SARS-CoV-2 sero-prevalence among general population and healthcare workers in India, December 2020 - January 2021

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Abstract

Background
Repeated cross-sectional serosurveys in the same geographic area establish the trend of the evolving pandemic. We present the findings of the third round of a national serosurvey to estimate the seroprevalence of SARS-CoV-2 infection among the general population and health care workers of India.

Methods
We conducted the third population-based serosurvey between Dec 18, 2020 and Jan 6, 2021 in the same 700 villages or wards from 70 districts in 21 states across India, which were selected for the first and second serosurveys. We enrolled from each district, at least 400 individuals aged ≥ 10 years from general population and 100 HCWs from sub-district level public health facilities. Serum samples from general population were tested for the presence of IgG antibodies against nucleocapsid (N) and spike protein (S1-RBD) of SARS-CoV-2 using the Abbott and Siemens assays respectively, whereas sera from HCWs were tested for anti-S1-RBD. For general population, sera positive for either of the antibodies were considered positive, while sera positive for anti-S1-RBD were considered as positive for HCW. Weighted seroprevalence estimates were adjusted for sensitivity and specificity of respective assays.

Findings
Of the 28,598 sera from general population, 4585 (16%) had IgG antibodies against N, 6647 (23.2%) against S1-RBD and 7436 (26%) against either. The weighted and assay characteristic adjusted seroprevalence against either of the antibodies was 24.1 (95%CI: 23.0% to 25.3%). Seroprevalence was lower in rural areas (21.4%, 95% CI: 20.3% to 22.6%) compared to urban non-slum (29.4%, 95% CI: 26.9% - 32.1%) and slum areas (34.6%, 95% CI: 31.0% to 38.3%). Among 7385 HCWs, the seroprevalence of anti-S1-RBD IgG antibodies was 25.6% (95% CI: 23.5% to 27.8%).

Interpretation
Nearly one in four individuals aged 10 years or older from general population as well as HCWs were exposed to SARS-CoV-2 by December 2020 amounting to 271 million infections in India.

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Keywords: SARS-CoV-2, COVID-19, IgG, seroprevalence, India

Research in context

Evidence before this study

Population based serosurveys are recommended to estimate the proportion of population already infected with SARS-CoV-2 and in particular, repeated cross sectional serosurveys conducted in the same geographical location provide estimates to monitor trends over a period of time. The information from the repeated cross-sectional surveys are valuable for the public health decision makers to design and revise containment strategies. Chen et al reviewed around 1500 studies and found that around two thirds of the studies used convenience sampling strategy to estimate seroprevalence and indicated a limited number of high-quality studies available among high-risk populations such as healthcare workers. The meta-analysis estimated an overall global seroprevalence of 8.0% in the general population and among healthcare workers was 17.1%. The first two nationwide serosurveys in India indicated that the prevalence of SARS-CoV-2 infection among adults had increased ten-fold, from 0.73% in May-June 2020 to 7.1% in August-September 2020. The second survey identified substantial transmission in rural areas, although seroprevalence continues to be higher in urban slum and non-slum areas.

Added value of this study

Information of seroprevalence on high risk population groups such as health care workers is crucial to estimate the risk of infection and prioritise for vaccination. The number of COVID-19 cases in India has been declining since mid-September. In this context we estimated the seroprevalence of SARS-CoV-2 antibodies in the general population and among HCWs across India using a representative sampling method. The findings indicate that about 24% individuals aged 10 years and above and about 26% HCWs working in sub-district level public health facilities were exposed to SARS-CoV-2 infection by December 2020. Sero-prevalence of SARS-CoV-2 infection was lower among adults aged 18-44 years and in rural areas. Of the 70 districts surveyed, anti-N antibody seropositivity has increased in 55 and declined in 15 on account of waning of antibodies. We used two assays serially to account for the waning of anti N antibodies and to estimate accurate seroprevalence.

Implication of all the available evidence

Around one fourth of the population have been exposed to SARS-CoV-2 infection and seroprevalence was similar between the general population and health care workers. The decline in cases could be due to higher seroprevalence in urban areas and warrants a focussed containment strategy such as prioritizing the elderly in rural population for vaccination, continued non-pharmaceutical interventions such as physical distancing, use of face masks and hand-hygiene to prevent surge of cases.

Introduction

With more than 10 million laboratory confirmed cases and nearly 150,000 reported deaths as of 31 December 2020, India has the second largest number of COVID-19 cases reported globally (1). The nationwide lockdown imposed during March to May 2020 in India was relaxed in a phased manner since June 2020, allowing inter-state and inter-district movement of people as well as restoration of economic activities (2,3). The two population-based serial serosurveys conducted in 70 Indian districts indicated that the prevalence of SARS-CoV-2 infection among adults had increased ten-fold, from 0.73% (95% CI: 0.34-1.13) in May-June, 2020 to 7.1% (95% CI: 6.2-8.2) in August-September, 2020 (4,5). The number of infections per reported COVID-19 case improved from 81.6-130.1 in May-June to 26-32 in August-September (4,5).

SARS-CoV-2 poses a high occupational risk to healthcare workers (HCWs), who are at the forefront of management of COVID-19 cases in hospital settings. Knowledge of the burden of infection among healthcare workers is important to gauge the risk of within and outside hospital transmission of SARS-CoV-2, and evaluate the in-hospital infection control practices and adherence to non-pharmaceutical interventions as well (6).

The number of COVID-19 cases in India has shown a downward trend since mid-September, with the reported number of cases declining from more than 90,000 per day in September to less than 20,000 cases per day in December 2020. This decline was seen in all Indian states, except in the states of Kerala and Maharashtra (7). We conducted the third round of nationwide serosurvey in December 2020-January 2021 to estimate the seroprevalence of SARS-CoV-2 antibodies in the general population and determine the trends in infections since the previous serosurveys. We also estimated the seroprevalence among HCWs working in sub-district level public health facilities.

Methods

Survey of general population:

We followed the same survey methodology as in the first and second nationwide serosurveys (4,5). Briefly, the third population-based serosurvey was conducted in the same 700 clusters (villages in rural areas and wards in urban areas) from 70 districts in 21 states across India, where previous serosurveys were done. We aimed to select a minimum of 400 individuals aged 10 years and above from each district. The survey teams first selected four random locations from each cluster. Starting from a random household in each location, contiguous households were visited till a minimum of four households were enrolled. All household members aged 10 years and above who were permanent resident of the area were enumerated and consenting individuals present at the time of visit of survey team were included in the survey. No additional visits were made to include households which were locked or household members not present at the first visit. From each cluster, at least 40 individuals were surveyed, with a minimum of 10 individuals from each random point. The survey was conducted between December 18, 2020 and January 6, 2021.

Survey of healthcare workers:

From each of the 70 districts identified for the general population survey, we selected 2-3 sub-district level public health facilities (e.g. *taluk* or sub-divisional hospital, community or primary health center). All consenting individuals working in these facilities were included to ensure participation of a minimum of 100 HCW from each district.

Data collection:

Eligible individuals from the general population and HCWs who consented to participate were interviewed using the Open Data Kit mobile application (https://opendatakit.org/) to collect information about socio-demographic details, history of symptoms suggestive of COVID-19 since March, 2020 (eg, fever, cough, shortness of breath, sore throat, new loss of taste or smell, fatigue), contact with laboratory confirmed COVID-19 cases, and history of COVID-19 illness. 3–5 mL of venous blood was collected from each participant, and centrifuged sera were transported to ICMR-National Institute of Epidemiology, Chennai under cold chain.

Laboratory investigations:

Serum samples collected from individuals from general population were tested for the presence of IgG antibodies against SARS-CoV-2 on the Advia Centaur Immunoassay system using the Siemens SARS-CoV-2 IgG Assay (Siemens Healthineers India, Mumbai) and Abbott Architect i2000SR automated analyzer using the Abbott SARS-CoV-2 IgG assay (Abbott Park, IL, USA). The Siemens assay detects IgG antibodies against S1 protein of the receptor binding domain (S1-RBD) whereas the Abbott assay detects IgG antibodies against nucleocapsid (N) protein of SARS-CoV-2. Sera from HCWs were tested only for IgG antibodies against S1-RBD. The sensitivity and specificity of the Siemens IgG assay is 100% and 99.90% respectively (8), while the Abbott IgG assay has a sensitivity of 100% and specificity of 99.6% (8). Sera with cut-off indices (COI) of >=1.0 on Siemens IgG assay or >=1·4 on Abbott IgG assay were considered as positive for IgG antibodies against SARS-CoV-2. As a part of quality control, 150 positive and 150 negative sera for each of these assays were re-tested.

Statistical analysis:

We described the characteristics of study participants as percentages, means, and standard deviations (SDs). The reported occupations were categorized as high-risk and low-risk categories, on the basis of the potential risk of exposure to a known or unknown COVID-19 case. We separately estimated the weighted seroprevalence of IgG antibodies against N protein and S1-RBD, along with 95% confidence interval (CI), using a random-effects model to account for cluster sampling. We calculated sampling weights as a product of the inverse of the sampling fraction for the selection of districts and the selection of villages or wards from each district. The weighted seroprevalence was further adjusted for the sensitivity and specificity of the respective assays (9). We estimated the overall seroprevalence in the general population by considering serum samples positive to either of the assays. The weighted overall seroprevalence was adjusted for the joint sensitivity and specificity of two assays (9). Seroprevalence among HCWs was considered on the basis of anti-S1 assay only.

We also calculated the overall seroprevalence by age group, sex, area of residence, and COVID-19-related characteristics of study participants.

The first serosurvey was conducted only among adults, whereas individuals aged >=10 years were surveyed in the second and third surveys. The serum samples in the second round were tested only for IgG antibodies against N protein using Abbott assay. For comparing the seroprevalence in the three surveys, we randomly selected one adult per household from the survey database, and estimated the adjusted seroprevalence of IgG antibodies against N protein among these adults.

We applied the overall adjusted seroprevalence in the general population aged 10 years or older to the total population of the entire country aged >=10 years to estimate the total number of SARS-CoV-2 infections. Studies indicate that IgG antibodies start appearing between 7 and 14 days after onset of symptom and RT-PCR positivity (10). We estimated the infection to case ratio by dividing the estimated number of SARS-CoV-2 infections by the number of reported COVID-19 cases detected by RT-PCR or rapid antigen test, at 1 week (Dec 19, 2020) and 2 weeks (Dec 12, 2020) before the median survey date (Dec 26, 2020).

Human participants protection:

We obtained written informed consent from individuals aged 18 years or older and assent from children aged between 12 and 17 years, with written informed consent from their parents or guardians, before the survey (11). The Institutional Human Ethics Committee of ICMR-National Institute of Epidemiology, Chennai approved the study protocol.

Results

Seroprevalence among general population

We enumerated 37,502 individuals aged 10 years and above residing in 17,178 households from 700 clusters in 70 districts. Of the 35,099 (93.6%) individuals who were available at the time of visit of survey teams, 28,598 (81.5%) consented to participate (Fig 1).

The mean age of study participants was 38.2 (SD: 16.4) years. Overall, 16,333 (57·1%) participants were in the age group of 18-44 years, while 6938 (24·3%) were aged between 45-60 years, 3037 (10·6%) were aged above 60 years and 2290 (8.0%) were below 18 years of age. Nearly three fourth participants (n=21,187, 74.1%) were residing in rural areas, 52% (n=14,763, 51.6%) were females, and 15.2% (n=4,333) had an occupation with higher risk of exposure to potentially infected persons. Of the 1949 (6.8) participants who reported history of respiratory symptoms since March 2020, 483 (24.8%) reported seeking medical care. A total of 3232 (11·4%) individuals reported having been tested for SARS-CoV-2 by RT-PCR or rapid antigen test in the past, of whom 289 (8.9%) reported a positive result (Table 1).

Of the 28,598 individuals tested, 4585 (16%) had IgG antibodies against N protein and 6647 (23.2%) had IgG antibodies against S1-RBD. The weighted and assay characteristics

adjusted seroprevalence of IgG antibodies against N and S1-RBD protein was 14.3% (95% CI: 13.6% – 15.0%) and 21.5% (95% CI: 20.5% - 22.6%), respectively. Overall, 7436 individuals had IgG antibodies against either N or S1-RBD protein, with the weighted and assay characteristic adjusted seroprevalence of 24.1% (95% CI: 23.0% - 25.3%) (Table 2). Seroprevalence in districts ranged between 4.9% in Mahisagar (Gujarat) to 44.4% in Bijapur (Chhattisgarh)

The overall seroprevalence was not different by sex (males: 23.2%, 95% CI: 22.1% - 24.5%; females: 24.9%, 95% CI: 23.7% - 26.3%). The seroprevalence was lowest among individuals aged 18-44 years and similar among other age groups. Individuals residing in rural areas had significantly lower seroprevalence (21.4%, 95% CI: 20.3% - 22.6%), as compared to those living in urban non-slum (29.4%, 95% CI: 26.9% - 32.1%) and urban slum areas (34.6%, 95% CI: 31.0% - 38.3%) (Table 3).

Seropositivity was higher among individuals who reported COVID-19 related symptoms (28.7%, 95% CI: 26.2% - 31.5%), had contact with COVID-19 case, either within (28.7%, 95% CI: 26.2% - 31.5%) or outside the household (24.9%, 20.0 - 30.6) and laboratory confirmed COVID-19 infection (63.2%, 56.7 - 69.1).

Seroprevalence among adults

In order to be able to compare the seroprevalence among adults between the three serosurveys, we randomly selected 16,565 adults, one per household, from the database. Of these, 2657 had IgG antibodies against N-protein with weighted and adjusted seroprevalence of 14.3% (95% CI: 13.5%-15.1%). The weighted seroprevalence of IgG antibodies against either N or S-RBD protein was 24.3% (95% CI: 23.1% - 25.6%).

Burden of SARS-CoV-2 infection by December 2020

Applying the overall seroprevalence to the population aged 10 years and above, we estimated that 27,14,04,207 (25,90,16,464 -28,49,18,110) individuals in India were infected by December 2020. With 1,00,27,311 and 1,01,81,165 COVID-19 cases reported by 12 Dec and 19 Dec 2020 respectively, we estimated that there were 27.1 (25.8 - 28.4) and 26.7 (25.4 - 28.0) infections per reported COVID-19 case.

Seroprevalence among healthcare workers

We included 7,385 individuals working in 199 sub-district level public health facilities in 70 districts in the survey. Their mean age was 38 (SD: 10.2) years and 4209 (56.9%) were females. 1066 (14.4%) reported history of respiratory symptoms since March 2020 and 3250 (44.1%) had contact with known COVID-19 case, 96% of whom were within household. In all, 664 (14.1%) of the 4700 who reported having underwent COVID-19 test were positive (Table 1).

The weighted and test performance adjusted seroprevalence of IgG antibodies against SARS-CoV-2 infection was 25.6% (95% CI: 23.5-27.8) (Table 2). Although the

seroprevalence was higher among doctors/nurses (26.6%, 95% CI: 23.6-29.8), the seroprevalence was not different among different categories of HCWs. Seroprevalence did not differ by age and sex. Seroprevalence was higher among symptomatics, reported contact with COVID-19 case within household and reported COVID-19 positive (Table 3)

Discussion

The third serosurvey findings indicated that nearly 24% of India's population aged ten years and above was exposed to SARS-CoV-2 infection by December 2020, with an estimated 271 million infections. The seroprevalence did not differ by sex but was lower among adults aged 18-44 years and in rural areas although lower than the urban areas. The results also indicate that about one-fourth of healthcare workers working in the peripheral public sector health facilities were positive for IgG antibodies.

We used antibody assays to detect IgG against N and S1-RBD proteins of SARS-CoV-2 in this survey. Unlike antibodies against the spike protein, antibodies against the nucleocapsid protein do not have a neutralizing effect on SARS-CoV-2 because the target protein is located inside the virus and is therefore not directly accessible for antibodies. Overall, S1 is a more specific antigen for SARS-CoV-2 antibody diagnostics. Nucleocapsid protein assays are reported to be more sensitive than S1 assays in detecting antibodies in mildly infected patients that are reported to show absent or delayed, and lower SARS-CoV-2 antibody responses (12,13). It has been shown that the anti-nucleocapsid antibodies appear earlier than the spike antibodies and therefore, may increase the clinical sensitivity of the assay, if samples are drawn early (14). IgG antibody response against different viral antigens is heterogeneous in nature and does not always correlate with each other (15). Therefore, detecting antibodies against two different antigens, with high sensitivity and specificity, is needed to confirm the findings and avoid false-negative results in surveillance studies. (16) Testing algorithms with more than one test may be necessary to rule out false positives by initial tests, as in HIV and hepatitis (14).

The seroprevalence studies provide information about the extent of transmission in the past and help to understand the future course of the pandemic. The seroprevalence of IgG antibodies against SARS-CoV-2 among individuals aged >=10 years in India, has increased from 6.6% in August to 24.1% in December 2020. The prevalence of IgG antibodies against N protein between the two serosurveys has increased at least by 2.2 folds. Serum samples from the previous serosurvey were not tested for anti-S1-RBD IgG antibodies. During the same period, the reported number of COVID-19 cases in India has increased 3.5 folds. The anti-N antibody seropositivity has decreased in 15 of 70 survey districts by 10.7% to 63.4%, with the steepest decline in Vizianagaram (Andhra Pradesh), Chennai (Tamil Nadu), and Ganjam (Odisha) districts. In the remaining 55 districts, sero-positivity to anti-N antibodies has increased by 1.04 to 76 folds (Supplementary table 1). This increase in seroprevalence was consistent with increase in the number of COVID-19 cases reported between August and December months in these districts (Supplementary table 2).

The seroprevalence was significantly lower in the 18-44 years age group in contrast to the second serosurvey when the prevalence was similar across age groups. Between August and December 2020, the age specific seroprevalence of anti-N antibodies among

individuals aged 18-44 years has increased by 1.8 folds, and by 2.6-3.1 folds in the remaining age groups. (Supplementary table 3) The lower seroprevalence in the active and productive age group compared with other age groups is not consistent with the current transmission pattern of COVID-19 in India (17). This age group was exposed to infection early in the pandemic as reflected in the relatively high incidence of COVID-19 among this age group during January-April 2020 (17) and hence the increase in seroprevalence could be relatively lower in this age group.

We found higher sero-prevalence of SARS-CoV-2 infection in urban areas compared to the rural areas. Although this pattern was similar to the serosurvey in August 2020, the seroprevalence was not different in slum and non-slum urban areas as observed during August 2020. Between August and December 2020, the increase in seroprevalence was highest in rural areas (2.5 fold), followed by urban non-slum (1.93 fold) and urban slum (1.07 fold) reflecting the varied distribution of susceptible population in these areas. The declining trend in the reported number of COVID-19 cases in India since mid-September 2020 points towards a reduction in transmission that could be attributed to higher seroprevalence in urban slum and non-slum areas considering these locations to be the drivers of the epidemic in the country. High seroprevalence of infection have been reported in some of the megacities (5). Our serosurvey findings also indicate that a large proportion of individuals in the rural area continue to remain susceptible to infection. Similar finding was observed in the recent serosurvey conducted in the India state of Karnataka (18).

Seroprevalence was substantially high and nearly double among individuals reporting contact with COVID-19 case within the household compared to contact outside the household. Household transmission of SARS-CoV-2 seems to be the predominant mode of transmission in the country suggestive of poor adherence to quarantine/isolation measures, use of mask and hand sanitation and inadequate ventilation within households. High secondary attack rates within households have been reported by other studies in India. (19-21)

The seroprevalence of anti-S1 IgG antibody was higher among HCWs working in sub-district level healthcare facilities compared to the general population substantiating the known higher risk of exposure among them. Seroprevalence among HCWs (25.6%) observed in our study was much higher than the 8.7% prevalence estimated in a systematic review and meta-analysis among HCWs (22). A comparable seroprevalence among clinical, paramedical, field and administrative workers in health facilities and by place of contact with known COVID-19 case suggests widespread transmission of SARS-CoV-2 in the survey areas.

Our study has several limitations. First, the participation of children aged 10–17 years in this survey was lower than the census-based age distribution in India (23). According to 2011 census, about 14% of the population were aged 10–17 years, whereas 8% of the study population were aged 10–17 years. The under-representation of children and over-representation of adults in the survey could lead to underestimation of the true seroprevalence, if we expect a real difference in the risk of exposure to SARS-CoV-2 across age groups. (Supplementary table 4) Although we enrolled the required number of individuals, about 18.5% of the eligible individuals declined to participate in the survey. If

this non-response was not at random, then this could introduce selection bias. Individuals who declined to participate were more likely to be male and younger than 18 years of age. Second, we used different assays to measure the IgG antibodies in three serosurveys. In the first serosurvey, laboratory assay which detected IgG antibodies against whole cell antigen was used, and positive sera were re-tested with assay which detected antibodies against S1 domain of the spike protein of SARS-CoV-2 (4). In the second serosurvey, a laboratory assay which detected IgG antibodies against nucleocapsid protein of the virus was used (5). As antibodies against nucleocapsid protein of SARS-CoV-2 virus have been shown to decline faster over a period of time, the actual seroprevalence might have been under-estimated and thereby the actual number of infections (24). For the same reason, the actual difference in seroprevalence between the first two surveys may have been under-estimated, as antibody assays for different viral proteins were used. In order to overcome these limitations, the serum samples were tested with both anti-nucleocapsid and anti-S1 assays in the third survey. Third, studies suggest decline in population level seropositivity on account of waning IgG antibodies over a period time, especially antibodies against N protein. Since the cut off indices specified by manufacturers are based on ≥ 14 days convalescent sera, lowering the COIs can improve the sensitivity of the assays used for population based serosurveys. (25) Irsara C et al suggested a lower COI of >0.54 for Abbott and 0.32 for Siemens IgG assays to improve the sensitivity. (16) Using these cut-offs, the overall seroprevalence was 37.4% (95% CI: 35.9-38.8) (Supplementary table 5)

In conclusion, the findings of the third nationwide serosurvey indicate that nearly one in four individuals aged 10 years or older from general population as well as healthcare workers were exposed to SARS-CoV-2 in India by December 2020. The seroprevalence increased between August and December 2020, and the decline in the number of COVID-19 cases seen in India since mid-September could be on account of higher sero-prevalence in urban areas. As three fourth of the population is still susceptible, it is necessary to continue ongoing surveillance for COVID-19 cases, especially in rural areas. It is also necessary to continue implementation of non-pharmaceutical interventions such as physical distancing, use of face masks and hand-hygiene. Govt of India has initiated COVID-19 vaccination since January 2021, targeting healthcare and frontline workers in the first phase and individuals aged above 50 years in the second phase. (26) As higher proportion of rural population is susceptible to infection and considering limited healthcare facilities in rural areas especially oxygen beds (27), elderly population in the rural areas may be prioritized for COVID-19 vaccination.

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MVM, TB, JWVT, MSaK, KR, DCSR, SP and BB did the study design. TB, MSaK, JWVT, SSe, RSa, AT, SA, RB, SDB, AKB, VC, DD, AKD, KRD, VD, GRD, SMSK, MSuK, AL, MM, AMa, CR, JT, RY, RA, KA, DKB, PB, DB, JB, ASC, DC, AC, HD, SD, RD, DE, PG, IH, RKH, BJ, AK, SK, NNK, JSK, AK, NK, VGVK, GGJN, GM, NKM, AM, KN, AN, ARN, AKP, GVP, MAQ, SDR, AR, SSa, RS, KS, VKS, HBS, PKS, PS, RSi, NS, DSV, AV, VCW, SurY, SY, KZ, AC, AD, RSD, SD, RK, AMK, KN, SN, CP, KP, SaP, ShP, HR, TR, YKS, ShS coordinated the field operations. CPGK coordinated the laboratory processing and testing of samples. VS, JWVT, MVM, RSa, and MSaK did the data analysis. MVM, TB, JWVT, MSaK, KR, SP, DCSR, and BB did the data interpretation. MVM, TB, VS, JWVT, RSa and MSaK accessed and verified the data.

MVM, TB, MSaK, JWVT and wrote the first draft of the manuscript. All authors approved the final version of the manuscript.

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The funder of the study was involved in reviewing the study design, writing of the manuscript, and the decision to submit the paper for publication. All authors had access to all the data in the study and had final responsibility for the decision to submit for publication.

Data Sharing: A subset of the key anonymised individual participant data collected during the study, along with a data dictionary, is available upon request to the corresponding author, after approval of a proposal with a signed data access agreement.

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Table 1: Characteristics of study participants

Characteristics	General population (N = 28598) Number (%)	Health care workers (N = 7385) Number (%)
Age (years)		
10 – 17	2290 (8.0)	-
18 – 44	16333 (57.1)	5351 (72.5)
45 – 60	6938 (24.3)	1956 (26.4)
Above 60	3037 (10.6)	78 (1.1)
Mean age (SD)	38.2 (16.4)	38.0 (10.2)
Sex		
Male	13817 (48.3)	3175 (43.0)
Female	14763 (51.6)	4206 (56.9)
Others	18 (0.1)	4 (0.1)
Residence		
Rural	21187 (74.1)	-
Urban non-slum	4821 (16.9)	-
Urban slum	2590 (9.0)	-
Occupation with high risk of exposure to COVID-19 (n=28575)	4333(15.2)	-
History of respiratory symptoms since Mar 2020	1889 (6.6)	1066 (14.4)
	n = 1889	n=1066
Medical care sought by symptomatics	474 (25.1)	557 (52.3)
	n = 474	n=557
History of hospitalization	73 (15.4)	173 (31.1)
	n=28576	n=7382
History of contact with known COVID-19 case	895 (3.1)	3250 (44.1)
Within Household	598 (2.1)	3120 (42.3)
Outside Household	297 (1.0)	130 (1.8)
Ever tested for COVID-19	3232 (11.4)	4700 (63.6)
RT-PCR	1028 (3.6)	1663 (22.5)

Rapid Antigen Test	1477 (5.2)	1509 (20.4)
RT-PCR & Rapid Antigen Test	330 (1.2)	1402 (19.0)
Don't Know the Type of Test	397 (1.4)	126 (1.7)
	n=3232	n=4700
Reported positive for COVID-19	287 (8.9)	664 (14.1)

Table 2: Sero-prevalence (%) of IgG antibodies against SARS-CoV-2 infection, India, Aug-Sept 2020

	General population aged10 years and above			Health Care Workers
	Anti-Nucleocapsid antibodies	Anti-S1-RBD antibodies	Anti-N or ant-S antibodies	Anti-S1-RBD antibodies
Number of individuals tested	28,598	28,598	28,598	7385
Number positives	4585	6647	7436	1899
Unweighted Prevalence* (%)	16.0 (15.3 - 16.8)	23.2 (22.2 - 24.3)	26.0 (25.0 - 27.1)	25.7 (23.7 - 27.9)
Weighted Prevalence** (%)	14.6 (13.9 - 15.3)	21.7 (20.6 - 22.8)	24.6 (23.5 - 25.7)	-
Adjusted Prevalence*** (%)	14.3 (13.6 - 15.0)	21.5 (20.4 - 22.6)	24.1 (23.0 - 25.3)	25.6 (23.5 - 27.8)

*Adjusted for clustering
**Weighted for sampling weights
***Adjusted for test performance (sensitivity 100% and specificity 99.6%)

Table 3: Seroprevalence (%) of IgG antibodies against SARS-CoV-2 infection by demographic characteristics, India, December 2020-January 2021

Characteristics	General population aged >=10 years (n=28,598)			Health care workers (n=7385)		
	No. Tested	No. Positive (anti-N/ anti-S antibodies)	Test Performance Adjusted Sero-prevalence % (95% CI)	No. Tested	No. Positive (Only S)	Test Performance Adjusted Sero-prevalence % (95% CI)
Sex						
Male	13817	3503	23.2 (22.1 - 24.5)	3175	810	25.4 (23.5 - 27.3)
Female	14763	3928	24.9 (23.7 - 26.3)	4206	1089	25.8 (23.0 - 28.7)
Others	18	5		4	0	-
Age (Years)						
10 - 17	2290	634	27.2 (24.9 - 29.4)	-	-	-
18 - 44	16333	3936	22.2 (21.1 - 23.4)	5351	1295	24.0 (21.9 - 26.3)
45 - 60	6938	2011	26.7 (25.2 - 28.2)	1956	587	29.9 (27.1 - 32.9)
Above 60	3037	855	26.3 (24.3 - 28.3)	78	17	21.6 (13.8 - 32.2)
Residence						
Rural	21187	4997	21.4 (20.3 - 22.6)	-	-	-
Urban non-slum	4821	1520	29.5 (27.0 - 32.1)	-	-	-
Urban slum	2590	919	34.7 (31.2 - 38.5)	-	-	-
Occupation with high risk of exposure to COVID-19 n=28575						
Yes	4333	1036	21.7 (20.1-23.3)			

No	24242	6391	24.5 (23.4-25.8)			
Symptom						
Yes	1889	651	28.7 (26.1 - 31.4)	1066	407	38.1 (32.9 - 43.5)
No	26709	6785	23.8 (22.7 - 24.9)	6319	1492	23.4 (21.4 - 25.7)
Contact Covid (n=28576)						
Within Household	598	225	42.5 (36.7 - 48.3)	-	-	-
Outside Household	297	96	24.9 (20.0 - 30.6)	-	-	-
No	23221	5850	23.4 (22.3 - 24.5)	-	-	-
Don't Know	4460	1256	25.6 (23.4 - 27.8)	-	-	-
Contact Covid (n=7382)						
Health Facility	-	-	-	3120	864	27.6 (24.8 - 30.4)
Within Household	-	-	-	130	46	35.3 (26.7 - 44.9)
Outside Health Facility/Household	-	-	-	191	57	29.7 (21.3 - 39.7)
No	-	-	-	3255	751	22.9 (20.2 - 25.9)
Don't Know	-	-	-	686	180	26.1 (22.9 - 29.5)
Ever tested for COVID-19 (n=28576)						
RT-PCR	1028	357	29.0 (25.9 - 32.2)	1663	477	28.6 (25.2 - 32.2)
Rapid Antigen Test	1477	485	26.5 (23.6 - 29.6)	1509	415	27.4 (23.7 - 31.3)
RT-PCR & Rapid Antigen Test	330	123	29.6 (24.5 - 35.1)	1402	386	27.4 (23.8 - 31.3)
Don't Know the Type of Test	397	128	20.3 (15.6 - 26.2)	126	23	18.1 (13.2 - 24.1)
Not tested	25344	6334	23.8 (22.7 - 24.9)	2682	597	22.1 (19.7 - 24.7)
Reported positive for COVID-19 (n=3232)						
Positive	287	178	63.6 (57.2 - 69.4)	664	395	59.4 (54.0 - 64.6)
Negative	2526	778	27.6 (25.2 - 30.2)	3982	900	22.4 (20.0 - 25.1)
Don't know	419	137	30.8 (25.3 - 36.8)	54	6	10.9 (4.2 - 25.4)

Table 4: Estimated number of infections among individuals aged 10 years above and infection fatality ratio

	Estimate (95% CI) by N - Seroprevalence	**Estimate (95% CI) by S-Seroprevalence**	**Estimate (95% CI) by N/S - Seroprevalence**	
Estimated number of infections	16,05,56,739 (15,26,41,970 - 16,84,71,508)	24,21,24,085 (22,97,36,342 - 25,45,11,829)	27,14,04,207 (25,90,16,464 - 28,49,18,110)	
Number of reported COVID-19 cases (12 Dec)	1,00,27,311	1,00,27,311	1,00,27,311	
Infection Case ratio (12 Dec)	**16.0 (15.2 - 16.8)**	**24.1 (22.9 - 25.4)**	**27.1 (25.8 - 28.4)**	
Number of reported COVID-19 cases (19 Dec)	1,01,81,165	1,01,81,165	1,01,81,165	
Infection Case ratio (19 Dec)	**15.8 (15.0 - 16.5)**	**23.8 (22.6 - 25.0)**	**26.7 (25.4 - 28.0)**