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SARS-CoV-2 seroprevalence in the city of Hyderabad, India in early 2021 ☆,☆☆

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ABSTRACT

Background: COVID-19 emerged as a global pandemic in 2020, spreading rapidly to most parts of the world. The proportion of infected individuals in a population can be reliably estimated via serosurveillance, making it a valuable tool for planning control measures. Our serosurvey study aimed to investigate SARS-CoV-2 seroprevalence in the urban population of Hyderabad at the end of the first wave of infections.

Methods: This cross-sectional survey, conducted in January 2021 and including males and females aged 10 years and above, used multi-stage random sampling. 9363 samples were collected from 30 wards distributed over six zones of Hyderabad, and tested for antibodies against SARS-CoV-2 nucleocapsid antigen.

Results: Overall seropositivity was 54.2%, ranging from 50% to 60% in most wards. Highest exposure appeared to be among those aged 30–39 and 50–59 years, with women showing greater seropositivity. Seropositivity increased with family size, with only marginal differences among people with varying levels of education. Seroprevalence was significantly lower among smokers. Only 11% of the survey subjects reported any COVID-19 symptoms, while 17% had appeared for COVID-19 testing.

Conclusion: Over half the city's population was infected within a year of onset of the pandemic. However, ~ 46% of people remained susceptible, contributing to subsequent waves of infection.

Introduction

Coronavirus disease (COVID-19) was declared a pandemic in March 2020, when the infection due to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) had spread worldwide (WHO, 2020). During the first year of the COVID-19 pandemic, nearly 90 million cases were reported globally, with ~ 2 million deaths 2021 (WHO, 2021). Serological studies estimating SARS-CoV-2 exposure in human populations suggest that the true number of SARS-CoV-2 infections may have been much higher than the officially reported cases (Chen et al., 2021). This

Abbreviations: ACE2, angiotensin-converting enzyme 2; CCMB, Centre for Cellular and Molecular Biology; CI, confidence interval; COVID-19, coronavirus disease; COI, cutoff index; CSIR, Council of Scientific and Industrial Research; GHMC, Greater Hyderabad Municipal Corporation; ICMR, Indian Council of Medical Research; NIN, National Institute of Nutrition; ODK, Open Data Kit; RT-PCR, reverse-transcription polymerase chain reaction; SARS, severe acute respiratory syndrome; SD, standard deviation; SPSS, Statistical Package for the Social Sciences.

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can be attributed to various factors, including the occurrence of asymptomatic infections, variable seeking of health care for clinically mild cases, varied testing strategies in different countries, false-negative virological tests, and incomplete case reporting.

Case reporting depends on several factors, including testing capacity, types of test used, testing strategies, and health-seeking behaviour of the population. Many SARS-CoV-2 infections are mild or asymptomatic in nature, and are less likely to be detected by the surveillance system. Therefore, population-based serosurveys are considered a valuable tool in estimating the proportion of the population infected with SARS-CoV-2. Another important use of serosurveys is to understand the demographic profiles of those at a higher risk of infection in different population groups. Large-scale population-based serosurveys are resource intensive, and allocating scarce public-health resources for this purpose could be challenging for many developing nations. Therefore, well designed population-based studies, with probability sampling and laboratory assays allowing high sensitivity and specificity, followed by appropriate data analysis, play a crucial role in estimating the prevalence of the infected and susceptible populations (Murhekar et al., 2021a; 2021b).

Serosurveys conducted in Mumbai (Malani et al., 2021), Chennai (Selvaraju et al., 2021), and Karnataka (Mohanan et al., 2021) have shown that, in urban areas, seroprevalence is much higher than that estimated at the national level. The Telangana media bulletin revealed that the positivity rate in Telangana in October 2020 was 6.2%, with a case fatality rate of 0.58% and a recovery rate of 85.9% (Government of Telangana 2021). Almost one-third of the cases were from Greater Hyderabad Municipal Corporation (GHMC) areas. The more recent ICMR national serosurveillance study (December 2020) reported a prevalence of 21.5%, compared with 12.2% in August and 0.33% in May 2020 (Murhekar et al., 2020; Murhekar et al., 2021b). Although this survey included three districts of Telangana, the estimates are indicative of national-level prevalence. At state level, the sample size was too small to be representative, and no sample was drawn from the GHMC area, which has a population of 10.3 million (Hyderabad being the fourth most populous city in India).

Considering the urgent need to estimate SARS-CoV-2 exposure in Hyderabad over the first year of the pandemic, our community-based seroprevalence study aimed to assess the transmission of SARS-CoV-2 infection in the GHMC area. Our analyses estimated SARS-CoV-2 seroprevalence in the general population of Hyderabad, the sociodemographic risk factors for infection, and the trends of infectivity among various age groups, locations, and socioeconomic backgrounds in the city of Hyderabad.

Methods

Study design and sample size

This cross-sectional survey included individuals aged 10 years and above. Assuming 10% seropositivity (Murhekar et al., 2021b), a relative precision of 20%, a confidence interval of 95%, a design effect of 2.5, and a non-response rate of 20%, an effective sample size of 2593 (rounded to 3000) individuals was estimated for each age category. To carry out segregated analyses across age groups (≥ 10 years to 18 years, 18 years to 60 years, and above 60 years), the survey was planned for a sample size of at least 9000 individuals from different locations (wards) in the city. The wards covered six different zones of Hyderabad, with the zones subdivided further into 19 circles (covering 30 wards).

Sampling procedure

The 30 wards were selected using a simple random sampling technique from the list of 150 wards in the GHMC area. Each selected ward was tentatively divided into four segments. From each segment, 25 households were chosen by selecting the first household randomly and covering the next 24 households contiguously. Thus, around 100 households were sampled from every ward, including all consenting and available males and females aged ≥ 10 years from each household. Subjects were included in the survey irrespective of their current COVID status. Non-consenting subjects, or those who were debilitated, bed-ridden, or severely sick, were excluded from the study.

In total, 5140 households (HHs) were contacted, of which 108 families (2.1%) were unobtainable or kept their door locked, and a further 576 families were rejected. From a final tally of 4456 HHs (9785 participants), 268 individuals were excluded (2.8%); this rejected population was random, with no particular gender or age group bias observed. 9517 blood samples were collected, along with the metadata, as described in the next section. 154 samples were later rejected after antibody assays, or had incomplete metadata, and final seroprevalence was assessed from the remaining 9363 samples.

Data collection and ethical approval

Ethical approval was obtained from the Institutional Ethical Committee. Data were collected by 15 field teams and three lab teams. Each field team consisted of a medical officer/scientist, a technician, and a phlebotomist. Each lab team consisted of a scientist (microbiologist) and three lab technicians. For supervision and monitoring, there were three survey coordinators, one lab coordinator, and one overall study coordinator. The data collection was completed in the month of January in two phases: 1st phase — January 8–12, 2021; 2nd phase — January 21–24, 2021. Data were collected using an ODK-based computer-assisted personal interview with a structured questionnaire (Supplementary material 1), which involved mostly closed-ended questions. This had been used in the previous three rounds of national serosurveys, including the districts and cities of Telangana.

The study team visited the randomly selected households and briefed them about the survey objectives and the processes involved. The state health department and other authorities actively participated in cooperating with the survey teams. Individual written informed consent was obtained from all participants. Subjects aged 10–18 years were asked for consent, which was countersigned by parents/legal guardians. A participant information sheet (PIS, Supplementary material 2) was also provided to each participant, elucidating the study details. Interviews were conducted in the households at the convenience of the participants, in order to ensure privacy. No gifts or monetary benefits were offered to subjects to participate in the survey. However, the antibody test result was shared with each individual confidentially.

After obtaining individual written informed consent, information on socioeconomic and demographic details (including name, age, gender, community, religion, educational status, occupation, family size, and number of rooms), exposure history to COVID-19, symptoms suggestive of COVID-19 since the beginning of the pandemic, and clinical history of comorbidities was recorded. When eligible individuals in a household were unavailable, the data collection team moved onto the next household to enroll the required number of subjects. Trained phlebotomists in each of the 15 survey teams collected 3–4 ml of venous blood from each participant. Serum was separated after centrifugation at ICMR-NIN. Estimation of SARS-CoV-2-specific antibodies was performed at CSIR-CCMB, Hyderabad. Data were stored securely under the principal investigator's responsibility, with a focus on ensuring the participant confidentiality. Samples were anonymized and the identifying details not shared with anyone except the principal investigator. However, each IgG antibody test result was shared with the individual for their information. Final reports and aggregated data were prepared without any identifying information.

Antibody titre assays and measurement

The samples were tested for total SARS-CoV-2 antibodies via electrochemiluminescence immunoassay using the Elecsys Anti-SARS-Cov-2 kit

Table 1
Demographic characteristics of study subjects

Variable		*N*	%
Gender	Male	4208	45.0
	Female	5142	54.9
	Other gender	13	0.1
Age group (years)	10–19	1542	16.5
	20–29	2017	21.5
	30–39	2012	21.5
	40–49	1575	16.8
	50–59	1132	12.1
	60–69	736	7.9
	≥ 70	349	3.7
Education level	Illiterate	1473	15.8
	Read and write	847	9.0
	Primary	1371	14.6
	Secondary	2318	24.8
	Intermediate	1263	13.5
	Graduate and above	2091	22.3
Family size	≤ 4	6098	65.1
	5–6	2743	29.3
	≥ 8	522	5.6
Number of rooms in the residence	≤ 2	4796	51.3
	3–4	3924	41.9
	5–6	555	5.9
	≥ 7	88	0.9

(Roche Cobas E411), based on a recombinant protein representing the nucleocapsid (N) antigen for antibody determination, as per the manufacturer's protocol. Samples that had a COI (cutoff index; signal sample/cutoff) > 1 were considered positive for the presence of antibodies.

Statistical analysis

Data were analyzed and visualized using SPSS v.22 and ggplot2. In-house scripts were used for filtering and categorization of data. Samples with unknown data fields were removed from analysis. Seroprevalence was calculated based on the number of samples with an antibody titre COI > 1, and analyzed according to the demographic measures surveyed. Sample characteristics and outcome variables (seroprevalence) were described as percentages according to age group, gender, education status, occupation, family size, and number of rooms in the household. The chi-square test was used to test the significance of differences in seroprevalence among groups, with $p < 0.05$ considered as statistically significant. Multivariate analysis was carried out with seropositivity as the dependent variable, with independent variables including age, gender, level of education, number of rooms, family size, hypertensivity, and diabetic status. For analysis of family transmission, households with only one member or those with no seropositive members were excluded.

Results

Over half the surveyed population showed prior exposure to SARS-CoV-2 infection

In total, 9517 blood samples were collected from 4456 households, residing in 30 wards distributed over six zones across the city of Hyderabad, India (see Methods). 154 samples were rejected or had incomplete metadata, so seroprevalence was assessed from the remaining 9363 samples. Of these, 5076 were positive for SARS-CoV-2 antibodies, giving an overall positivity of 54.2% (95% CI, 53.2–55.2). Most of the wards surveyed had a uniform distribution of seropositivity, ranging from 50–60% (Figure 1). However, a few wards showed evidence of higher exposure to the coronavirus (maximum ward seroprevalence of ~ 72%), while eight wards had seroprevalence of < 50%, indicating a more susceptible population in these areas. Out of the six zones making up the city, Secunderabad had the highest seroprevalence (61.6%), while L.B. Nagar showed the lowest seroprevalence (43.3%).

Prevalence among various socioeconomic and demographic groups

The socioeconomic status and demographics of the participants are summarized in Table 1. The study participants were ≥ 10 years of age (mean age = 36.6 years; SD = 16.4) and were grouped into seven age groups. The lowest seroprevalence was found among those aged > 70 years (47.6%; $p < 0.05$, 95% CI), possibly reflecting a poorer geriatric immune response or lower mobility and/or a greater degree of precautions taken by older individuals during the pandemic. The highest exposure levels were found in the 30–39 and 50–59 year-old age groups (56.7%). Individuals in their 20s and 30s accounted for the largest proportion of samples (43% of total respondents), while there was a lower representation of older individuals (349 samples in the > 70 years age group).

Approximately 55% of the samples were from females. Enrolled individuals consisted of 5143 females and 4209 males, with the weighted seroprevalence was marginally higher in females (55.2%; 95% CI: 53.8–56.6%) compared with males (53.0%; 95% CI, 51.5–54.5%). This difference was statistically significant ($p = 0.036$), and the same trend was seen across all the age groups, except in individuals aged 10–29 years (Table 2).

Nearly 84% of the participants were literate, with the most common levels of education being secondary school (24.75%) and graduation and above (22.3%). SARS-CoV-2 exposure levels were similar across the various educational strata, ranging between 52.7% and 57.5%, aside from the graduates, where the level remained low, at 49.2% ($p < 0.001$). The exposure levels also showed an increasing trend with the family size, ranging from 53.1% when the family size was up to four people to 58.8% when it was eight or more ($p < 0.05$) (Table 2). Multivariate analysis confirmed that older age groups had lower odds of being seropositive, while lower education levels and bigger family size had higher odds of seropositivity (Table 3).

Degree of transmission in households

The majority (71.4%) of the individuals reported no known contact with COVID-positive persons and yet 52.6% of them were seropositive (with possibly unknown sources of infection); this was similar to the overall population prevalence (Table 2). 3.61% of individuals reported contact with a known COVID-positive person outside their own household; of these, 67.3% were found to be seropositive. Only 2.57% of the total participants reported contact within their household, and the seropositivity was found to be the highest (78.4%) within this group, suggestive of effective family transmission.

In order to estimate the degree of household transmission, our study analyzed the family members across all the households surveyed. Families consisted of 1–9 members, living in single- or multi-room homes (1 to >5 rooms per household). The majority of the households surveyed comprised small families with four or fewer members (65.1%). Nearly half of the surveyed households dwelt in houses with only two rooms (51.2%). 1473 households had no seropositive family members and were not considered for the family transmission analysis. Among families where at least one member was seropositive, no specific trends could be observed with increasing room number or space for isolation in the context of avoiding infection spread.

Correlation with confirmed COVID-19 or other diseases

Although more than half the population was positive in the antibody assay, indicating prior exposure to SARS-CoV-2, very few individuals appeared for COVID testing (17% of our study group) (Figure 2a). Importantly, 87.2% of the individuals testing positive for COVID (via either rapid antigen test or RT-PCR) still had detectable antibodies to the virus, suggesting retention of the antibody response at the time of this study (Figure 2b), compared with only ~ 53% of those who were not tested, or 55% of those who were negative for the COVID test. However, since the

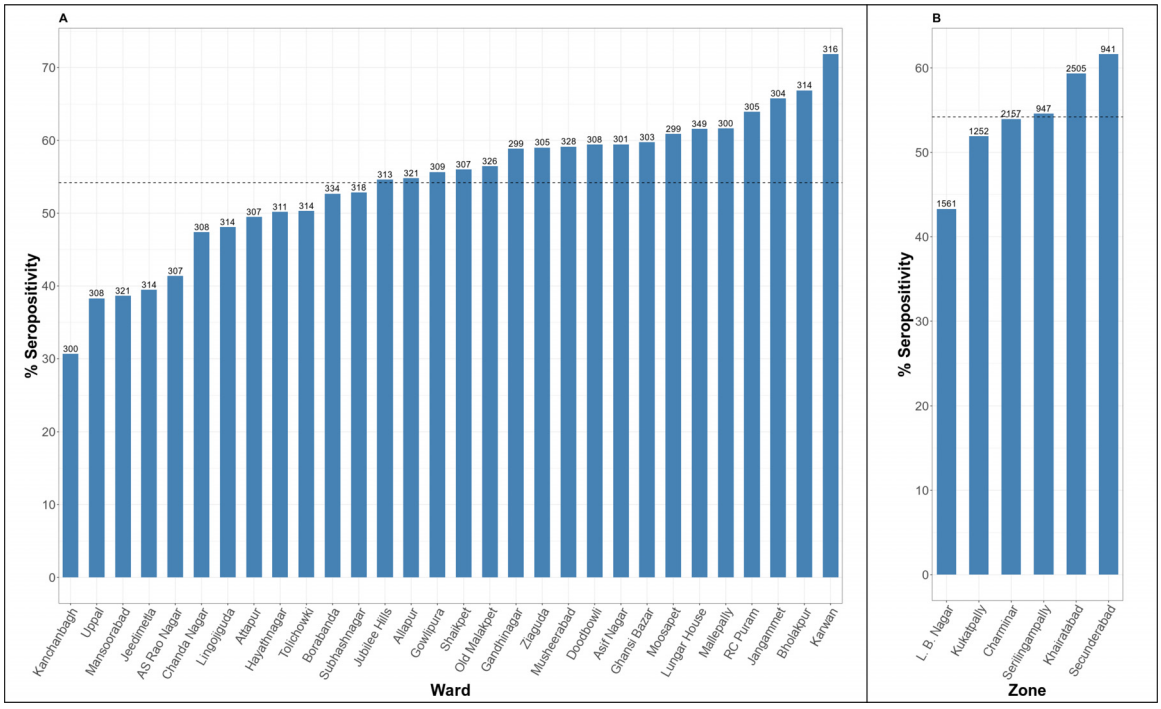

Figure 1. Estimated seroprevalences across different GHMC wards in Hyderabad. Seropositivity (%; *y*-axis) plotted across (A) 30 wards and (B) six zones in Hyderabad. An average positivity of 54.2% was found (dotted line; 95% CI: 53.2–55.2). Most of the wards surveyed had a uniform seropositivity distribution, ranging from 50% to 60%. Values above the bars indicate the numbers of individuals surveyed in the group.

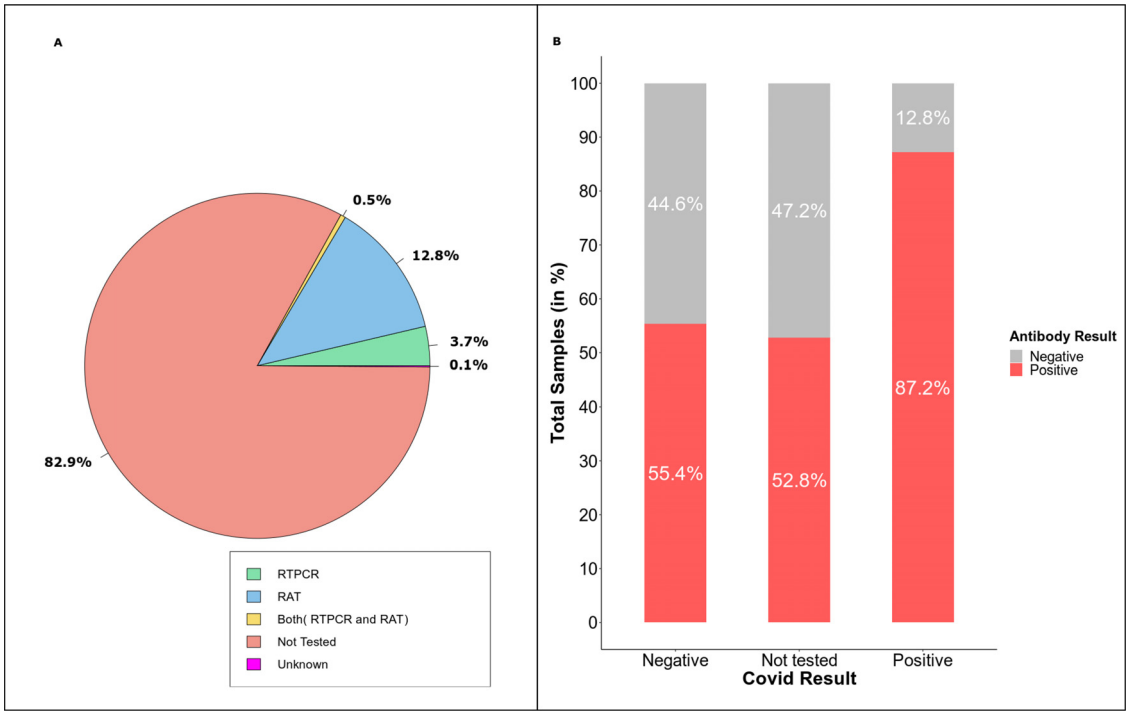

Figure 2. Distribution of survey subjects by COVID testing status. (A) Pie-chart representing the percentages of participants who appeared for a COVID test (RAT and/or RT-PCR). (B) Percentages of individuals (*y*-axis) who were found to be seropositive (red) or not (grey), categorized according to COVID test result (*x*-axis).

precise dates of the COVID testing were not available, the period of the retention of antibody response could not be estimated from this study.

Out study also examined symptoms status, and found that only about 11% of the total individuals surveyed (1009 out of 9363) reported any of the symptoms known to be associated with COVID-19. These results suggest that most of the seropositive people were unaware of having contracted the infection, and a majority of them remained asymptomatic. As expected, seropositivity was higher in the symptomatic group (61.7%) compared with the asymptomatic group.

Among the eight symptoms covered in our survey (Table 2), cough and fever were reported by nearly 550 (5.87%) individuals, while diarrhea, excessive tiredness, sore throat, and loss of smell and taste were

Table 2
Prevalence of SARS-CoV-2 antibodies among people of GHMC, Telangana by sample characteristics

Variable		*N*	Seropositivity (%)	95% CI		*p*-value
				Lower	Upper	
Gender	Male	4208	53.0	51.5	54.5	0.036
	Female	5142	55.2	53.8	56.6	
	Other gender	13	53.8	26.7	80.9	
Age group (years)	10–19	1542	54.6	52.1	57.1	0.004
	20–29	2017	52.7	50.5	54.9	
	30–39	2012	56.7	54.5	58.9	
	40–49	1575	53.7	51.2	56.2	
	50–59	1132	56.7	53.8	59.6	
	60–69	736	51.0	47.4	54.6	
	≥ 70	349	47.6	42.4	52.8	
Education level	Illiterate	1473	55.6	53.1	58.1	0.0001
	Read and write	847	55.8	52.5	59.1	
	Primary	1371	52.7	50.1	55.3	
	Secondary	2318	57.5	55.5	59.5	
	Intermediate	1263	55.3	52.6	58.0	
	Graduate and above	2091	49.2	47.1	51.3	
Family size	≤ 4	6098	53.1	51.8	54.4	0.005
	5–7	2743	55.9	54.0	57.8	
	≥ 8	522	58.8	54.6	63.0	
Number of rooms in residence	≤ 2	4796	54.9	53.5	56.3	0.216
	3–4	3924	53.7	52.1	55.3	
	5–6	555	53.2	49.0	57.4	
	≥ 7	88	45.5	35.1	55.9	
History of contact with COVID-19 subjects	Yes (in HH)	241	78.4	73.2	83.6	0.0001
	Yes (outside HH)	339	67.3	62.3	72.3	
	No	6688	52.6	51.4	53.8	
	Do not know	2095	54.5	52.4	56.6	
RT-PCR/RAT test status	Positive	298	87.2	83.4	91.0	0.0001
	Negative	1291	55.2	52.5	57.9	
Symptoms presented by the study subjects	Cough	545	62.0	57.9	66.1	
	Breathlessness	97	64.9	55.4	74.4	
	Fever	552	66.8	62.9	70.7	
	Sore throat	340	60.6	55.4	65.8	
	Loss of smell	87	86.2	79.0	93.4	
	Loss of taste	69	87.0	79.1	94.9	
	Excessive tiredness	153	68.0	60.6	75.4	
	Diarrhea	40	72.5	58.7	86.3	
Comorbidities reported by study subjects	Diabetes	852	53.9	50.6	57.2	
	Hypertension	1235	53.2	50.4	56.0	
	Hypertension or diabetes	1623	54.1	51.7	56.5	
	Any heart disease	122	54.9	46.1	63.7	
	Cancer	14	50.0	23.8	76.2	
	Chronic respiratory diseases	38	42.1	26.4	57.8	
	Renal diseases	17	58.8	35.4	82.2	
	Liver diseases	7	42.9	6.2	79.6	
	Thyroid diseases	518	51.2	46.9	55.5	
	Smoking	275	40.0	34.2	45.8	

reported by very few individuals (< 340). Loss of smell and taste, however, showed the strongest association with seropositivity among the few individuals who reported these symptoms (> 86%). Among those reporting the relatively more common symptoms of cough and fever, seroprevalence was also found to be higher than the population average (61–72.5%). Most of the symptomatic individuals suffered from only one or two symptoms (487/1009, 48.3% and 328/1009, 32.5%, respectively) while a few reported a combination of three or more symptoms (194/1009, 19.2%).

Very few participants reported being afflicted with comorbidities or other systemic diseases associated with increased severity of COVID-19, with 78% of the subjects having none of the eight comorbidities tested (Table 2). Furthermore, even among the individuals with more prevalent comorbidities, such as diabetes and hypertension (1623 individuals), there was no change in seropositivity, which remained at 54.1%. Lower seropositivity (40%) was found among self-declared smokers compared with the non-smokers. Although the number of participants who smoked was low (275), these results were significant ($p < 0.05$, 95% CI) and suggested possible protection against COVID-19. It remains to be established if there were any behavioural links that reduced the chance of infection in this study group, or whether they had poorer or shorter duration of antibody response.

Discussion

The Indian Council of Medical Research (ICMR) has been carrying out repeated cross-sectional surveys in 70 districts from 21 states for national-level estimation, and three rounds of surveys have already been completed and reported. Since these surveys are not appropriate for drawing inferences at a micro level, our survey was designed to estimate seroprevalence levels at the end of the first year of the pandemic in the GHMC area (Hyderabad, India), between the first and the second waves of infections.

Pan-India seroprevalence studies began in May 2020 (when the assumed prevalence was 1% or lower). A series of studies carried out in New Delhi in 2020 showed that the adjusted seroprevalence declined from 28.4% in August to 24.1% in September and 24.7% in October. It was also reported that participants with lower per capita income,

Table 3
Multivariate analysis of factors affecting seropositivity among people of GHMC

		Unadjusted OR	95% CI		AdjustedOR	95% CI	
			Lower	Upper		Lower	Upper
Age group	10–19	Reference					
	20–29	0.93	0.81	1.06	1.00	0.87	1.15
	30–39	1.09	0.95	1.24	1.14	0.99	1.30
	40–49	0.97	0.84	1.11	0.99	0.86	1.16
	50–59	1.09	0.93	1.27	1.09	0.92	1.30
	60–69	0.86	0.72	1.03	0.86	0.71	1.06
	≥ 70	**0.75***	0.60	0.95	**0.76***	0.59	0.99
Sex	M	Reference					
	F	**1.09***	1.01	1.18	1.06	0.98	1.16
Level of education	Illiterate	**1.29***	1.13	1.48	**1.28***	1.10	1.49
	Read and write	**1.31***	1.11	1.53	**1.25***	1.05	1.48
	Primary	**1.15***	1.00	1.32	1.11	0.97	1.29
	Secondary	**1.40***	1.24	1.58	**1.37***	1.21	1.55
	Intermediate	**1.28***	1.11	1.47	**1.25***	1.09	1.45
	Graduation and above	Reference					
Number of rooms	≤ 2	1.46	0.96	2.23	**1.58***	1.02	2.45
	3–4	1.39	0.91	2.12	1.51	0.98	2.34
	5–6	1.36	0.87	2.14	1.37	0.87	2.17
	≥ 7	Reference					
Family size	≤ 4	Reference					
	5–7	**1.12***	1.02	1.22	**1.14***	1.04	1.25
	≥ 8	**1.26***	1.05	1.51	**1.36***	1.12	1.65
Hypertensive or diabetic	Either	0.99	0.89	1.11	1.06	0.93	1.20
	None	Reference					

* Statistically significant at $p < 0.05$

those living in slums or overcrowded households, and those with diabetes comorbidity had significantly higher statistical odds of having antibody positivity (Sharma et al., 2021). At its lowest, seroprevalence was, found to be 1% in the state of Kerala and at a pan-India level in June 2020 (Murhekar et al., 2020), increasing to 19% in November 2020 (Kallathiyan et al., 2020). Our study documented a much higher seroprevalence level in Hyderabad (54.2%) than those seen in other states, such as Tamil Nadu (31%) (Malani et al., 2021; Malani et al., 2021), Uttar Pradesh, Gujarat, West Bengal, Madhya Pradesh, Karnataka, and Chhattisgarh (41%) (Singh et al., 2021), in the same timeframe (November 2020 to January 2021). Some studies reported much lower seroprevalences, for example 17.6% in Ahmedabad (Prakash et al., 2021) and 3.1% in Srinagar (Khan et al., 2020), in November–December 2020. The findings of our study were similar to those from Mumbai (Malani et al., 2021), Chennai (Selvaraju et al., 2021), and Karnataka (Mohanan et al., 2021) in July 2020, suggesting that urban populations experienced much higher seroprevalences than the national average prevalent at that time.

Globally, some larger geographical regions have also reported lower seropositivity levels when compared with urban and other localized studies. A study conducted from September to December 2020 in southern Italy found only 5.8% seropositivity (Napolitano et al., 2021). Another study in France by (Gégout Petit et al., 2021), conducted in June 2020, showed a seroprevalence of 2.1%, while a similar population-based study estimated 9% seropositivity for the population of Saint Petersburg, Russia (Barchuk et al., 2021). An important caveat to note is that antibody testing kits used in seroprevalence surveys are not very sensitive; nor are they all uniform. Thus, direct comparisons of results from different studies should be interpreted cautiously.

Our study found gender-related differences in seropositivity levels, as also documented by some of the above-mentioned serosurveys in India. Females appear to generate better protective antibody responses than do males following vaccination against influenza, yellow fever, dengue, and several other viruses (Offord, 2021). Differential exposure and susceptibility between the genders, as well as behavioural and immunological divergence, have been cited to account for similar seroprevalence differences found in other surveys across the country. However, a recent review looking at global seroprevalence rates concluded that, in most other countries, males had a slightly higher seropositivity than females, or there was no difference found between the genders (Lai et al., 2020).

Although we found no correlation with any known comorbidities, some difference in seroprevalence was found with smoking, which causes the upregulation of the ACE-2 receptor (Leung et al., 2020). Most of the survey subjects appeared to be asymptomatic for the known COVID-19 symptoms prevalent in the first wave of infections, and were likely to be unaware of their infected status. It is unclear whether genetic and/or environmental and behavioural differences contributed to any of the observed differences among individuals. Larger studies in these target groups are needed for direct comparison and further conclusions.

The strength of our study lay in its robust sampling mechanism and the uniformly high coverage in terms of the geographical distribution of the study area. However, self-reporting meant that the recording of histories of comorbidities, and demographic and socio-economic inputs, was based on the information provided by the participants. The timeframe for history of COVID-19 infection and symptoms (a reference period covering up to 9 months at the time of the survey) could also be a source of recall bias. Around 11% of the families and 13% of eligible subjects in all the age groups were not available in their houses, and could not participate in the survey. Finally, considering that SARS-CoV-2 infection was still considered a stigmatising event at the time of the survey, some participants may not have disclosed accurate information. The same holds true for risk behaviours such as smoking and medical histories. Thus, social desirability bias issues should be kept in mind while evaluating the data.

A significant aspect of our study was the identification of pockets of low seroprevalence (as low as 31%) at the start of this year. These represented a reservoir of uninfected and susceptible individuals, and may have contributed to the high levels of infection seen across the country in the second wave. With the ongoing vaccination drive expected to take many months to complete, and the emergence of novel variants of the virus that may have properties relating to immune escape or increased transmission, we cannot afford to let our guard down at this stage. Frequent serosurveys will be essential in monitoring the course of the pandemic in the months ahead.

Conclusions and implications

Our study showed that overall SARS-CoV-2 seropositivity was around 54% across the population of GHMC, Hyderabad, Telangana, not including children below 10 years of age. It is highly desirable that, irrespective of the seropositivity levels seen at the beginning of this year, most eligible individuals get vaccinated, taking advantage of the robust protection provided by the available vaccines. As demonstrated in recent months, high levels of SARS-CoV-2 infection provide the replicating virus with a chance to acquire mutations, with consequences for ongoing pandemic mitigation strategies. In the worst-case scenario, the benefits gained by high seroprevalence or the ongoing vaccination drive may be undone by emerging immune-escape variants. It is therefore highly advisable to promote the continued use of non-pharmacological measures, such as mask wearing, hand hygiene, and physical distancing, while avoiding indoor and large-scale gatherings.

Author contributions

AL, NMR, SS: Overall execution of the study and draft writing of the manuscript.

NA, JJB, PUK, SS, DTS: Supervision of data collection, quality control of data entry, and critical review of the manuscript.

MAV, SKT, KBT: Estimation of IgG antibodies from serum samples.

BDK: Processing of blood and preparation of serum aliquots.

MVM, MSK, RSN: Study methodology and development of ODK plot form online data collection.

NKB, PS, DS, SS, DTS: Data processing, data analysis, and visualization.

RA, DAB, BPPS, CKD, SD, MMK, IIM, BNK, PS, PRV, PR, KRR, PRN, BSK, GS, JSR, MVR, SF, BDK, GSR: Supervision of teams, data collection, and review of manuscript.

RH, RKM: Overall coordination of the study and critical review of the manuscript.

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Informed consent

Ethical approval was obtained from the Institutional Ethical Committee (NIN-ICMR). Written informed consent was obtained from all the survey participants. Samples were anonymized, and privacy of individual participants was maintained.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijregi.2021.10.009.

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