

Seroprevalence of SARS-CoV-2 in slums versus non-slums in Mumbai, India

Estimating seroprevalence is crucial for controlling the transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). There are few published serosurveys in low-income and middle-income countries, which comprise over two-thirds of confirmed cases of COVID-19.¹ India has 6·1 million confirmed cases—a fifth of the worldwide total. Socioeconomic disparities and population density might drive disease dynamics in megacities that account for a large share of India's cases. To address these issues, we estimated prevalence in six slum and non-slum communities across three wards (one each from the three zones) of Mumbai, India.

This study was approved by the Indian Government and Institutional Review Boards at participating institutions (appendix p 1). On the basis of power calculations to estimate a 1·5 percentage-point difference in prevalence in a two-sided test with 95% CI in each study site, we aimed to test a total of 8870 individuals from both slum and non-slum communities across three wards: 2249 from Matunga, 1622 from Chembur West, and 576 from Dahisar (appendix p 11). We confined sampling between June 29 and July 19, 2020, to ensure that prevalence did not change substantially during the study. Individuals aged 12 years or older were eligible; those who did not consent or had contraindications to venipuncture were excluded.

Working in eight of the largest slums per ward, we divided each slum into areas covering roughly 400 homes. We sampled 100 homes per area, starting from the centroid of each area and selecting every fourth home. We divided the non-slum areas of each ward into cells of equal size so that sampling 100 persons per cell would

meet our target sample size for that ward. Starting from a building at the centre of each cell, we obtained consent from resident associations to recruit one household per floor. We sampled adjacent buildings this way until the target was met or the study period ended.

Surveyors sought voluntary consent from one person per household, rotating through a list of eight demographic groups (female and male participants from four age strata) across households. Our final sample is a function of the population distribution across groups and consent rate per group.

We collected data on household demographics and 5 mL of blood from participants via venipuncture. Samples were tested for IgG antibodies to the nucleocapsid via chemiluminescence by use of Abbott Diagnostics Architect test (Abbott, IL, USA), for which sensitivity ranged from 90·0% (95% CI 74·4–96·5)² to 96·9% (89·5–99·5)³ and specificity from 100·0% (95·4–100·0)² to 99·9%.³

We estimated the proportion of tests that were positive using Abbott's recommended cutoff (1·4) and score CIs. We used binomial regression of test results on indicators for age and sex to estimate demographic correlates of positive tests. By use of weights that matched the demographic distribution in samples and their respective sites, we calculated age-weighted and sex-weighted proportions. We used data from India's 2011 Census to aggregate adjusted proportions to the slum and non-slum level across wards. We derived adjusted seroprevalence from adjusted proportions using the Rogan-Gladen⁴ correction for imperfect test accuracy, assuming low and high estimates of sensitivity and associated specificity. CIs for adjusted proportions are adjusted Wald intervals and those for seroprevalence are unadjusted Wald intervals; statistical comparisons employ Wald tests. We examined sensitivity to the cutoff recommended

by Abbott by plotting the distribution of underlying IgG scores and estimated proportions under different cutoffs. We mapped the proportion of positive tests to location using latitude and longitude rounded to 4 significant digits. We analysed 4202 samples from slums and 2702 samples from non-slums (appendix pp 11–13).

Consent rates in slums were comparable with other studies.¹ For instance, in slums in Matunga, we recruited 45·6% of households visited. Based on field notes, over half of the households not sampled were due to homes being empty rather than non-consent. Recruitment fell short of sample-size targets in non-slum areas due to low consent rates. However, such rates cannot be quantified because we do not have information on the number of flats per building.

The proportions of positive tests by age and sex in different sites (appendix p 9) show markedly higher proportions in slums than in non-slums. Regression estimates (appendix p 14) suggest that unadjusted positive proportions were higher among women than among men (slums $p < 0·001$; non-slums $p < 0·001$). Intriguingly, although proportions of positive tests among individuals aged older than 60 years were lower in non-slums (vs age 12–24 years; $p < 0·0223$), it was higher in slums (vs age 25–39 years; $p < 0·001$).

Reweightings our sample to account for population demographics (appendix p 12) and population in each ward showed that 54·1% of samples in slums and 16·1% of those in non-slums tested positive (appendix p 8)—a significant difference ($p < 0·001$). Our estimates of adjusted seroprevalence are higher in slums (means ranging from 55·1% to 61·4%) than in non-slums (mean ranging from 12·0% to 18·9%) across wards (appendix p 8). Underlying IgG scores are higher and the positive rate is more sensitive to the manufacturer's recommended cutoff in slums than in non-slums (appendix pp 16–17).



Lancet Glob Health 2020

Published Online
November 13, 2020
[https://doi.org/10.1016/S2214-109X\(20\)30467-8](https://doi.org/10.1016/S2214-109X(20)30467-8)

See Online for appendix

Mapping our estimates to locations (appendix p 10) showed sharp differences over distances as little as 100 m. Our estimates of seroprevalence suggest a high reproductive rate of SARS-CoV-2 in slums. Combined with reported COVID-19 cases and numbers of death in sampled wards, our findings suggest a high asymptomatic spread of the infection and an infection fatality rate of 0.076% in slums and 0.263% in non-slums. The higher prevalence in slums could be driven by population density, lower adherence to distancing measures, and poorer hygiene. This stark variation in prevalence within wards also highlights the importance of geographic variation for epidemiological modelling⁵ and policy discussions of herd immunity. Although moderate consent rates might bias our estimates of proportions of positive tests, the unadjusted age-weighted and sex-weighted proportions are not significantly different (appendix p 15).

JS reports to the Municipal Corporation of Greater Mumbai. All other authors declare no competing interests. The author list is provided in alphabetical order on first name basis.

Copyright © 2020 The Author(s). Published by Elsevier Ltd. This is an Open Access article under the CC BY-NC-ND 4.0 license.

**Anup Malani, Daksha Shah,
Gagandeep Kang, Gayatri Nair Lobo,
Jayanthi Shastri, Manoj Mohanan,
Rajesh Jain, Sachee Agrawal,
Sandeep Juneja, Sofia Imad,
*Ullas Kolthur-Seetharam**
ullas@tifr.res.in

Medical School and Law School, University of Chicago, Chicago, IL, USA (AM); Brihanmumbai Municipal Corporation, Mumbai, India (DS); Department of Gastrointestinal Sciences, Vellore Christian Medical College, Vellore, India (GK); ATE Chandra Foundation, India (GNL); Kasturba Hospital, Mumbai, India (JS); Sanford School of Public Policy, Duke University, Durham, NC, USA (MM); Clinical Development Services Agency, India (RJ); Topiwala National Medical College and BYL Nair Charitable Hospital, Mumbai, India (SA); School of Technology and Computer Science, Tata Institute for Fundamental Research, Mumbai, India (SJ); IDFC Institute, Mumbai, India (SI); and Department of Biological Sciences, Tata Institute for Fundamental Research, Mumbai 400 005, India (UK-S)

We thank the Municipal Corporation of Greater Mumbai (Suresh Kakani, Mangla Gomare, the Assistant Commissioners, and Municipal Officers of

Health of the three wards) and NITI-Aayog-Government of India (Alok Kumar and Madan Gopal) for their support during the duration of the project. The authors also thank Poonam Choksi (ATE Chandra Foundation), Priya Maisheri (CDSA), and Sandeep Singhal (Nexus Venture Partners) for their contribution to the study. Finally, we thank all field teams and participants involved in this project. The study was funded by Action Covid19 Team, ATE Chandra Foundation, and Godrej Seeds and Genomics. One of the co-authors, GNL (ATECF) participated in study design and facilitated implementation of the field work. The study sponsors (including GNL) had no role in analysis, interpretation of data, writing the manuscript, and decision to submit for publication.

- 1 Hallal PC, Hartwig FP, Horta BL, et al. SARS-CoV-2 antibody prevalence in Brazil: results from two successive nationwide serological household surveys. *Lancet Glob Health* 2020; **8**: e1390–98.
- 2 US Food and Drug Administration. EUA authorized serology test performance. <https://www.fda.gov/medical-devices/coronavirus-disease-2019-covid-19-emergency-use-authorizations-medical-devices/eua-authorized-serology-test-performance> (accessed Oct 25, 2020).
- 3 Bryan A, Pepper G, Wener MH, et al. Performance characteristics of the Abbott Architect SARS-CoV-2 IgG assay and seroprevalence in Boise, Idaho. *J Clin Microbiol* 2020; **58**: e00941–20.
- 4 Rogan WJ, Gladen B. Estimating prevalence from the results of a screening test. *Am J Epidemiol* 1978; **107**: 71–76.
- 5 Britton T, Ball F, Trapman P. A mathematical model reveals the influence of population heterogeneity on herd immunity to SARS-CoV-2. *Science* 2020; **369**: 846–49.