Full title: Structural factors contributing to SARS-CoV-2 infection risk in the urban slum setting

Short title: SARS-CoV-2 infections in the urban slum setting

Keywords: SARS-CoV-2, urban slums, children, gender, social inequity

Authors: Mariam O. Fofana1*, Nivison Nery Jr2,3*, Juan P. Aguilar Ticona2,3*, Emilia M.M.A. Belitardo3, Renato Victoriano3, Rôsangela O. Anjos3, Moyra M. Portilho3, Mayara C. de Santana3, Daiana de Oliveira3, Jaqueline S. Cruz7, M. Cate Muencker3, Ricardo Khouri3, Elsio A. Wunder Jr1, Matthew D.T. Hitchings4, Olutunji Johnson6, Mitermayer G. Reis1,3,5, Guilherme S. Ribeiro3,5, Derek A.T. Cummings7,8, Federico Costa1,2,3, Albert I. Ko1,3

*These authors contributed equally to this work

Affiliations
1. Department of Epidemiology of Microbial Diseases, Yale School of Public Health, New Haven CT, USA
2. Instituto de Saúde Coletiva, Universidade Federal da Bahia, Salvador BA, Brazil
3. Instituto Gonçalo Moniz, Fundação Oswaldo Cruz, Salvador BA, Brazil
4. Department of Biostatistics, University of Florida, Gainesville FL, USA
5. Faculdade de Medicina, Universidade Federal da Bahia, Salvador BA, Brazil
6. Department of Mathematics, University of Manchester, Manchester, UK
7. Department of Biology, University of Florida, Gainesville FL, USA
8. Emerging Pathogens Institute, University of Florida, Gainesville FL, USA

Corresponding Authors:
Mariam O. Fofana
Room 319A
60 College St
New Haven, CT 06510
mariam.fofana@yale.edu

Albert I. Ko
Room 319B
60 College St
New Haven, CT 06510
albert.ko@yale.edu

Funding statement
This work was supported by grants from the National Institutes of Health (R01 AI052473, U01AI088752, R01 TW009504 and R25 TW009338 to A.I.K.), UK Medical Research Council (MR/T029781/1 to F.C.), Wellcome Trust (102330/Z/13/Z; 218987/Z/19/Z to F.C.), Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES88881.130749/2016-01 to G.S.R.), Brazilian National Council for Scientific and Technological Development (CNPq 440891/2016-7 and research scholarship to G.S.R.), Bahia Foundation for Research Support (FAPESB SUS0019/2021 and PET0022/2016 to G.S.R.), and the Sendas Family Fund at the
Yale School of Public Health (A.I.K.). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

**Conflicts of Interest:** A.I.K serves as an expert panel member for Reckitt Global Hygiene Institute, scientific advisory board member for Revelar Biotherapeutics and a consultant for Tata Medical and Diagnostics and Regeneron Pharmaceuticals, and has received grants from Merck, Regeneron Pharmaceuticals and Tata Medical and Diagnostics for research related to COVID-19, all of which are outside the scope of the submitted work. Other authors declare no conflict of interest.
Abstract

Background
The structural environment of urban slums, including physical, demographic and socioeconomic attributes, renders inhabitants more vulnerable to SARS-CoV-2 infection. Yet, little is known about the specific determinants that contribute to high transmission within these communities.

Methods and findings
We performed a serosurvey of an established cohort of 2,035 urban slum residents from the city of Salvador, Brazil between November 2020 and February 2021, following the first COVID-19 pandemic wave in the country. We identified high SARS-CoV-2 seroprevalence (46.4%, 95% confidence interval [CI] 44.3-48.6%), particularly among female residents (48.7% [95% CI 45.9-51.6%] vs. 43.2% [95% CI 39.8-46.6%] among male residents), and among children (56.5% [95% CI 52.3-60.5%] vs. 42.4% [95% CI 39.9-45.0%] among adults). In multivariable models that accounted for household-level clustering, the odds ratio for SARS-CoV-2 seropositivity among children was 1.96 (95% CI 1.42-2.72) compared to adults aged 30-44 years. Adults residing in households with children were more likely to be seropositive; this effect was particularly prominent among individuals with age 30-44 and 60 years or more. Women living below the poverty threshold (daily per capita household income <$1.25) and those who were unemployed were more likely to be seropositive.

Conclusions
During a single wave of the COVID-19 pandemic, cumulative incidence as assessed by serology approached 50% in a Brazilian urban slum population. In contrast to observations from
industrialized countries, SARS-CoV-2 incidence was highest among children, as well as women living in extreme poverty. These findings emphasize the need for targeted interventions that provide safe environments for children and mitigate the structural risks posed by crowding and poverty for the most vulnerable residents of urban slum communities.
Introduction

More than 1 billion people who reside in urban slums or informal settlements are at increased risk of COVID-19, but also most likely to suffer loss of employment and income due to disease control measures such as lockdowns [1,2]. Although several studies have demonstrated an association of socioeconomic deprivation with increased COVID-19 risk and mortality, such studies have generally relied on ecological designs, or have compared poor communities to wealthier ones [3,4]. Moreover, studies relying on passive reporting of cases may suffer from surveillance bias. Prior studies of transmissible and non-transmissible diseases have shown variations in risk not only between communities but also within socially deprived environments, where certain segments of the population may be particularly vulnerable [5,6]. Yet, there remains little known about the SARS-CoV-2 risk gradients within urban slum communities and how these risk gradients may inform targeted interventions for this vulnerable population. Although the conditions and structure of each slum community are unique, there may be valuable common insights: regardless of geography, slums are invariably densely populated, have poor infrastructure, lack of access to services, and are inhabited by residents who experience significant housing and financial insecurity.

Brazil is among the countries that have suffered the highest burden of COVID-19, with more than 622,000 deaths reported as of February 2022 among its 213 million inhabitants over the course of several epidemic waves, the first of which occurred between May and September 2020 [7,8]. Brazil also has roughly 30 million people—16% of its urban population—residing in slum settlements within cities [9]. Prior to the pandemic, we had been performing long-term longitudinal follow-up of a cohort from the city of Salvador, Brazil to characterize the
transmission dynamics and burden of leptospirosis [10], dengue [11], chikungunya [12] and Zika [13] among urban slum residents. Herein, we describe the findings of a serological survey of this cohort conducted after the first epidemic wave in Brazil in 2020, which aimed to examine the socioeconomic and structural factors that influence SARS-CoV-2 infection in the urban slum setting and characterize the gradients of risk within these deprived communities.

Methods

Study site and population

Our study was conducted in the Pau da Lima community in Salvador, Brazil, which has been previously described [10,11,13,14]. Geographically, Pau da Lima consists of hills and valleys, with a population of approximately 25,000 inhabitants per the most recent national census. The study site, shown in Fig. 1(A-C), encompasses four valleys, covering a densely populated area of 0.35 km². Approximately half of the households do not hold legal titles to their homes, and more than 70% of the heads of household earn less than the Brazilian minimum wage [9]. As part of a longitudinal study started in 2001, individuals who reside in the community (defined as sleeping 3 nights or more per week in Pau da Lima), aged 2 years or more and who consented (parental consent for minors) were recruited into an open cohort and participated in household and serological surveys conducted annually or biannually. The most recent survey prior to the pandemic was conducted from September to November 2019 (Figure 1). A survey was performed between November 2020 and February 2021, after the first epidemic wave of COVID-19 and preceding the rollout of vaccines to the general population in February 2021, such that the presence of SARS-CoV-2 antibodies was reflective of prior infection.
Data collection

Surveys and serum samples were collected between November 18, 2020 and February 26, 2021, after the first epidemic wave and in the initial stages of the second wave (Fig. 1D). A community field research team conducted a census of each household, listing the number of residents, gender, and number of people per room. The head of household contributed information on the income of each wage-earning resident in the household. Household income per capita was estimated as the total income of all residents divided by the number of residents in each household. Participants who consented also completed a detailed individual-level survey, including data on COVID-19 exposures, COVID-19 cases in the household, preventive behaviors (e.g. handwashing, mask use), medical history, and symptom history. The survey includes participant-reported socioeconomic variables such as type of employment, race/ethnicity, and level of education. Blood samples were collected by venipuncture from consenting participants and stored in a cooler for transport to the laboratory facility. After centrifugation, the obtained sera were aliquoted and maintained at -20°C until analysis.

Laboratory methods

We measured anti-S IgG in serum samples collected from all cohort participants after the first epidemic wave, and from a subset of participants in a survey conducted prior to the introduction of SARS-CoV-2 in Brazil. Levels of immunoglobulin G against the SARS-CoV-2 spike protein (anti-S IgG) were measured using a commercially available ELISA kit (Euroimmun AG, Lübeck, Germany) according to the manufacturer’s instructions. Samples were diluted 1:100 in sample buffer, and a set of calibrator, positive, and negative control samples were included on each plate. Optical density (OD) was measured at a wavelength of 450 nm and normalized values
were derived by dividing the OD value of each test sample by the value of the calibrator. All samples with a normalized OD $\geq 0.8$ were defined as positive, based on a Bayesian estimation of optimal cutoffs (Fig S2). We also measured anti-S IgG in a subset of serum samples collected from cohort participants prior to the introduction of SARS-CoV-2 in Brazil.

**Data analysis**

The primary outcome was SARS-CoV-2 seropositivity as assessed by anti-S IgG. Independent variables included demographic, socioeconomic, and household variables as assessed from the household and individual surveys. For categorical variables, proportions were compared using the Chi-square test. For continuous variables, we first conducted a visual assessment of correlation with SARS-CoV-2 anti-S IgG positivity and compared distributions using the Wilcoxon rank-sum test. We assessed measures of association using univariable logistic regression. For variables that appeared to have a non-linear relationship with seropositivity risk, we used a spline in a generalized additive model. Variables with a statistically significant ($p<0.05$) association with SARS-CoV-2 seropositivity were included in a multivariable logistic regression model.

Our descriptive analyses revealed higher seroprevalence among participants aged <18 years compared to adults. To further elucidate (1) whether children are more susceptible to COVID-19 and (2) whether they contribute to higher transmission in this setting, we performed a multilevel, multivariable logistic regression that incorporated clustering at the household level and nonlinear effects of age. Individual and per capita income both showed a strong positive correlation with age among adults; we therefore did not include income and age simultaneously in the model. We
assessed model fit based on Akaike Information Criterion (AIC) to select the most parsimonious explanatory model.

As we noted a higher seroprevalence among women compared to men, we conducted a similar analysis among the subset of adult participants (aged ≥18 years), to assess whether the association between gender and SARS-CoV-2 exposure was mediated by income, employment, and household structure in this population. Participants with missing values for independent variables were excluded from the relevant analyses (pairwise deletion). All analyses were conducted using the software R, version 4.1.1 [15].

**Ethical considerations**

The study was approved by the Institutional Review Boards of the Gonçalo Moniz Institute, Oswaldo Cruz Foundation (Fiocruz) and the Brazilian National Commission for Ethics in Research (CAAE 35405320.0.1001.5030 and 17963519.0.0000.0040), and the Yale University Human Research Protection Program (2000031554).

**Results**

**Population demographics**

A total of 2,035 individuals (1,456 adults and 579 children) in 948 households were recruited from a total of 2,481 eligible residents (Figure S1). Serological samples were obtained for every resident in 403 households (917 individuals). Table 1 describes the demographic and socioeconomic characteristics of the study population. The median age was 29 years [IQR 16-44] and 58% were female. The median size of participating households was 3 [IQR 2-4], with a
median household daily per capita income of 2.32 USD [IQR 0.80-4.64]. Most participants reported their ethnicity as Black (51%) or Brown (42%). Overall, 35% (500/1,427) of adult participants had six or fewer years of formal education, and 58% (748/1,288) were unemployed. The majority of participants reported frequent (every day or most days) adherence to handwashing (70.5%), alcohol gel use (67.0%), and face mask use (72.5%), while fewer participants reported frequent social distancing (43.4%) or physical distancing of 2 meters in public spaces (46.6%).

Seroprevalence

Figure 1D shows the serology assay results for the cohort, overlaid on the epidemic curve of confirmed COVID-19 cases in Salvador, Brazil. Among 195 samples that were selected and tested from the pre-pandemic survey, September 9 to November 11, 2019, two (1.0%) were positive. Fitting the observed anti-S IgG levels with a Bayesian mixture model revealed little overlap between the predicted distributions of OD values for individuals with and without a serological response (Figure S2). Based on this model, a cutoff of 0.8 has greater than 95% specificity in identifying serological response (Table S1).

Of the 2,035 samples collected from November 2020 to February 2021, a total of 945 (46.4%, 95% confidence interval [CI] 44.3-48.6%) had positive IgG levels against SARS-CoV-2. Among the 945 seropositive individuals, 273 (28.9% [95% CI 26.0-31.9%]) reported having at least one COVID-19 related symptom (cough, coryza, sore throat, shortness of breath, fever, chills, anosmia, dysgeusia or headache) since the beginning of the pandemic. The frequency of reported symptoms was lower among seronegative individuals (19.4% [95% CI 17.1-21.9%]; difference
9.5% [95% CI 5.7-13.4%]). The proportion of households with at least one seropositive individual was 62.3%.

Risk factors
Seroprevalence was significantly higher among children (56.5% [95% CI 52.3-60.5%]) than adults (42.4% [39.9-45.0%]) and in female (48.7% [45.9-51.6%]) compared to male (43.2% [39.8-46.6%]) participants (Table 1, Figures 2A and 2B). Additional variables associated with seropositivity in univariable analyses included low per capita household income and residents per household among all participants, and unemployment and not being married or in a stable union among adults. We did not observe a significant association with race or education level (Tables 1 and S2). The reported use of non-pharmaceutical interventions was not significantly associated with the risk of seropositivity (Table S3). Because risk factors (including structural environment of the home, health attitudes, and preventive behaviors) are likely to be correlated among members of a household, we further conducted an analysis using a multilevel multivariable model to account for household-level clustering of risk.

Household composition
Adults who have larger households, and those who shared their residence with children were more likely to be SARS-CoV-2 seropositive (Fig 2C and 2D). The effect of the presence of children was particularly pronounced among adults aged 30-44 years (OR 1.57, 95% CI 1.08-2.28) and those aged 60 years or more (OR 1.84, 95% CI 0.93-3.64). Children were also more likely to be seropositive if they lived with other children, but there was no significant difference
in seroprevalence between children who lived with one adult and those who lived with two adults (Fig 2E).

To examine whether the higher seroprevalence among children was mediated by increased crowding in households with children, we implemented binomial regression models with random intercepts per household to account for clustering, and compared several alternative models (Table 2). First, we compared a baseline model including a binary variable for the presence of children in the household (Table 2, Model 1) to an alternative model including the total number of residents in the household (Model 2). Model 2 demonstrated a better fit based on the AIC. We further conducted a mediation analysis on the effect of the presence of children in the household. The OR for the association of presence of children with SARS-CoV-2 seropositivity in Model 1 was 1.32 (95% CI 0.94-1.87). However, after including household size as a variable in Model 3, the effect measure was attenuated (OR 0.90, 95% CI 0.61-1.32), consistent with a mediation effect. We observed similar findings in models that included income rather than age (Table S5).

In the three main models, the OR for SARS-CoV-2 seropositivity among children remained stable (2.08 [1.49-2.89] to 1.96 [1.42-2.72]), suggesting that the higher seropositivity among children was not entirely attributable to household size.

**Poverty and unemployment among women**

We explored the associations between gender and sociodemographic characteristics to elucidate the mechanisms underlying the significantly higher SARS-CoV-2 positivity in women compared to men (48.7% vs 43.2%, p = 0.015). Women were more likely to be unemployed than men (68.0% [95% CI 64.7-71.2%] vs 41.5% [95% CI 37.1-46.1%]) and had lower income per capita
in their households (Fig 3A) regardless of employment status (median [interquartile range] 2.44 [1.56-4.64] vs 3.41 [1.78-6.67] USD/day among employed adults; 1.60 [0-3.33] vs 1.74 [0-4.00] USD/day among unemployed adults). After accounting for income and employment, women had increased risk for SARS-CoV-2 seropositivity compared to men (Fig 3B). Women who were unemployed and had a household per capita income below 1.25 US dollars per day were significantly more likely to be seropositive compared to men with the same employment and income status (OR 2.5, 95% CI 1.9-3.4; Fig 3B).

Discussion

From the early days of the COVID-19 pandemic, there was recognition that the fragile structural and social environment of urban slums constitutes an important yet poorly understood risk [2,16]. Although studies have described socioeconomic disparities in COVID-19 risk and outcomes [17,18], few have focused on the particular risk of urban slums. In this community-based study conducted in the city of Salvador, Brazil, we found that nearly half of residents in an urban slum had evidence of SARS-CoV-2 infection after the first wave of the epidemic in 2020. In contrast, a national, regionally stratified serosurvey conducted in June 2020 estimated seroprevalence to be 5.5% in Salvador and 3.2% in the Northeast region where the city is situated [19]. This finding is consistent with studies in other settings that reported higher seroprevalence in slums than in non-slum settings [4,20], highlighting the increased vulnerability of socioeconomically deprived communities.

We were able to collect detailed demographic and socioeconomic data at both individual and household levels and overcome the limitations of previous studies. Although a few studies have
investigated COVID-19 risk in slum compared to non-slum areas, none to date has examined the
gradients of risk within a slum community. Our findings suggest that even within an overall
socioeconomically deprived environment, there is a gradient of risk associated with income,
employment, and household composition.

We found that children in this urban slum setting had high SARS-CoV-2 seroprevalence,
significantly greater than observed in adults, which sharply contrasts with patterns of
transmission in high-income countries and urban populations within these countries. Most
studies to date have reported lower or similar seroprevalence of COVID-19 among children
compared to adults during the early phase of the pandemic [21]. Serosurveys relying on residual
clinical samples have reported higher prevalence among children, but may not be reflective of
the general population of children who do not regularly undergo blood draws [22–24]. The
community-based design of our study allows for better comparability of seroprevalence between
children and adults.

Prior studies of respiratory viruses such as influenza showed that school-aged children are
reservoirs of transmission [25,26] but it remains unclear whether this is the case with SARS-
CoV-2, particularly in densely populated and socially deprived environments such as urban
slums. Interestingly, we found that adults aged 30-44 and 60 years or more were more likely to
be SARS-CoV-2 seropositive if they lived with children, suggesting that multigenerational
composition of urban slum households contributes to infection risk in specific adult groups (age
bearing parents and grandparents). Yet, we were unable due to the cross-sectional design to
determine whether children were more likely to be the index case within households.
Although SARS-CoV-2 seropositivity was associated with larger household size; however, the ORs for children were similar in models that did and did not include the total number of household residents, suggesting that the high seropositivity in children cannot be exclusively attributed to household size. Schools in Salvador closed in-person instruction for a prolonged period from March 2020 to May 2021 [27]. Yet, children may have continued to socialize in similarly assortative patterns within their urban slum community (e.g., contact with other children in neighboring houses). The combination of school closures and the lack of safe childcare options and targeted public health prevention may have resulted in higher exposure to SARS-CoV-2 in high-risk urban slum environments, as suggested by the high incidence during a single pandemic wave in this study.

We found that women in this urban slum community had significantly higher risk compared to men. Although there is evidence for sex differences in the immune response to SARS-CoV-2 infection and disease severity [28], serological surveys have generally found similar or lower prevalence among women compared to men [29]. Thus, the gender difference in risk observed in our study was likely driven by social rather than biological determinants. Interestingly higher seroprevalence among women has also been reported in other urban slum settings: two serosurveys conducted in urban slums Mumbai and Bangalore, India, reported a higher seroprevalence among women than men, but did not investigate potential mediators of this effect [4,30]. We found that women who were unemployed and had the lowest household income were significantly more likely to be seropositive for SARS-CoV-2. Thus, in addition to the disparity...
between slum and non-slum areas, the risk gradient within slums results in even higher SARS-CoV-2 infection risk for the poorest women.

A limitation of this study is that our data do not allow for identification of time of infection nor of primary cases within households, such that we were unable identify which household members were first to be infected and estimate what proportion of SARS-CoV-2 transmission occurred within households. While the majority of the survey occurred during the nadir between two waves, some participants were surveyed during the initial phase of the second wave. Seroprevalence may thus overestimate infection risk attributable to the first wave. Our observational design does not allow for a complete decomposition of the complex interactions between gender, employment, income, household structure and other unmeasured variables: households with children are larger, and larger households have lower per capita income, such that regression model estimates are not truly independent. Nevertheless, our data highlight the need for targeted interventions that address the risk experienced by the most vulnerable segments of slum communities, such as women who are unemployed, and the poorest households.

Potential sources of bias include selection bias as participants in the study may differ from residents who chose not to participate. Ascertainment and recall bias cannot be excluded, as many of the exposure variables were participant-reported. Finally, we did not have complete serological data for all household members. However, in sensitivity analyses using only data from households with serological data for all residents, our findings remained consistent (Figures S4, S5, S6).
Conclusions

Our study provides key insights into the gradient of SARS-CoV-2 infection risk within the deprived environment of urban slums, leveraging a large community-based cohort with detailed demographic and socioeconomic data at both individual and household levels. While the specific micro-environment of each community is unique, Pau da Lima shares features with urban slum communities in general: vulnerability to COVID-19 derives from the physical environment (construction quality, crowding, poor ventilation, poor access to sanitation facilities), as well as the social environment (financial precarity, mobility, social contact patterns) \[31,32\]. For example, slum residents are less able to isolate as they must travel to work and maintain an income and depend on often crowded and poorly ventilated public transportation to places of work typically located far from slum areas \[33\].

As has become evident, effective responses to the COVID-19 pandemic must include not only biomedical interventions but also the deployment of social support systems to mitigate the profound disruptions caused by the disease itself and control measures \[34,35\]. Participants in our study reported high adherence to hand hygiene and mask use but less frequent social and physical distancing, possibly because such measures are less feasible and effective in the crowded environment of slums. Moreover, given that the structural risk factors that we have identified cannot be readily modified, interventions such as vaccination that can mitigate risk independent of socioeconomic status remain crucial. Despite concerns about vaccine hesitancy, we previously reported 66% acceptance of vaccination for SARS-CoV-2 among adults in this community, similar to countries such as the United States \[14,36\]. Bridging the gap in vaccine
access for populations in low- and middle-income countries, where most urban slums are located, must be a priority to achieve an equitable pandemic response.
Figures and tables

Figure 1. Study population and context. Panel A shows an aerial image of study area. Panel B depicts the location of participating households. The choropleth reflects the spatially adjusted seroprevalence within the study area. Panel C is a representative photo of the study area. D: Confirmed cases of COVID-19 in Salvador, Brazil, up to October 2021 (blue). Overlaid over the epidemiologic curve, in purple, are the normalized OD values of serological samples collected from cohort participants prior to the pandemic (September 11 to November 24, 2019) and during the second wave (November 17, 2020 to February 26, 2021).
Figure 2. Seroprevalence among children and in their households. A: Age distribution of SARS-CoV-2 seronegative (median 33, interquartile range [IQR] 19-46) and seropositive (median 24 years, IQR 14.0-41) individuals. B: Odds ratio (OR) for SARS-CoV-2 seropositivity and 95% confidence interval (CI) associated with age, as estimated using a generalized additive model. C: Distribution of household size by age among SARS-CoV-2 seronegative and seropositive individuals. Seropositive individuals tended to be in larger households compared to seronegative individuals in the same age group. D: OR and 95% CI stratified by age group and presence of children in the household. E: Variation in seroprevalence among children by household composition (number of children and number of adults). The number of other children in the household was associated with higher seroprevalence, but there was no statistically significant difference between households with one adult and those with two adults. Asterisks indicate statistically significant differences (Bonferroni-adjusted p<0.05: *, <0.01: **, <0.001: ***).
Figure 3. Socioeconomic vulnerability among women. A: Household income (per capita) by employment status and gender. B: Seroprevalence by household income (per capita), employment status and gender. Asterisks indicate statistically significant differences (Bonferroni-adjusted p<0.05: *; <0.01: **; <0.001: ***).
Table 1: Study population and demographic characteristics. Employment, education and marriage were assessed for adult (>18 years) participants. Variables with statistically significant effects in univariable analyses are indicated in bold.

| Variable (N)   | Category | Number (%) | SARS-CoV-2 IgG + (%) | 95% CI     |
|---------------|----------|------------|----------------------|------------|
| All participants |          |            |                      |            |
| Age (2035)    | <18      | 579 (28.5%)| 327 (56.5%)          | 52.3-60.5% |
|               | 18-29    | 449 (22.1%)| 215 (47.9%)          | 43.2-52.6% |
|               | 30-44    | 515 (25.3%)| 215 (41.8%)          | 37.5-46.2% |
|               | 45-59    | 331 (16.3%)| 121 (36.6%)          | 31.4-42%   |
|               | >=60     | 161 (7.9%) | 67 (41.6%)           | 34-49.6%   |
| Gender (2035) | Female   | 1190 (58.5%)| 580 (48.7%)          | 45.9-51.6% |
|               | Male     | 845 (41.5%)| 365 (43.2%)          | 39.8-46.6% |
| Race (2018)   | Black    | 1038 (51.4%)| 466 (44.9%)          | 41.8-48%   |
|               | Brown    | 842 (41.7%)| 403 (47.9%)          | 44.4-51.3% |
|               | Others   | 38 (1.9%)  | 18 (47.4%)           | 31.3-64%   |
|               | White    | 100 (5.0%) | 49 (49.0%)           | 38.9-59.1% |
| Daily per capita income (USD) (1783) | <1.25 | 631 (35.4%)| 315 (49.9%)          | 46-53.9%   |
|               | 1.25-2.49| 496 (27.8%)| 231 (46.6%)          | 42.1-51.1% |
|               | 2.5-4.99 | 377 (21.1%)| 167 (44.3%)          | 39.2-49.5% |
|               | >=5      | 279 (15.7%)| 107 (38.4%)          | 32.7-44.4% |
| Adults        |          |            |                      |            |
| Years of schooling (1427) | 0 to 6 | 500 (35.0%)| 195 (39.0%)          | 34.7-43.4% |
|               | 7 to 9   | 296 (20.7%)| 132 (44.6%)          | 38.9-50.5% |
|               | > 9      | 631 (44.2%)| 282 (44.7%)          | 40.8-48.7% |
| Marriage or stable union (1456) | No    | 949 (65.2%)| 413 (43.5%)          | 40.3-46.7% |
|               | Yes      | 507 (34.8%)| 205 (40.4%)          | 36.2-44.9% |
| Employment (1288) | Formal | 339 (26.3%)| 131 (38.6%)          | 33.5-44.1% |
|               | Informal | 201 (15.6%)| 87 (43.3%)           | 36.4-50.4% |
|               | Unemployed    | 748 (58.1%)| 328 (43.9%)         | 40.3-47.5% |
| Individual income (1086) | <1.25 | 404 (37.2%)| 179 (44.3%)          | 39.4-49.3% |
|               | 1.25-2.49 | 86 (7.9%)  | 33 (38.4%)           | 28.3-49.5% |
|               | 2.5-4.99 | 111 (10.2%)| 43 (38.7%)           | 29.8-48.5% |
|               | >=5      | 485 (44.7%)| 198 (40.8%)          | 36.4-45.4% |
Table 2: Effect of children in household on odds of SARS-CoV-2 seropositivity. All models include age (A) and gender (G) as independent variables. Additionally, Model 1 includes a binary variable for the presence of children in the household (C), whereas Model 2 includes the total number of residents in the household (R). Model 3 includes all of the above variables.

| Variable          | Category | Model 1 (AGC) | Model 2 (AGR) | Model 3 (AGCR) |
|-------------------|----------|---------------|---------------|----------------|
| Age               | <18      | 2.08 (1.49-2.89) | 1.96 (1.42-2.72) | 1.99 (1.43-2.77) |
|                   | 18-29    | 1.44 (1.02-2.05) | 1.39 (0.98-1.98) | 1.38 (0.97-1.97) |
|                   | 30-44    | (Ref)          | (Ref)          | (Ref)          |
|                   | 45-59    | 0.74 (0.5-1.11) | 0.77 (0.52-1.14) | 0.76 (0.51-1.13) |
|                   | >=60     | 1.13 (0.67-1.91) | 1.24 (0.74-2.08) | 1.22 (0.72-2.05) |
| Gender            | Male     | (Ref)          | (Ref)          | (Ref)          |
|                   | Female   | 1.53 (1.2-1.95) | 1.50 (1.18-1.91) | 1.51 (1.18-1.92) |
| Children in home  | (Y/N)    | 1.32 (0.94-1.87) |               | 0.90 (0.61-1.32) |
| Total residents   |          | 1.23 (1.12-1.35) | 1.24 (1.12-1.38) |

AIC 2625 2608 2610
 ICC 0.408 0.397 0.397
References

1. United Nations Department of Social and Economic Affairs. The sustainable development goals report 2021. New York; 2021. Available: https://unstats.un.org/sdgs/report/2021/The-Sustainable-Development-Goals-Report-2021.pdf

2. Corburn J, Vlahov D, Mberu B, Riley L, Caiaffa WT, Rashid SF, et al. Slum Health: Arresting COVID-19 and Improving Well-Being in Urban Informal Settlements. J Urban Health. 2020;97: 348–357. doi:10.1007/s11524-020-00438-6

3. Rocha R, Atun R, Massuda A, Rache B, Spinola P, Nunes L, et al. Effect of socioeconomic inequalities and vulnerabilities on health-system preparedness and response to COVID-19 in Brazil: a comprehensive analysis. The Lancet Global Health. 2021;9: e782–e792. doi:10.1016/S2214-109X(21)00081-4

4. Malani A, Shah D, Kang G, Lobo GN, Shastri J, Mohanan M, et al. Seroprevalence of SARS-CoV-2 in slums versus non-slums in Mumbai, India. The Lancet Global Health. 2021;9: e110–e111. doi:10.1016/S2214-109X(20)30467-8

5. Reis RB, Ribeiro GS, Felzemburgh RDM, Santana FS, Mohr S, Melendez AXTO, et al. Impact of Environment and Social Gradient on Leptospira Infection in Urban Slums. Gurtler RE, editor. PLoS Neglected Tropical Diseases. 2008;2: e228. doi:10.1371/journal.pntd.0000228

6. LaVeist TA, editor. Race, ethnicity, and health: a public health reader. 1st ed. San Francisco: Jossey-Bass; 2002.
7. Tosta S, Giovanetti M, Brandão Nardy V, Reboredo de Oliveira da Silva L, Kelly Astete Gómez M, Gomes Lima J, et al. Short Report: Early genomic detection of SARS-CoV-2 P.1 variant in Northeast Brazil. Jonsson CB, editor. PLoS Negl Trop Dis. 2021;15: e0009591. doi:10.1371/journal.pntd.0009591

8. Lamarca AP, de Almeida LGP, da Silva Francisco Junior R, Cavalcante L, Machado DT, Brustolini O, et al. Genomic Surveillance Tracks the First Community Outbreak of the SARS-CoV-2 Delta (B.1.617.2) Variant in Brazil. J Virol. 2021; JVI.01228-21. doi:10.1128/JVI.01228-21

9. Instituto Brasileiro de Geografia e Estadística [Brazilian Institute of Geography and Statistics]. População residente, total, urbana total e urbana na sede municipal, em números absolutos e relativos, com indicação da área total e densidade demográfica, segundo os municípios—Bahia—2010 Synopsis of demographic census, 2010. 2010. Available: https://www.ibge.gov.br/estatisticas/downloads-estatisticas.html

10. Hagan JE, Moraga P, Costa F, Capian N, Ribeiro GS, Wunder EAJ, et al. Spatiotemporal Determinants of Urban Leptospirosis Transmission: Four-Year Prospective Cohort Study of Slum Residents in Brazil. PLoS Negl Trop Dis. 2016;10: e0004275. doi:10.1371/journal.pntd.0004275

11. Kikuti M, Cunha GM, Paploski IAD, Kasper AM, Silva MMO, Tavares AS, et al. Spatial Distribution of Dengue in a Brazilian Urban Slum Setting: Role of Socioeconomic Gradient in Disease Risk. PLoS Negl Trop Dis. 2015;9: e0003937. doi:10.1371/journal.pntd.0003937
12. Anjos RO, Mugabe VA, Moreira PSS, Carvalho CX, Portilho MM, Khouri R, et al. Transmission of Chikungunya Virus in an Urban Slum, Brazil. Emerg Infect Dis. 2020;26:1364–1373. doi:10.3201/eid2607.190846

13. Rodriguez-Barraquer I, Costa F, Nascimento EJM, Nery N, Castanha PMS, Sacramento GA, et al. Impact of preexisting dengue immunity on Zika virus emergence in a dengue endemic region. Science. 2019;363: 607–610. doi:10.1126/science.aav6618

14. Aguilar Ticona JP, Nery NJ, Victoriano R, Fofana MO, Ribeiro GS, Giorgi E, et al. Willingness to Get the COVID-19 Vaccine among Residents of Slum Settlements. Vaccines (Basel). 2021;9. doi:10.3390/vaccines9090951

15. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; Available: https://www.R-project.org/

16. Pereira RJ, Nascimento GNL do, Gratão LHA, Pimenta RS. The risk of COVID-19 transmission in favelas and slums in Brazil. Public Health. 2020;183: 42–43. doi:10.1016/j.puhe.2020.04.042

17. Castro RR, Santos RSC, Sousa GJB, Pinheiro YT, Martins RRIM, Pereira MLD, et al. Spatial dynamics of the COVID-19 pandemic in Brazil. Epidemiol Infect. 2021;149: e60. doi:10.1017/S0950268821000479

18. Mena GE, Martinez PP, Mahmud AS, Marquet PA, Buckee CO, Santillana M. Socioeconomic status determines COVID-19 incidence and related mortality in Santiago, Chile. Science. 2021;372: eabg5298. doi:10.1126/science.abg5298
19. Hallal PC, Hartwig FP, Horta BL, Silveira MF, Struchiner CJ, Vidaletti LP, et al. SARS-CoV-2 antibody prevalence in Brazil: results from two successive nationwide serological household surveys. The Lancet Global Health. 2020;8: e1390–e1398. doi:10.1016/S2214-109X(20)30387-9

20. Macchia A, Ferrante D, Battistella G, Mariani J, González Bernaldo de Quirós F. COVID-19 among the inhabitants of the slums in the city of Buenos Aires: a population-based study. BMJ Open. 2021;11: e044592. doi:10.1136/bmjopen-2020-044592

21. Viner RM, Mytton OT, Bonell C, Melendez-Torres GJ, Ward J, Hudson L, et al. Susceptibility to SARS-CoV-2 Infection Among Children and Adolescents Compared With Adults: A Systematic Review and Meta-analysis. JAMA Pediatr. 2021;175: 143–156. doi:10.1001/jamapediatrics.2020.4573

22. Flamand C, Alves Sarmento C, Enfissi A, Bailly S, Beillard E, Gaillet M, et al. Seroprevalence of anti-SARS-CoV-2 IgG at the first epidemic peak in French Guiana, July 2020. Bowman N, editor. PLoS Negl Trop Dis. 2021;15: e0009945. doi:10.1371/journal.pntd.0009945

23. Reicher S, Ratzon R, Ben-Sahar S, Hermoni-Alon S, Mossinson D, Shenhar Y, et al. Nationwide seroprevalence of antibodies against SARS-CoV-2 in Israel. Eur J Epidemiol. 2021;36: 727–734. doi:10.1007/s10654-021-00749-1

24. Bajema KL, Wiegand RE, Cuffe K, Patel SV, Iachan R, Lim T, et al. Estimated SARS-CoV-2 Seroprevalence in the US as of September 2020. JAMA Intern Med. 2021;181: 450. doi:10.1001/jamainternmed.2020.7976
25. Read JM, Zimmer S, Vukotich C, Schweizer ML, Galloway D, Lingle C, et al. Influenza and other respiratory viral infections associated with absence from school among schoolchildren in Pittsburgh, Pennsylvania, USA: a cohort study. BMC Infect Dis. 2021;21:291. doi:10.1186/s12879-021-05922-1

26. Cauchemez S, Bhattarai A, Marchbanks TL, Fagan RP, Ostroff S, Ferguson NM, et al. Role of social networks in shaping disease transmission during a community outbreak of 2009 H1N1 pandemic influenza. Proceedings of the National Academy of Sciences. 2011;108:2825–2830. doi:10.1073/pnas.1008895108

27. Valverde F. Prefeitura apresenta protocolos de retomada da educação em Salvador. A Tarde. 30 Apr 2021. Available: https://atarde.uol.com.br/bahia/salvador/noticias/2166644-prefeitura-apresenta-protocolos-de-retomada-da-educacao-em-salvador. Accessed 5 Oct 2021.

28. Takahashi T, Ellingson MK, Wong P, Israelow B, Lucas C, Klein J, et al. Sex differences in immune responses that underlie COVID-19 disease outcomes. Nature. 2020;588: 315–320. doi:10.1038/s41586-020-2700-3

29. Lai C-C, Wang J-H, Hsueh P-R. Population-based seroprevalence surveys of anti-SARS-CoV-2 antibody: An up-to-date review. International Journal of Infectious Diseases. 2020;101: 314–322. doi:10.1016/j.ijid.2020.10.011

30. George CE, Inbaraj LR, Chandrasingh S, de Witte LP. High seroprevalence of COVID-19 infection in a large slum in South India; what does it tell us about managing a pandemic and beyond? Epidemiol Infect. 2021;149: e39. doi:10.1017/S0950268821000273
31. Lilford RJ, Oyebode O, Satterthwaite D, Melendez-Torres GJ, Chen Y-F, Mberu B, et al. Improving the health and welfare of people who live in slums. The Lancet. 2017;389: 559–570. doi:10.1016/S0140-6736(16)31848-7

32. Buckley RM. Targeting the World’s Slums as Fat Tails in the Distribution of COVID-19 Cases. J Urban Health. 2020;97: 358–364. doi:10.1007/s11524-020-00450-w

33. Pinchoff J, Kraus-Perrotta C, Austrian K, Tidwell JB, Abuya T, Mwanga D, et al. Mobility Patterns During COVID-19 Travel Restrictions in Nairobi Urban Informal Settlements: Who Is Leaving Home and Why. J Urban Health. 2021;98: 211–221. doi:10.1007/s11524-020-00507-w

34. Clapp J, Calvo-Friedman A, Cameron S, Kramer N, Kumar SL, Foote E, et al. The COVID-19 Shadow Pandemic: Meeting Social Needs For A City In Lockdown: Commentary describes how New York City Health + Hospitals staff developed and executed a strategy to meet patients’ intensified social needs during the COVID-19 pandemic. Health Affairs. 2020;39: 1592–1596. doi:10.1377/hlthaff.2020.00928

35. Bariola N, Collins C. The Gendered Politics of Pandemic Relief: Labor and Family Policies in Denmark, Germany, and the United States During COVID-19. American Behavioral Scientist. 2021; 000276422110031. doi:10.1177/00027642211003140

36. Solís Arce JS, Warren SS, Meriggi NF, Scacco A, McMurry N, Voors M, et al. COVID-19 vaccine acceptance and hesitancy in low- and middle-income countries. Nat Med. 2021;27: 1385–1394. doi:10.1038/s41591-021-01454-y
