table 4: Factors associated with COVID-19 among the contacts of Tamil Nadu, India March – May 2020

Risk factors	Crude RR (95% CI)	RR with age-adjusted (95% CI)	RR with age and sex-adjusted (95% CI)
Community contacts of non-congregation Primary cases	Ref	Ref	Ref
Community contact of Congregation Primary cases	1.0 (0.7-1.5)	0.9 (0.6-1.4)	0.9 (0.6-1.4)
Household contacts of non-congregation Primary cases	4.9 (3.8-6.4)	4.7 (3.7 – 6.2)	4.7 (36.4-6.1)
Household contacts of Congregation Primary cases	16.4 (13.3–20.2)	16.2 (13.1-20.0)	16.1 (13.0-20.0)

Table 5: Factors associated with COVID-19 among the contacts stratified by the symptomatic status of the primary cases of Tamil Nadu, India March – May 2020

Symptomatic Primary	Type of contacts	Crude RR (95% CI)	Adjusted RR with Age and Sex (95% CI)
Yes	Community contacts of non-congregation Primary cases	Ref	Ref
	Community contact of Congregation Primary cases	10.5 (6.0-33.0)	8.6 (2.6 – 29.1)
	Household contacts of non-congregation Primary cases	15.5 (6.0-39.8)	14.6 (5.7 – 37.7)
	Household contacts of Congregation Primary cases	26.7 (10.8-65.9)	25.3 (10.2 – 63.0)
No	Community contacts of non-congregation Primary cases	Ref	Ref
	Community contact of Congregation Primary cases	0.9 (0.6-1.4)	0.9 (0.5 – 1.3)
	Household contacts of non-congregation Primary cases	4.6 (3.5-6.0)	4.4 (3.4 – 5. 8)
	Household contacts of Congregation Primary cases	16.48 (13.17-20.63)	16.52 (13.16 – 20.74)

Reference:

[1] World Health Organization. Statement on the second meeting of the International Health Regulations (2005) Emergency Committee regarding the outbreak of novel coronavirus (2019-nCoV). https://www.who.int/news-room/detail/30-01-2020-statement-on-the-second-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov) (2020).

[2] WHO; Coronavirus disease (COVID-19): Contact tracing 2020 [Available from: https://www.who.int/news-room/q-a-detail/coronavirus-disease-covid-19-contact-tracing.

[3] Halloran ME. Secondary Attack Rate. In: Peter A, Theodore C, editors. Encyclopedia of Biostatistics. New York: John Wiley & Sons Ltd; 2005

[4] Li W, Zhang B, Lu J, Liu S, Chang Z, Cao P, et al. The characteristics of household transmission of COVID-19. Clinical Infectious Diseases. 2020.

[5] Liu Y, Eggo RM, Kucharski AJ. Secondary attack rate and superspreading events for SARS-CoV-2. The Lancet. 2020 Mar 14;395(10227):e47

[6] Luo L, Liu D, Liao X, Wu X, Jing Q, Zheng J, Liu F, Yang S, Bi H, Li Z, Liu J. Contact settings and risk for transmission in 3410 close contacts of patients with COVID-19 in Guangzhou, China: a prospective cohort study. Annals of internal medicine. 2020 Aug 13

[7] Yang J, Zheng Y, Gou X, Pu K, Chen Z, Guo Q, et al. Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. International Journal of Infectious Diseases. 2020; 94:91-5

[8] Cheng HY, Jian SW, Liu DP, Ng TC, Huang WT, Lin HH. High transmissibility of COVID-19 near symptom onset. medRxiv. 2020 Jan 1

[9] Wilder-Smith A, Chiew CJ, Lee VJ. Can we contain the COVID-19 outbreak with the same measures as for SARS?. The Lancet Infectious Diseases. 2020 Mar 5

[10] Jahan N, Rubeshkumar P, Karuppiah M, Sambath I, Sendhilkumar M, Ilangovan K, et al. Entry and initial spread of COVID-19 in India: Epidemiological analysis of media surveillance data, India, 2020. Clinical Epidemiology and Global Health. 2020.

[11] MediaBulletin180320COVID19.pdf [Internet]. [cited 2020 May 31]. Available from: https://stopcorona.tn.gov.in/wp-content/uploads/files/MediaBulletin180320COVID19.pdf

[12] Ali, A. (2020, April 1). Coronavirus was a test of secular nationalism. Then Tablighi Jamaat became the scapegoat. *The Print*. https://theprint.in/opinion/coronavirus-test-of-secular-nationalism-tablighi-jamaat-became-scapegoat/392764/

[13] Gathering at Nizamuddin a highly irresponsible act, says Kejriwal. (2020, March 31). *The Hindu*. https://www.thehindu.com/news/cities/Delhi/gathering-at-nizamuddin-a-highly-irresponsible-act-says-kejriwal/article31221982.ece

[14] Chandna, H. (2020, April 18). 30% of India's Covid-19 positive caseload linked to Tablighi Jamaat meet, says govt. *The Print*. https://theprint.in/health/30-of-indias-covid-19-positive-caseload-linked-to-tablighi-jamaat-meet-says-govt/404426/

[15] Of 14,378 total Covid-19 cases in India, 4,291 linked to Delhi's Markaz event: Health ministry. (2020, April 18). *India Today*. https://www.indiatoday.in/india/story/coronavirus-india-total-cases-linked-tablighi-jamaat-markaz-nizamuddin-event-health-ministry-1668456-2020-04-18

[16] NDTV. 1,023 COVID-19 Cases Linked To Mosque Event, Tamil Nadu Leads: 10 Points: NDTV; [Available from: https://www.ndtv.com/india-news/coronavirus-tablighi-jamaat-1-023-of-2-902-covid-19-cases-linked-to-mosque-event-tamil-nadu-leads-2206193

[17] National Centre for Disease Control Directorate General of Health Services MoH&FW, GOI, New Delhi The updated case definitions and contact-categorisation [internet]. [citied 2020 Jun 2]. Available from https://nirth.res.in/virology/Revised_case_definitions_for_COVID_19.pdf

[18] Guidelines for investigating clusters of health events. MMWR Recomm Rep. 1990 Jul 27;39(RR-11):1-23. PMID: 2117247. .

[19] Koh WC, Naing L, Chaw L, Rosledzana MA, Alikhan MF, et al. (2020) What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLOS ONE 15(10): e0240205. https://doi.org/10.1371/journal.pone.0240205

[20] Madewell ZJ, Yang Y, Longini IM Jr, Halloran ME, Dean NE. Household Transmission of SARS-CoV-2: A Systematic Review and Meta-analysis. JAMA Netw Open. 2020 Dec 1;3(12):e2031756. doi: 10.1001/jamanetworkopen.2020.31756. PMID: 33315116; PMCID: PMC7737089.

[21] Lei H, Xu X, Xiao S, Wu X, Shu Y. Household transmission of COVID-19-a systematic review and meta-analysis. *J Infect*. 2020;81(6):979-997. doi:10.1016/j.jinf.2020.08.033

[22] Keeling MJ, Hollingsworth TD, Read JM. The Efficacy of Contact Tracing for the Containment of the 2019 Novel Coronavirus (COVID-19). medRxiv. 2020.

[23] COVID-19 National Emergency Response Center Epidemiology and case management team, Korea Centers for disease Control and prevention. Coronavirus disease-19: summary of 2,370 contact investigations of the first 30 cases in the Republic of Korea. Public Health Res Perspect. 2020;11(2):81–84. doi: 10.24171/j.phrp.2020.11.2.04

[24] Wei L, Lv Q, Wen Y, Feng S, Gao W, Chen Z, Cao B, Wu X, Lu Y, Zhao J, Zou X. Household transmission of COVID-19, Shenzhen, January-February 2020. medRxiv. 2020 Jan 1

[25] Park SY, Kim YM, Yi S, Lee S, Na BJ, Kim CB, Kim JI, Kim HS, Kim YB, Park Y, Huh IS. Coronavirus disease outbreak in call center, South Korea. Emerging infectious diseases. 2020 Aug;26(8):1666.

[26] Chaw, L., Koh, W., Jamaludin, S., Naing, L., Alikhan, M., & Wong, J. (2020). Analysis of SARS-CoV-2 Transmission in Different Settings, Brunei. *Emerging Infectious Diseases*, *26*(11), 2598-2606. https://dx.doi.org/10.3201/eid2611.202263

[27] Koh WC, Naing L, Chaw L, Rosledzana MA, Alikhan MF, et al. (2020) What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. PLOS ONE 15(10): e0240205. https://doi.org/10.1371/journal.pone.0240205

[28] MOHFW. Revised guidelines for Home Isolation of very mild/pre-symptomatic/asymptomatic COVID-19 cases. MOHFW 2020 July 2 [Available from RevisedHomeIsolationGuidelines.pdf (mohfw.gov.in)]

[29] Quadri SA. COVID-19 and religious congregations: Implications for spread of novel pathogens. International Journal of Infectious Diseases. 2020 Jul 1;96:219-21.

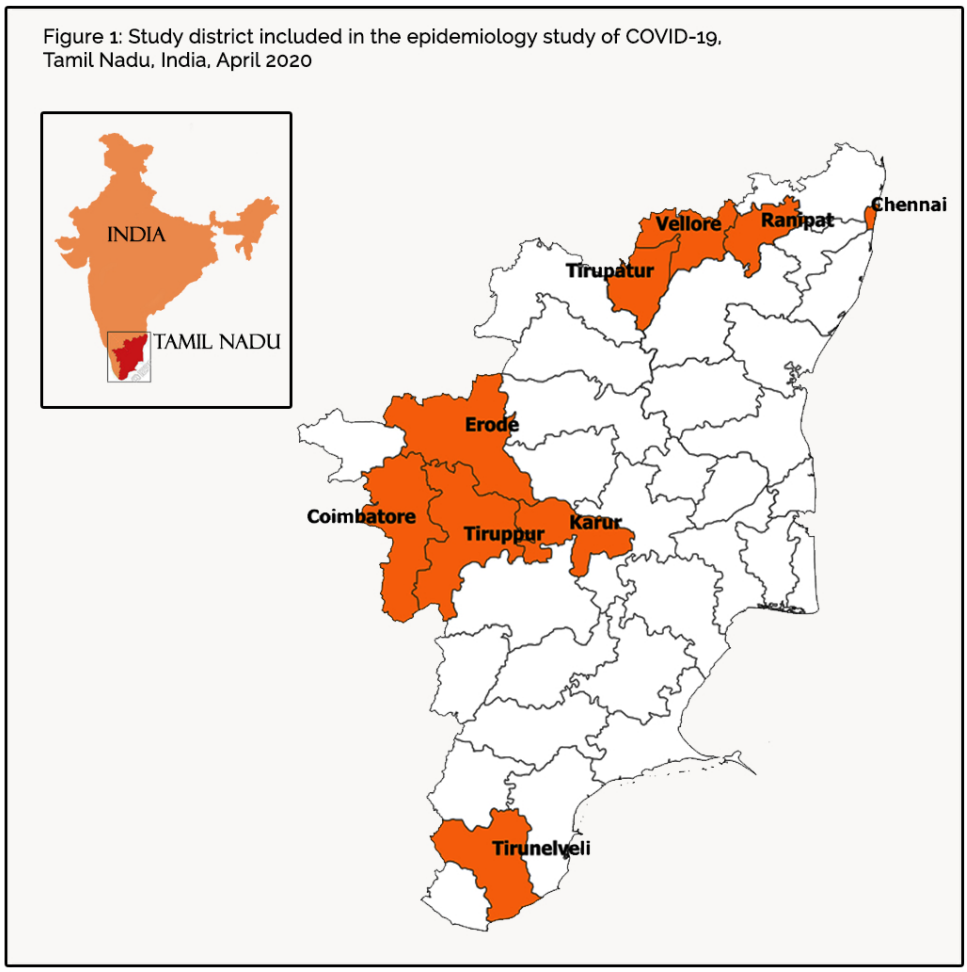
[30] Choi JY. COVID-19 in South Korea. Postgraduate Medical Journal. 2020;96(1137):399-402.

[31] Yusef D, Hayajneh W, Awad S, Momany S, Khassawneh B, Samrah S, Obeidat B, Raffee L, Al-Faouri I, Issa AB, Al Zamel H. Large outbreak of coronavirus disease among wedding attendees, Jordan. Emerging infectious diseases. 2020 Sep;26(9):2165.

[32] Shim E, Tariq A, Choi W, Lee Y, Chowell G. Transmission potential and severity of COVID-19 in South Korea. International Journal of Infectious Diseases. 2020;93:339-44.

[33] Hamner L, Dubbel P, Capron I, Ross A, Jordan A, Lee J, et al. High SARS-CoV-2 Attack Rate Following Exposure at a Choir Practice - Skagit County, Washington, March 2020. MMWR Morbidity and mortality weekly report. 2020;69(19):606-10

[34] The Times of India; Avoid mass gatherings, says govt as corona cases hit 31: [Available from: http://timesofindia.indiatimes.com/articleshow/74520610.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst]



Map of Tamil Nadu included in the epidemiological study of COVID-19. There are nine of the 38 districts included in the study.

90x90mm (300 x 300 DPI)

Reporting checklist for cohort study.

Based on the STROBE cohort guidelines.

Instructions to authors

Complete this checklist by entering the page numbers from your manuscript where readers will find each of the items listed below.

Your article may not currently address all the items on the checklist. Please modify your text to include the missing information. If you are certain that an item does not apply, please write "n/a" and provide a short explanation.

Upload your completed checklist as an extra file when you submit to a journal.

In your methods section, say that you used the STROBE cohortreporting guidelines, and cite them as:

von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies.

		Reporting Item	Page Number
Title and abstract			
Title	#1a	Indicate the study's design with a commonly used term in the title or the abstract	1

Abstract	#1b	Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background / rationale	#2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	#3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	#4	Present key elements of study design early in the paper	4
Setting	#5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4
Eligibility criteria	#6a	Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up.	5
Eligibility criteria	#6b	For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	#7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnosti4c criteria, if applicable	5
Data sources / measurement	#8	For each variable of interest give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is	5

		more than one group. Give information separately for for exposed and unexposed groups if applicable.	
Bias	#9	Describe any efforts to address potential sources of bias	n/a
Study size	#10	Explain how the study size was arrived at	4
Quantitative variables	#11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen, and why	5
Statistical methods	#12a	Describe all statistical methods, including those used to control for confounding	5
Statistical methods	#12b	Describe any methods used to examine subgroups and interactions	n/a
Statistical methods	#12c	Explain how missing data were addressed	n/a
Statistical methods	#12d	If applicable, explain how loss to follow-up was addressed	n/a
Statistical methods	#12e	Describe any sensitivity analyses	n/a
Results			
Participants	#13a	Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-	5

		up, and analysed. Give information separately for for exposed and unexposed groups if applicable.	
Participants	#13b	Give reasons for non-participation at each stage	n/a
Participants	#13c	Consider use of a flow diagram	n/a
Descriptive data	#14a	Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders. Give information separately for exposed and unexposed groups if applicable.	5
Descriptive data	#14b	Indicate number of participants with missing data for each variable of interest	5
Descriptive data	#14c	Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	#15	Report numbers of outcome events or summary measures over time. Give information separately for exposed and unexposed groups if applicable.	6
Main results	#16a	Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	6
Main results	#16b	Report category boundaries when continuous variables were categorized	n/a
Main results	#16c	If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a

Other analyses	#17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6
Discussion			
Key results	#18	Summarise key results with reference to study objectives	7
Limitations	#19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias.	8
Interpretation	#20	Give a cautious overall interpretation considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence.	8
Generalisability	#21	Discuss the generalisability (external validity) of the study results	n/a
Other Information			
Funding	#22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	10