PUBLICAÇÃO OFICIAL DO NÚCLEO HOSPITALAR DE EPIDEMIOLOGIA DO HOSPITAL SANTA CRUZ E PROGRAMA DE PÓS GRADUAÇÃO EM PROMOÇÃO DA SAÚDE - DEPARTAMENTO DE BIOLOGIA E FARMÁCIA DA UNISC

ISSN 2238-3360

Revista de Epidemiologia e Controle de Infecção

Original Article

SARS-CoV-2 seroprevalence among adults in the cities of Mariana and Ouro Preto, Minas Gerais, Brazil

Soroprevalência do SARS-CoV-2 em adultos nas cidades de Mariana e Ouro Preto, Minas Gerais, Brasil

Seroprevalencia del SRAS-CoV-2 en adultos en las ciudades de Mariana y Ouro Preto, Minas Gerais, Brasil

Site doi: https://doi.org/10.17058/reci.v15i1.19515

Submitted: 06/14/2024
Accepted: 12/11/2024
Available online: 03/25/2025

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ABSTRACT

Background and Objectives: At the beginning of the Covid-19 pandemic, the absence of a national protocol for epidemiological surveillance and control hindered the understanding of the true prevalence of Covid-19 in Brazil. This study aimed to estimate the anti-SARS-CoV-2 antibodies prevalence and describe the serological profile according to socioeconomic, geographic, and health characteristics in Mariana and Ouro Preto municipalities, Minas Gerais. **Methods:** A cross-sectional population-based serological survey was conducted with 1,762 adults from October to December 2020. A qualitative immunochromatographic rapid test assessed infection; georeferencing and statistical inference analyses were performed. **Results:** The infection prevalence was 5.2%. Multivariate analysis revealed that lower per capita family income (≤ 0.5 minimum wage) (OR: 3.63; 95% CI: 1.70–7.76), higher density of occupants per room (≥ 1.0) (OR: 0.42; 95% CI: 0.23–0.76), and previous contact with suspected or confirmed cases of Covid-19 (OR: 2.58; 95% CI: 1.16–5.73) were significantly associated with seropositivity. Seropositive individuals reported higher frequencies of fatigue (14.8%), dyspnea (9.3%), ageusia (9.3%), and anosmia (8.8%), in addition to lower educational performance (p=0.024), lower per capita family income (p=0.018), and a greater number of comorbidities (p=0.041). A heterogenous geographic distribution was observed, with concentrations in census sectors with average incomes of one to three minimum wages. **Conclusion:** The study highlights a heterogeneous distribution of SARS-CoV-2 infections, with seropositive individuals predominantly coming from lower socioeconomic segments and presenting greater health vulnerabilities. These findings emphasize the need for targeted public health strategies and interventions to improve disease surveillance and mitigate health disparities in similar contexts.

Keywords: *Coronavirus infections. Sero-epidemiological studies. Socioeconomic factors.*

RESUMO

Justificativa e Objetivos: No início da pandemia, a ausência de um protocolo nacional de vigilância e controle epidemiológico dificultou a compreensão da verdadeira prevalência da Covid-19 no Brasil. Este estudo teve como objetivo estimar a prevalência de anticorpos anti-SARS-CoV-2 e descrever o perfil sorológico de acordo com as características socioeconômicas, geográficas e de saúde das cidades de Mariana e Ouro Preto, Minas Gerais. **Métodos:** Uma pesquisa sorológica transversal de base populacional foi realizada com 1.762 adultos, entre outubro e dezembro de 2020. Um teste rápido imunocromatográfico qualitativo foi usado para avaliar a infecção; foram realizadas análises de georreferenciamento e inferência estatística. **Resultados:** A prevalência de infecção foi de 5,2%. A análise multivariada revelou que a menor renda familiar per capita (≤ 0,5 salário mínimo) (OR: 3,63; IC95%: 1,70-7,76), a maior densidade de ocupantes por quarto (> 1,0) (OR: 0,42; IC95%: 0,23–0,76) e o contato prévio com casos suspeitos ou confirmados de Covid-19 (OR: 2,58; IC95%: 1,16-5,73) foram significativamente associados à soropositividade. Os indivíduos soropositivos relataram frequências mais altas de fadiga (14,8%), dispneia (9,3%), ageusia (9,3%) e anosmia (8,8%), além de menor escolaridade (p=0,024), menor renda familiar per capita (p=0,018) e maior número de comorbidades (p=0,041). Foi observada uma distribuição geográfica heterogênea, com concentrações em setores censitários com renda média de um a três salários mínimos. **Conclusões:** O estudo destaca uma distribuição heterogênea da infecção por SARS-CoV-2, com indivíduos soropositivos predominantemente de segmentos socioeconômicos mais baixos e apresentando maiores vulnerabilidades de saúde. Esses achados enfatizam a necessidade de estratégias e intervenções de saúde pública direcionadas para melhorar a vigilância de doenças e mitigar as disparidades de saúde em contextos semelhantes.

Descritores: *Infecções por coronavírus. Estudos soroepidemiológicos. Fatores socioeconômicos.*

RESUMEN

Justificación y Objetivos: Al inicio de la pandemia, la ausencia de un protocolo nacional de vigilancia epidemiológica y control complicó la comprensión de la verdadera prevalencia del Covid-19 en Brasil. Este estudio tuvo como objetivo estimar la prevalencia de anticuerpos anti-SARS-CoV-2 y describir el perfil serológico de acuerdo con las características socioeconómicas, geográficas y sanitarias de las ciudades de Mariana y Ouro Preto, Minas Gerais. **Métodos:** Se realizó una encuesta serológica transversal de base poblacional con 1.762 adultos entre octubre y diciembre de 2020. Se utilizó una prueba rápida inmunocromatográfica cualitativa para evaluar la infección; se realizaron análisis de georreferenciación e inferencia estadística. **Resultados:** La prevalencia de la infección fue del 5,2%. El análisis multivariante reveló que los menores ingresos familiares per cápita (≤ 0,5 salario mínimo) (OR: 3,63; IC95%: 1,70-7,76), la mayor densidad de ocupantes por habitación (> 1,0) (OR: 0,42; IC95%: 0,23–0,76) y el contacto previo con casos sospechosos o confirmados de Covid-19 (OR: 2,58; IC 95%: 1,16-5,73) se asociaron significativamente con la seropositividad. Los individuos seropositivos informaron de una mayor frecuencia de fatiga (14,8%), disnea (9,3%), ageusia (9,3%) y anosmia (8,8%), además de un menor nivel educativo (p=0,024), una menor renta familiar per cápita (p=0,018) y un mayor número de comorbilidades (p=0,041). Se observó una distribución geográfica heterogénea, con concentraciones en sectores censales con ingresos medios de uno a tres salarios mínimos. **Conclusiones:** El estudio destaca una distribución heterogénea de la infección por SRAS-CoV-2, con predominio de individuos seropositivos de los segmentos socioeconómicos más bajos y que presentan mayores vulnerabilidades sanitarias. Estos hallazgos subrayan la necesidad de estrategias e intervenciones de salud pública específicas para mejorar la vigilancia de la enfermedad y mitigar las disparidades sanitarias en contextos similares.

Palabras Clave: *Infecciones por coronavirus. Estudios seroepidemiológicos. Factores socioeconómicos*

INTRODUCTION

At the beginning of the Covid-19 pandemic, the lack of a national protocol for epidemiological surveillance, disease control, or mitigation hindered the understanding of the true prevalence of coronavirus disease (Covid-19) throughout Brazil. The high number of cases and deaths revealed significant transmission patterns of severe acute respiratory syndrome coronavirus (SARS-CoV-2), the etiological agent of Covid-19. Failures in control measures increased the vulnerability of the Brazilian population to infection.[1]

Notably, Brazil has reported more than 22.1 million positive cases of Covid-19and confirmed more than 616,600 deaths from the disease by the beginning of the second week of December 2021; it is believed that the records do not reflect the true extent of SARS-CoV-2 infection.[2] In addition to the country's low testing rates, the literature suggests that many infected people remain asymptomatic or manifest mild symptoms and therefore do not have laboratory confirmation of infection.[3]

Population-based surveys are essential for visualizing the epidemiological scenario, as they contribute to understanding the dynamics of virus transmission and disease evolution, supporting the implementation of public health policies.[1,4] There are few studies with this design focused on estimating the frequency of infected individuals in the Brazilian population.[5] Until September 2020, only two studies had estimated the profile of infection by SARS-CoV-2 in Brazil using household surveys. One of them, nationwide, investigated individuals living in 133 cities; the other described the seropositivity profile in the city of São Paulo.[1,6]

In Minas Gerais, the epidemiological bulletins available from the State Health Department indicated the record of 295,169 cases until September 2020, with a considerable increase in the number of unconfirmed suspected cases. This scenario evidenced the need and relevance of implementing strategies to improve the diagnosis of SARS-CoV-2 infection in municipalities and contribute to the knowledge of the prevalence of infection, supporting decision-making in the field of prevention and healthcare for the population exposed to the virus.[7]

Related to what was discussed above, the hypothesis adopted is that the population's sociodemographic, social vulnerability and health characteristics could be associated with seropositivity for SARS-CoV-2, assuming that individuals under greater socioeconomic and health vulnerability would have a higher seroprevalence of anti-SARS-CoV-2 antibodies.

This study aimed to estimate the anti-SARS-CoV-2 antibodies prevalence and describe the serological profile according to socioeconomic, geographic, and health characteristics in the cities of Mariana and Ouro Preto, Minas Gerais.

METHODS

Study design and setting

This is a descriptive study, based on primary data from a sero-epidemiological survey conducted in the cities of Mariana and Ouro Preto, from October to December 2020.

Mariana and Ouro Preto are neighbor municipalities of the Inconfidentes micro-region, located in the central macro-region of the state of Minas Gerais, with estimated populations of 61,288 and 74,558 residents, respectively. The main economic activities are the extraction of iron ore, tourism, services, and the federal higher educational institutions located in the cities, which generate high population mobility due to workers' and students' daily commute.[8]

Participants

It was considered eligible for this study individuals living in permanent households at the headquarters of the cities, aged 18 years or older. It was excluded individuals who, at the time of data collection, were in isolation/quarantine due to Covid-19; those who presented loss of cognitive function, were referred by family members or had difficulty understanding the questionnaire during the initial evaluation; individuals whose blood samples could not be collected due to difficulties in venous access and those who were not at home at the time the team visited.

To select participants, it was adopted conglomerate sampling in three stages: by census sector (considering the number of households and the average income of each sector, according to data from the Brazilian Institute of Geography and Statistics (IBGE); by household (selected from a systematic sampling); by resident (randomly selected via a drawing application). For each city, four strata were defined, according to the average nominal monthly income of the head of the household, available in the 2010 census, to ensure the representativeness of the different socioeconomic levels in the sample.

Variables

The variables included in this survey were as follows: SARS-CoV-2 infection—defined by the presence or absence of antibodies in the immunochromatographic rapid test, without distinction between immunoglobulin class (IgM or IgG) and classified as seropositive or seronegative; demographic and socioeconomic variables: sex (female or male); the age group (18–34 years, 35–59 years, 60 years or older); self-reported race/skin color (black, white, mixed-race, yellow, or indigenous); marital status (single, married/in a stable

union, separated/divorced, or widowed); education (complete or incomplete elementary school, complete or incomplete high school, higher education and/or graduate school); family income—minimum wage of R$1,045.00 (< 1 minimum wage, from 1 to 3 minimum wages, ≥ 4 minimum wages); per capita family income—minimum wage (≤ 0.5 minimum wages, > 0.5 minimum wages); density of residents per room (≤ 1.0 residents or > 1.0 residents); prior contact with suspected or confirmed cases of Covid-19 (no or yes); prior SARS-CoV-2 testing (no or yes); self-assessment of health (good, very good, regular, poor, or very poor); characteristic clinical symptoms of Covid-19 in the 15 days before the study, evaluated individually (feverish sensation, sore throat, cough, dyspnea, diarrhea, anosmia, ageusia, fatigue, skin patches); presence of comorbidities (none; 1–2; ≥ 3).

Data collection

The household survey was composed of three moments of data collection in each city, from October to December 2020, with an interval of 21 days between each collection, due to the incubation period of the virus (Mariana: October 16 to 18; November 06 to 08 and November 27 to 29; Ouro Preto: October 30 to November 01; November 20 to 22 and December 11 to 13). The collections were performed on weekends (Friday, Saturday, and Sunday), to enable the participation of residents who worked during the week. In the previous week, the research team carried out the enrollment of households in the pre-selected census sectors.

The selection of census sectors, included in each stage of the survey, considered the number of households and the average income, according to IBGE data, ensuring the representativeness of different socioeconomic strata (<1 minimum wage, from 1 to 3 minimum wages, ≥4 minimum wages) in the final sample. A total of 14,078 and 17,753 households were considered, distributed across 49 and 36 eligible census sectors in Mariana and Ouro Preto, respectively. To select the number of households, we initially enrolled the selected census sectors, counting the number of households in each sector. After this inventory, the household selection interval (k) was calculated, according to the equation: k = Ni / (xi/ni), in which Ni = total number of households in the census sector; xi = sample size; ni = number of households to be selected in the census sector.

Data collection was performed during face-to-face interviews at home, using an electronic questionnaire.[9] Data Goal® software (Data Goal Startup, Belo Horizonte, Minas Gerais, Brazil) was used to apply the questionnaire and collect longitude and latitude of the interviewee's home.

Participant's blood was collected for testing for anti-SARS-CoV-2 antibodies after the interview via peripheral venous access, performed by trained phlebotomists, using a 7.5 mL S-Monovette® serum gel tube (SARSTEDT AG & Co. KG., Nümbrecht, Germany). After blood centrifugation, serological analysis was performed using the non-differentiated qualitative immunochromatographic method for antibodies (IgG and IgM) anti-coronavirus 2 (One Step Covid 2019® test, Guangzhou Wondfo Biotech, China), following the manufacturer's guidelines.[9]

The data collected in the Data Goal application was exported to a single spreadsheet in Office Excel® software (Microsoft Corporation, Redmond, Washington, USA) and underwent consolidation and subsequent consistency analysis.

Bias control

To control possible biases, the interviewers were trained in the use of the digital questionnaire and how to approach the interviewees. In addition, sample selection was randomized; collection was done on weekends to increase the participation of workers; losses were controlled by the collection team coordinators, using printed spreadsheets; the online questionnaire was used to avoid errors and missing data; investigation was done using serum samples, increasing the sensitivity of the test and ensuring greater accuracy.

Sample size

For sample size calculation, each city was considered separately, using information from the 2010 demographic census. It was adopted a 95% confidence level, an estimate of infection that ranged from 3% to 10% according to the moment of the survey, and a design effect equal to 1.5.9 To calculate the sample size, it was used the OpenEpi tool (https://www.openepi.com/Menu/OE_Menu.htm), which estimated a minimum of 732 interviews for each city, to which it was added a percentage of 20% of recomposition for losses due to refusals, absence of the randomly selected resident, and the possibility of closed households during the visit, totaling the need to randomly select, in each city, 879 individuals for the study.

Statistical analysis

Descriptive and statistical inference analyses were performed considering the complex sample design, using the svy command of the Stata® software, version 16.1 (Stata Corp, College Station, TX, USA). Data were presented as percentages and confidence intervals (95% CI), considering the total sample and the distribution in the two cities. Pearson's Chi-squared test was used to compare the frequency of Covid-19 clinical symptoms and the distribution of sociodemographic, social vulnerability, and health characteristics of study

participants between positive and negative for anti-SARS-CoV-2 antibodies, with a 5% significance level.

Geographic analyses were performed by georeferencing the investigated households, using version 2.10.1 of QGIS (Open Source Geospatial Foundation, Beaverton, Oregon, USA), an open-source geographic information system, which enabled the preparation of thematic maps relating income and the distribution of positive cases of SARS-CoV-2 infection. For income categorization, income ranges were adopted, calculated from the data obtained in the interview, to identify which socioeconomic level presented the highest percentage of positive cases.

In addition to the analyses, it was carried out weighted logistic regression to adjust the model to the complex sample design. The variables included in the multivariate model were selected based on biological plausibility and univariate analysis, considering those with a p-value < 0.20 as the initial criterion. The variables were then gradually removed from the model using the stepwise backward method, until all the remaining variables had a p-value < 0.05. Although the density of occupants per room variable did not meet the $p < 0.20$ criterion in the univariate analysis, we chose to include it in the multivariate model due to its epidemiological importance, previously described in the literature, as a relevant fator in household transmission of SARS-CoV-2. It was assessed the collinearity between the variables in the model using the variance inflation fator (VIF). The results indicated the absence of significant collinearity, with VIF < 10 for all the variables included in the model.

Ethical issues

In compliance with current ethical aspects regarding research involving human beings (Resolution 466/2012 of the Brazilian National Health Council), the study was approved by the Universidade Federal de Minas Gerais (UFMG) Research Ethics Committee, under CAAE no. 32815620.0.1001.5149 and Opinion no. 4,292,475.

RESULTS

A total of 5,279 households were approached, 2,536 (48.0%) from Mariana and 2,743 (52.0%) from Ouro Preto. Of the total, 1,912 (36.1%) households were closed (967 in Mariana, and 945 in Ouro Preto); in 1,079 (20.3%), residents refused to participate (560 in Mariana, and 519 in Ouro Preto); in 499 (9.4%), the selected resident was absent (232 in Mariana, and 267 in Ouro Preto); and in 1,789 (33.8%), residents agreed to participate in the study, 27 (0.4%) were excluded due to incomplete interviews. In the end, 1,762 individuals were evaluated, of which 764 (43.4%) were from Mariana and 998 (56.6%) from Ouro Preto.

Regarding the sociodemographic characteristics of the study participants, considering both cities, it was observed a predominance of women (51.9%), aged 35 to 59 years old (47.2%), unmarried individuals (53.2%), black or mixed-race (67.9%), with more than nine years of schooling (68.8%), and with a per capita family income of ≤ 0.5 minimum wage (60.6%). There was a significant difference in the distribution of the education and density of occupant per room variables, which showed a higher number of people with higher education in the city of Ouro Preto. Regarding the other variables, there were no significant differences between the two cities (Table 1).

Table 1. Distribution of sociodemographic characteristics of the study participants, in Mariana and Ouro Preto, Minas Gerais, October to December 2020.

Parameter	Total[a] (n=1.762)	Mariana[a] (n=764)	Ouro Preto[a] (n=998)	p-value[b]
Sex				0.892
Female	51.9 (44.8;59.0)	51.3 (37.0;65.5)	52.4 (47.0;57.8)	
Male	48.1 (41.0;55.2)	48.7 (34.5;63.0)	47.6 (42.2;53.0)	
Age group (years)				
18-34	34.0 (30.5;37.6)	29.0 (22.5;36.5)	37.2 (32.1;42.6)	0.118
35-59	47.2 (43.1;51.4)	55.6 (43.7;66.9)	51.4 (46.4;56.3)	
60 or more	18.8 (16.0;21.9)	15.4 (10.3;22.5)	11.4 (8.5;15.3)	
Marital status				
Married/stable union	33.6 (29.3;38.1)	29.0 (22.5;36.5)	37.2 (32.1;42.6)	0.212
Single	53.2 (47.2;59.2)	55.6 (43.7;66.9)	51.4 (46.4;56.3)	
Separated/divorced or widowed	13.2 (10.3;16.8)	15.4 (10.3;22.5)	11.4 (8.5;15.3)	
Race/skin color				
White	26.1 (22.1;30.7)	22.0 (14.8;31.5)	28.5 (22.9;34.9)	
Black	21.5 (17.7;25.8)	23.1 (14.4;34.9)	18.9 (14.8;23.7)	0.577
Brown	46.4 (37.3;50.1)	49.1 (36.3;62.1)	47.0 (42.3;51.7)	
Yellow or indigenous	6.0 (4.8;9.0)	5.7 (3.0;10.6)	5.6 (4.3;7.3)	
Education				
Elementary school complete or incomplete	31.2 (26.7;36.0)	37.9 (30.6;45.9)	25.8 (21.5;30.6)	
High school complete or incomplete	59.7 (55.8;63.6)	57.2 (49.8;64.2)	61.8 (57.9;65.6)	**0.002**
Higher and/or post-graduate education	9.1 (6.6;12.3)	4.9 (2.6;9.0)	12.4 (8.9;17.0)	
Family income per capita				
>0.5 minimum wage	39.4 (34.3;44.6)	35.7 (28.8;43.2)	42.6 (35.5;49.9)	0.183
≤ 0.5 minimum wage	60.6 (55.4;65.6)	64.3 (56.8;71.2)	57.4 (50.1;64.5)	
Density of occupant per room				**0.036**
≤ 1.0	42.1 (36.2;48.3)	34.8 (25.1;46.0)	48;0 (42.7;53.3)	
> 1.0	57.9 (51.7-63.8)	65.2 (54.0;74.9)	52.0 (46.7;57.3)	

Legend: a) data shown as percentages and 95% confidence intervals; b) Pearson's chi-square test.

Anti-SARS-CoV-2 antibodies prevalence in the total sample was 5.2% (95% CI 3.8;7.0). The presence of at least one characteristic clinical symptom in the 15 days preceding the blood sample collection was reported by 29.9% (95% CI 25.1;34.9) of participants, and 27.7% (95% CI 23.4;32.5) of the seronegative individuals reported the presence of some Covid-19 characteristic symptom. In contrast, 43.6% (95% CI 28.1;60.3) of seropositive individuals reported the presence of these symptoms (p=0.034) (data not shown). The most frequent clinical symptoms among seropositive individuals were: fatigue (14.8%), dyspnea (9.3%), ageusia (9.3%), and anosmia (8.8%) (Table 2).

Table 2. Frequency of clinical symptoms of Covid-19 according to SARS-CoV-2 infection, in Mariana and Ouro Preto, Minas Gerais, October to December 2020.

Symptom	Seropositive % (95% CI)[a]	Seronegative % (95% CI)[a]	p-value[b]
Feverish sensation	1.2 (0.7;2.2)	2.8 (0.8;9.1)	0.131
Sore throat	5.7 (1.6;17.9)	4.8 (3.6;6.5)	0.803
Coughing	19.6 (8.0;40.9)	16.2 (12.6;20.6)	0.613
Dyspnea	9.3 (3.8;21.0)	4.0 (2.7;6.2)	**0.047**
Diarrhea	4.4 (1.8;10.2)	4.9 (3.2;7.3)	0.805
Anosmia	8.8 (4.2;17.5)	2.4 (1.3;3.5)	**0.001**
Ageusia	9.3 (4.0;20.3)	1.4 (0.7;2.9)	**<0.001**
Fatigue	14.8 (6.0;32.4)	5.1 (3.6;7.1)	**0.027**
Skin blemishes	1.9 (0.2;1.2)	1.2 (0.7;2.0)	0.676

Legend: a) 95% CI: 95% confidence interval; b) Pearson's Chi-squared test.

It was found a higher prevalence of seropositive individuals with low education (p=0.024), per capita income below 0.5 minimum wage (p=0.018), density of occupant per room lower than 1.0 (p=0.018) and with three or more comorbidities (p=0.041) (Table 3).

Table 3. Sociodemographic, social vulnerability and health characteristics of study participants, according to serological profile, in Mariana and Ouro Preto, Minas Gerais, October to December 2020.

Parameter	Seropositives % (95%CI)[a]	Seronegatives % (95%CI)[a]	p-value[b]
Sex			0.149
Female	6.3 (4.4;9.0)	93.7 (91.0;95.6)	
Male	4.0 (2.4;6.5)	96.0 (93.4;97.6)	
Age group (years)			0.164
18-34	4.3 (2.6;6.7)	95.7 (93.3;97.3)	
35-59	4.5 (2.8;7.2)	95.5 (92.7;97.2)	
60 or more	8.6 (4.3;16.2)	91.4 (83.8;95.6)	
Marital status			0.486
Married/stable union	3.7 (2.3;6.3)	96.3 (96.4;97.7)	
Single	5.8 (3.2;10.5)	94.2 (89.5;96.8)	
Separated/divorced or widowed	6.0 (3.5;10.0)	94.0 (90.0;96.5)	
Race/skin color	2.8 (7.4;9.6)	97.2 (90.4;99.3)	
White			0.839
Black	5.5 (3.7;8.1)	94.5 (91.9;96.3)	
Brown	4.7 (2.9;7.6)	95.3 (92.4;97.1)	
Yellow or indigenous	6.1 (2.0;17.0)	93.9 (83.0;98.0)	
Education			**0.024**
Elementary school complete or incomplete	7.9 (4.6;3.3)	92.1 (86.7;95.4)	
High school complete or incomplete	4.0 (2.6;6.0)	96.0 (94.0;97.4)	
Higher and/or post-graduate education	2.5 (1.2;5.1)	97.5 (94.8;98.8)	
Family income per capita			**0.018**
>0.5 minimum wage	3.1 (1.9;5.0)	96.9 (94.9;98.1)	
≤ 0.5 minimum wage	6.4 (4.3;9.4)	93.6 (90.5;95.7)	
Density of occupant per room			**0.018**
≤ 1.0	7.4 (5.0;10.7)	92.6 (94.3;97.7)	
> 1.0	3.6 (2.3;5.7)	96.4 (89.3;95.0)	
Prior contact with suspected or confirmed case of Covid-19			0.136
No	4.3 (3.1;6.0)	95.7 (94.0;96.9)	
Yes, with a suspected or confirmed case	7.0 (4.0;12.1)	93.0 (87.9;96.0)	
Prior testing for SARS-CoV-2			0.356
Yes	3.9 (2.0;0.7)	96.1 (92.7;98.0)	
No	5.5 (3.9;7.8)	94.5 (92.2;96.1)	
Self-assessment of health			0.236
Good/very good	4.5 (3.1;9.7)	95.5 (93.5;97.0)	
Fair/bad/very bad	7.4 (3.7;14.1)	92.6 (85.9;92.2)	
Presence of comorbidities			**0.041**
None	4.0 (2.5;6.7)	96.0 (93.3;97.5)	
1-2	4.5 (2.8;7.2)	95.5 (92.8;97.2)	
≥ 3	11.5 (5.3;22.9)	88.5 (93.0;96.2)	

Legend: a) 95% CI: 95% confidence interval; b) Pearson's Chi-squared test

The geographical distribution of the percentages of seropositive individuals by income was heterogeneous within each city, with a higher frequency in census sectors where the average income ranged from one to three minimum wages, similar to Mariana and Ouro Preto (Figure 1).

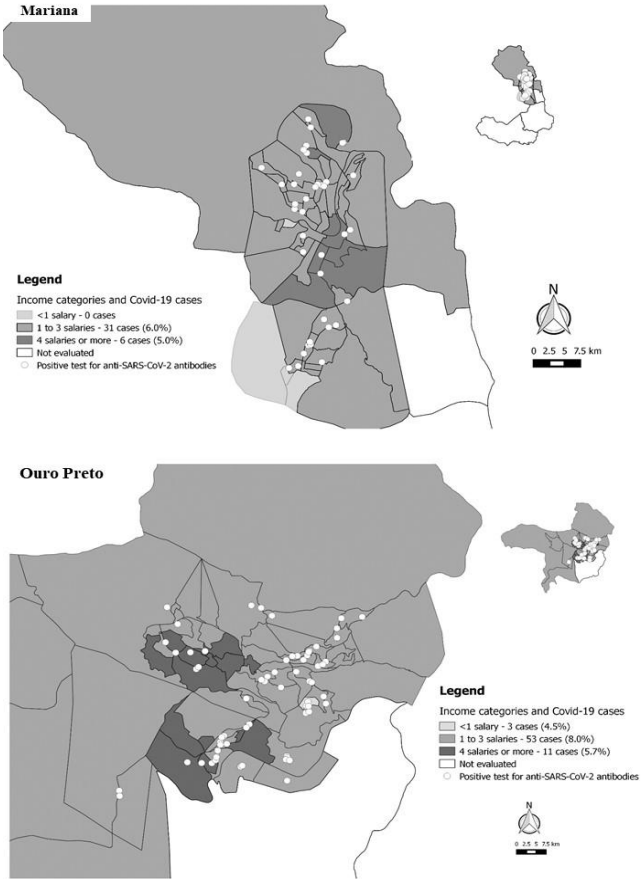

Figure 1. Spatial distribution of the percentages of positive cases for anti-SARS-CoV-2 antibodies by census sector and income bracket in Mariana and Ouro Preto, Minas Gerais, from October to December 2020. *The percentages indicated on the maps represent the proportion of positive cases within each specific income bracket (<1 minimum wage, 1 to 3 minimum wages, 4 salaries or more), in relation to the total number of individuals tested in that same income bracket.*

In the multivariate analysis, conducted by weighted logistic regression, it was found that those in the extremes of the education spectrum (elementary school and higher education) were associated with a greater chance of testing positive for anti-SARS-CoV-2 antibodies compared to those with complete or incomplete high school education. Per capita family income above 0.5 minimum wage was shown to be a protective factor for infection, reducing the chance of testing positive (OR: 0.27; 95% CI: 0.13–0.59; p=0.001) compared to those with income less than or equal to 0.5 minimum wage. Similarly, the density of occupants per room ≥ 0.5 remained associated with a lower chance of infection (OR: 0.47; 95% CI: 0.23–0.97; p=0.043), which may reflect specific characteristics of the analyzed population and the pattern of household transmission in the region. Finally, previous contact with suspected or confirmed cases of Covid-19 was associated with a greater chance of testing positive for anti-SARS-CoV-2 antibodies (OR: 2.58; 95% CI: 1.16–5.73; p=0.020).

Table 4. Associated factors with Covid-19 seropositivity in a multivariate model, in Mariana and Ouro Preto, Minas Gerais, October to December 2020.

Parameter	Univariate OR	p-value	Multivariate OR	p-value
Education				
High school complete or incomplete	1.00		1.00	
Elementary school complete or incomplete	2.14 (1.01-4.53)	**0.047**	2.56 (1.01-5.03)	**0.046**
Higher and/or post-graduate education	1.78 (0.75-4.23)	0.186	3.30 (1.18-9.27)	**0.024**
Family income per capita				
>0.5 minimum wage	1.00		1.00	
≤ 0.5 minimum wage	0.42 (0.22-0.82)	**0.011**	0.27 (0.13-0.59)	**0.001**
Density of occupant per room				
≤ 1.0	1.00		1.00	
> 1.0	0.47 (0.25-0.89)	**0.020**	0.41 (0.23-0.76)	**0.005**
Prior contact with suspected or confirmed case of Covid-19				
No	1.00		1.00	
Yes, with a suspected or confirmed case	1.71 (0.86-3.39)	0.123	2.58 (1.16-5.73)	**0.020**

The multivariate analysis was conducted using a weighted logistic regression model. Variables were selected based on biological plausibility and an initial p-value < 0.20 in univariate analysis, with stepwise backward elimination until all variables in the final model presented p < 0.05. Despite not meeting the initial p-value criterion, density of occupants per room was included in the multivariate model due to its epidemiological importance in household Covid-19 transmission. The model was adjusted for sex and age, and collinearity was assessed using the Variance Inflation Factor (VIF), with no collinearity detected (VIF < 10).

DISCUSSION

Anti-SARS-CoV-2 antibodies prevalence was 5.2% and the main symptoms reported were fatigue, dyspnea, ageusia, and anosmia. Seropositive individuals were less educated, their per capita income was ≤ 0.5 minimum wage, had three or more comorbidities, and resided in census sectors with average middle income (one to three minimum wages).

The study evaluated a representative probabilistic sample of the two cities, enabling the results to be generalized to adults living in their urban areas. Moreover, it provides estimates of the prevalence of SARS-CoV-2 infection in a period not well explored by household surveys.[1,6,10]

The prevalence of infection in Mariana and Ouro Preto, from October to December 2020, was higher than the values found for the Southeast region (less than 1%), in the national survey conducted in 133 municipalities, in May and June 2020.[1] This difference is possibly due to the period of investigation and the pandemic period in the region, a finding that is supported by the survey conducted in the city of São Paulo, in late September 2020, which showed a prevalence of infection close to 14%.[6]

The lower percentage of seropositive individuals who reported the absence of symptoms in the 15 days before the interview, as indicated in this study, corroborates the results of the national survey conducted by Menezes et al.,[11] which found less than 1% of asymptomatic individuals tested positive. These findings show that most individuals with antibodies against SARS-CoV-2 had mild symptoms.[11]

The relationship between the positive serological profile and the main symptoms reported is described in the literature, which indicates the predominance of ageusia and anosmia in mild cases of the disease, and

dyspnea as the main symptom among severe cases that can evolve to death.[12,13] In an European multicenter cohort study, it was observed that more than 85% of the participants had ageusia and/or anosmia, symptoms that showed high specificity when included as screening criteria for the diagnosis of Covid-19.[14]

Because they did not meet the criteria for testing and continued in contact with other people, seropositive individuals who showed no symptoms may have influenced the dynamics of infection transmission in Mariana and Ouro Preto. However, it has been reported that the viral load of these individuals is similar to that of symptomatic individuals, making them potential silent disseminators of the disease.[15] In this context, the results of this study support the need for and importance of adopting mass testing of the population to detect asymptomatic positive cases or those with mild symptoms of the disease.

The relationship between the infection and the low education level and socioeconomic status found in the Mariana and Ouro Preto population suggests that there possibly were difficulties in implementing prevention and control measures for Covid-19 in this population. The difficulty of leaving home for work and the limitation in understanding the high risk of getting sick compromises the adherence to measures that prevent the spread of the virus. According to data from the United Kingdom on Covid-19 control actions, income is a determining factor for adherence to social distancing measures, and people with lower income are three times less likely to perform social isolation.[16] In Brazil, a study of Covid-19 seroprevalence in blood donors in the state of Rio de Janeiro observed that the lower the level of education, the greater the chance of testing positive for the disease.[17]

In Mariana and Ouro Preto, three or more comorbidities were observed among individuals with anti-SARS-CoV-2 antibodies. This result is different from that observed in the national survey, which found no difference in the prevalence of infection between individuals with and without chronic diseases.[18] However, the national data show that 43% of the individuals with comorbidities had similar sociodemographic characteristics to the individuals seropositive for SARS-CoV-2 in Mariana and Ouro Preto (women, white or mixed-race skin, low education, and lower socioeconomic status). The literature shows that aging and the consequent increase in comorbidities enhance the severity of Covid-19 and the risk of death from the disease.[19-21]

The heterogeneous distribution of cases of SARS-CoV-2 infection in the cities of Mariana and Ouro Preto is consistent with projections of the transmission of Covid-19 in intra-urban space. These projections indicate that the dispersion of coronavirus-2 was initiated in regions of higher income and extended to less developed regions, in which territorial use and social conditions can be propelling factors for the spread of the virus.[22] The spread of the disease to areas of greater vulnerability potentially compromises the quality of life and health conditions of the population,[23] especially in the context of restriction of circulation necessary to control the SARS-CoV-2 spread. This profile of case distribution , which starts in higher-income areas and spreads to less developed areas, emphasizes that the disease is socially determined,[4] as is the case with other diseases, such as HIV infection.[24]

This study has limitations due to the restriction of the sample to two medium-sized Brazilian cities, which represent only 12.2% of Brazilian municipalities, as well as the exclusion of residents from the rural areas of the municipalities. This geographic limitation reduces the generalizability of the results to other regions of Brazil, especially to rural areas and more populated urban centers. Additionally, the lack of temporal comparisons limits the ability to observe changes in seroprevalence over different phases of the pandemic, such as before and after the vaccination campaigns. Another limitation is the use of rapid serological tests, which, although widely used during the pandemic, are subject to lower sensitivity and specificity compared to other diagnostic methods, such as RT-PCR.[25] This reliance on rapid tests may have affected the accuracy of seroprevalence estimates, potentially underestimating or overestimating the true prevalence of anti-SARS-CoV-2 antibodies in the population. However, the results play an important role in providing information on the socio-economic and health impacts on the population resulting from social distancing. From a social perspective, this study allowed us to expand the offer of Covid-19 testing to the population of the cities of Mariana and Ouro Preto, contributing to public management with disease monitoring at a time when Brazil was experiencing the beginning of the increase in cases, which culminated in the peak of transmission throughout the national territory in 2021, transforming the country into one of the largest centers of dissemination of Covid-19 worldwide.

Results showed that the seroprevalence of SARS-CoV-2 infection in Mariana and Ouro Preto was higher than that found in cities in the Southeast region in the first semester of 2020 (May to June) and lower than that observed in a city in the Northeast before the study (July to August). Despite the heterogeneous distribution of individuals with anti-SARS-CoV-2 antibodies in the two cities, the results indicate that they mostly belong to social segments with lower income, which shows a profile of socioeconomic vulnerability in the infected group. These results emphasized the importance of epidemiological surveys for monitoring highly transmissible diseases, such as Covid-19, and suggest that health surveillance actions and strategies for coping

with the disease should consider the characteristics of the population.

Future research should expand the scope of the study to include other geographic areas, especially rural regions and larger urban centers, as well as conduct longitudinal analyses to explore temporal variations in seroprevalence and the impact of vaccination campaigns. Such studies would provide a more comprehensive understanding of the socio-demographic and geographic disparities associated with SARS-CoV-2 infection and strengthen public health policies aimed at reducing vulnerabilities in different population groups.

ACKNOWLEDGEMENTS

The authors acknowledge the Federal University of Ouro Preto (UFOP) and the Nutrition and Public Health Research Group (GPENSC) for their support and incentive. And also the support of the Municipal Health Secretariats of the municipalities evaluated in the study.

FINANCIAL SUPPORT

This study was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior-Brazil (CAPES) [nº 88887.504994/2020-00] and finance code 001 for PhD student scholarship.

REFERENCES

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(11): e1390-e1398. http://doi.org/10.1016/S2214-109X(20)30387-9

2. BRASIL. Ministério da Saúde. Painel coronavírus Brasil. Brasília: Ministério da Saúde; 2020. https://covid.saude.gov.br/

3. Rodriguez-Morales AJ, Gallego V, Escalera-Antezana JP, et al. Covid-19 in Latin America: The implications of the first confirmed case in Brazil. Travel Med Infect Dis. 2020; 35: 101613. https://doi.org/10.1016/j.tmaid.2020.101613

4. Cestari VRF, Florêncio RS, Sopusa GJB, et al. Social vulnerability and Covid-19 incidence in a Brazilian metropolis. Cien Saude Colet. 2021; 26(3): 1023-1033. https://doi.org/10.1590/1413-81232021263.42372020

5. Santos JPC, Siqueira ASP, Praca HLF, et al. Vulnerability to severe forms of Covid-19: an intra-municipal analysis in the city of Rio de Janeiro, Brazil. Cad Saúde Pública. 2020; 36(5): e00075720. https://doi.org/10.1590/0102-311X00075720

6. SÃO PAULO. Prefeitura Municipal. Inquérito Sorológico Adultos (>18) para SARS-CoV-2: Evolução da Prevalência da Infecção no MSP. Resultado das 8 fases. São Paulo: Prefeitura Municipal; 2020. https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/saude/2020_10_13_inq_soro_adulto.pdf

7. MINAS GERAIS. Secretaria de Estado da Saúde. Boletim epidemiológico coronavirus. Belo Horizonte: Secretaria de Estado da Saúde; 2021. https://coronavirus.saude.mg.gov.br/boletim

8. BRASIL. Instituto Brasileiro de Geografia e Estatística. Atlas do Censo Demográfico 2010. Rio de Janeiro: Instituto Brasileiro de Geografia e Estatística; 2013. https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=264529

9. Meireles AL, Lourenção LG, Menezes Junior LAA, et al. Covid-Inconfidentes - SARS-CoV-2 seroprevalence in two Brazilian urban areas in the fourth quarter 2020: study protocol and initial results. PSM. 2023; 21(1): 53127. https://doi.org/10.15517/psm.v21i1.53127

10. Silva AAMD, Lima-Neto LG, Azevedo CMPES, et al. Population-based seroprevalence of SARS-CoV-2 and the herd immunity threshold in Maranhão. Rev Saude Publica. 2020; 54: 131. https://doi.org/10.11606/s1518-8787.2020054003278

11. Menezes AMB, Victora CG, Hartwig FP, et al. High prevalence of symptoms among Brazilian subjects with antibodies against SARS-CoV-2. Sci Rep. 2021; 13279. https://doi.org/10.1038/s41598-021-92775-y

12. Iser BPM, Sliva S, Raymundo VT, et al. Suspected Covid-19 case definition: a narrative review of the most frequent signs and symptoms among confirmed cases. Epidemiol. Serv. Saúd. 2020; 29(3): e2020233. https://doi.org/10.5123/S1679-49742020000300018

13. Chen T, Wu D, Chen H, et al. Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. BMJ. 2020; 368: m1091. https://doi.org/10.1136/bmj.m1091

14. Lechien JR, Chiesa-Estomba CM, De Siati DR, et al. Olfactory and gustatory dysfunctions as a clinical presentation of mild-to-moderate forms of the coronavirus disease (Covid-19): a multicenter European study. Eur Arch Otorhinolaryngol. 2020; 277(8): 2251-2261. https://doi.org/10.1007/s00405-020-05965-1

15. Byambasuren O, Cardona M, Bell K, et al. Estimating the extent of asymptomatic Covid-19 and its potential for community transmission: Systematic review and meta-analysis. JAMMI. 2020; 5(4): 223-234. https://doi.org/10.3138/jammi-2020-0030

16. Mesenburg MA, Hallal PC, Menezes AMB, et al. Chronic non-communicable diseases and Covid-19: EPICOVID-19 Brazil results. Rev Saude Publica. 2021; 55: 38. https://doi.org/10.11606/s1518-8787.2021055003673

17. Atchimson C, Bowman L, Vrinten C, et al. Early perceptions and behavioural responses during the Covid-19 pandemic: a cross-sectional survey of UK adults. BMJ Open. 2021; 11: e043577. http://dx.doi.org/10.1136/bmjopen-2020-043577

18. Amorim Filho L, Szwarcwald CL, Mateos SOG, et al. Seroprevalence of anti-SARS-CoV-2 among blood donors in Rio de Janeiro, Brazil. Rev Saude Publica. 2020; 54: 69. http://dx.doi.org/10.11606/s1518-8787.2020054002643

19. Høy B, Hall EOC. "Take good care of yourself" An integrative review of older widows' self-care for health and well-being. J Women Aging. 2022; 34(1): 1-30. https://doi.org/10.1080/08952841.2020.1753484

20. Guimarães-Ximenes-Neto FR, Carneiro-Flor SM, Carvalho-da-Silva RC, et al. Descriptive study of the initial cases of Covid-19 in a city in the interior of Ceará, Brazil. Arch Med (Manizales). 2021; 21(2): 536-547. https://doi.org/10.30554/archmed.21.2.3989.2021

21. Moreira AC, Lourenção LG, Sassaki NSGMS, et al. Mortality risk associated with blood sugar levels in patients with septicemia in

Intensive Care. Rev Rene. 2016; 17(3): 324-9. http://dx.doi.org/10.15253/2175-6783.2016000300004

22. Thomé B, Rezende LFM, Schveitzer MC, et al. Differences in the prevalence of risk factors for severe Covid-19 across regions of São Paulo City. Rev. bras. epidemiol. 2020; 23: e200087. https://doi.org/10.1590/1980-549720200087

23. Oliveira JF, Oliveira AMN, Barlem ELD, et al. The vulnerability of the family: reflections about human condition. Rev Bras Enferm. 2021; 74(1): e20190412. http://dx.doi.org/10.1590/0034-7167-2019-0412

24. Tauyr TFL, Lourenção LG, Ponce MAZ, et al. Vulnerability of the Brazilian LGBT population in HIV treatment. J Infect Dev Ctries. 2021; 15(10): 1481-1488. https://doi.org/10.3855/jidc.13707

25. Menezes-Júnior LAAd, Batista AP, Lourenção LG, et al. Rapid Serological Test for Covid-19, One-Step-Covid-2019: Accuracy and Implications for Pandemic Control. Covid. 2024; 4(8): 1315-1323. https://doi.org/10.3390/covid4080093

AUTHORS' CONTRIBUTIONS

Adriana Lúcia Meireles contributed to project administration and supervision, interpretation of results, review and final approval of the version to be published. **Ana Maria Sampaio Rocha** contributed to bibliographical research, abstract writing, introduction, methodology, discussion, interpretation and description of results, preparation of tables, conclusions and final approval of the version to be published. **Bárbara dos Santos Simões** contributed to bibliographical research, abstract writing, introduction, methodology, discussion, interpretation and description of results, preparation of tables, conclusions and final approval of the version to be published. **Luciano Garcia Lourenção** contributed to data collection, article writing, review and final approval of the version to be published. **Luiz Antônio Alves de Menezes-Júnior** contributed to data collection, statistics, interpretation and description of results, preparation of tables, review and final approval of the version to be published. **Irene Carolina Sousa Justiniano** contributed to data collection, interpretation and description of results, discussion, conclusion and final approval of the version to be published. **Hillary Nascimento Coletro** contributed to data collection, interpretation and description of results, discussion, conclusion and final approval of the version to be published. **Samara Silva de Moura** contributed to data collection, interpretation and description of results, discussion, conclusion and final approval of the version to be published. **Amanda Popolino Diniz** contributed to data collection, interpretation and description of results, discussion, conclusion and final approval of the version to be published. **Thaís da Silva Sabião** contributed to data collection, interpretation and description of results, discussion, conclusion and final approval of the version to be published. **Aline Priscila Batista** contributed to data collection, processing in the laboratory and final approval of the version to be published. **Nara Nunes Lage** contributed to data collection, processing in the laboratory and final approval of the version to be published. **Keila Furbino Barbosa** contributed to data collection, processing in the laboratory and final approval of the version to be published. **Cássio Zumerle Masioli** contributed to data collection, processing in the laboratory and final approval of the version to be published. **Carolina Ali Santos** contributed to data collection, supporting patients' medical treatment and final approval of the version to be published. **Márcio Antônio Moreira Galvão** contributed to data collection and final approval of the version to be published. **Raquel de Deus Mendonça** contributed to interpretation and description of results, discussion, conclusion and final approval of the version to be published. **George Luiz Lins Machado-Coelho** contributed to project administration and supervision, interpretation of results, review and final approval of the version to be published.

All authors approved the final version to be published and are responsible for all aspects of the work, including ensuring its accuracy and integrity.

Please cite this article as: Meireles AL, Rocha AMS, Simões BS, Lourenção LG, de Menezes-Júnior LAA, Justiniano ICS, Coletro HN, de Moura SS, Diniz AP, Sabião TS, Batista AP, Lage NN, Barbosa KF, Masioli CZ, Santos CA, Galvão MAM, Mendonça RD, Machado-Coelho GLL. SARS-CoV-2 seroprevalence among adults in the cities of Mariana and Ouro Preto, Minas Gerais, Brazil. Rev Epidemiol Control Infect [Internet]. 2025 Feb. 16;15(1). Available from: https://online.unisc.br/seer/index.php/epidemiologia/article/view/19515