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MAJOR ARTICLE

# High Severe Acute Respiratory Syndrome Coronavirus 2 Antibody Prevalence After the Third Epidemic Wave (May–October 2021) in Matadi, Democratic Republic of the Congo

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***Background.*** By the end of the third wave of the coronavirus disease 2019 (COVID-19) epidemic (May–October 2021), only 3130 of the 57 268 confirmed cases of coronavirus disease 2019 (COVID-19) in the Democratic Republic of the Congo (DRC) were reported in Kongo Central. This province, and especially its capital city, Matadi, has essential trade and exchanges with Kinshasa, the epicenter of the COVID-19 epidemic in DRC. Kinshasa accounted for 60.0% of all cases during the same period. The true burden of COVID-19 in Matadi is likely underestimated. In this study, we aimed to determine the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) seroprevalence and associated risk factors after the third wave in Matadi.

***Methods.*** We conducted a population-based cross-sectional study in October 2021. Consenting participants were interviewed and tested using an enzyme-linked immunosorbent assay commercial kit. We applied univariable and multivariable analysis to evaluate factors associated with seropositivity and adjusted the seroprevalence for the test kit performance.

***Results.*** We included 2210 participants from 489 households. Female participants represented 59.1%. The median age was 27 years (interquartile range, 16–45 years). The crude SARS-CoV-2 seroprevalence was 82.3%. Age was identified as the main risk factor as younger age decreased the seropositivity odds. Accounting for clustering at the household level increased the seroprevalence to 83.2%. The seroprevalence increased further to 88.1% (95% confidence interval, 86.2%–90.1%) after correcting for the laboratory test kit performance.

***Conclusions.*** The SARS-CoV-2 seroprevalence was very high, contrasting with reported cases. Evidence generated from this population-based survey remains relevant in guiding the local COVID-19 response, especially vaccination strategies.

**Keywords.** antibodies; Matadi; SARS-CoV-2; seroprevalence; third wave.

The Democratic Republic of the Congo (DRC) has experienced 5 waves of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as of October 2022 [1, 2]. The 5 waves peaked respectively in June 2020, January 2021, June 2021, December 2021, and May 2022 [1, 2]. After the third epidemic wave, as of 10 October 2021, 57 268 laboratory-confirmed cases were reported, including 1089 deaths out of 415 055 performed tests [1]. These numbers were far less catastrophic than initially predicted. However, several studies in sub-Saharan Africa have pointed out that data on laboratory-confirmed cases are largely underestimating the extent of community transmission [3–6]. In DRC, a survey conducted by Nkuba et al in Kinshasa showed that after the first wave, 292 infections went undiagnosed for every polymerase chain reaction (PCR)–confirmed case [3]. This discrepancy can be explained by factors such as limited testing capacities, a non-comprehensive case definition excluding asymptomatic or paucisymptomatic infections, and stigma preventing infected individuals from seeking healthcare services [7]. In such a context, serological surveys are critical to providing data on the actual spread of infection and guiding infection control.

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Kinshasa province, the DRC's capital city, has been a hotspot and epidemic epicenter based on the number of confirmed reported cases. Two seroprevalence surveys have been conducted after the first and second waves and revealed extremely progressive spreading of SARS-CoV-2 infection with 16.6% [3] and 76.5% of seroprevalence [8], respectively. However, there has been no population-based seroprevalence survey to evaluate the real burden of coronavirus disease 2019 (COVID-19) in other areas.

Matadi is the capital city of Kongo Central, the nearest province to Kinshasa. It is one of the major DRC points of entry and has important commercial exchanges with Kinshasa. Despite the geographical proximity and intense economic exchanges with Kinshasa, the reported COVID-19 cases in Matadi seem low, representing only 5.2% of all country cases as of 10 October 2021 [1]. Furthermore, data on the true number of cases and the proportion of pauci- and asymptomatic infections not meeting the case definition and thus missed by PCR testing are unknown.

In this study, we aimed to determine the SARS-CoV-2 seroprevalence and associated risk factors in Matadi to understand the real extent of population exposure after the third wave (May–October 2021) of the COVID-19 epidemic.

## METHODS

### Study Design and Population

We conducted a population-based cross-sectional study in Matadi on 16–24 October 2021, after the DRC's third wave of the COVID-19 epidemic. The study was adapted from the World Health Organization population-based, age-stratified seroepidemiological investigations master protocol [9]. Matadi is the main seaport city of DRC and the political capital of the Kongo Central Province. It is located on the left bank of the Congo River, 352 km from Kinshasa, the capital city of DRC. It has an estimated population of 402 397 and is divided into 2 health districts: Matadi and Nzanza. Matadi health district accounts for 55% of the city population and comprises 12 of the 22 health areas [10, 11].

The sample size was calculated based on an expected seroprevalence of at least 15% [3], a precision of 1%, a design effect of 2, and a nonresponse rate of 30%. We had to recruit at least 2156 participants in both health districts using probability-proportional-to-size sampling, with 1183 participants from Matadi health district and 973 from Nzanza health district. After including all 22 health areas of Matadi, we calculated the number of participants to select per health area based on their respective weights. Thereafter, the number of households in each health area was defined by dividing the number of participants by 5 (average household size). We applied a 2-stage sampling to select households. In the first stage, 30% of streets/villages were selected within each health area with a probability proportional to the size (number of inhabitants per street/village). Then, the number of households to select per street was determined based on the weights of respective streets/villages. Surveyors enumerated households within a given street/village and determined a sampling interval that was used to systematically select households from a random starting point. Individuals at least 5 years of age who stayed in Matadi >2 weeks before the survey and had no contraindications to venipuncture were eligible for the study. To avoid oversampling participants <18 years old, residents aged 18 years and older were invited to participate in all households, whereas residents aged 5–17 years were invited to participate in only 50% of households. The latter corresponded to every other household from the selection starting point, applying the sampling interval.

### Patient Consent Statement

We obtained written informed consent from adults (participants aged ≥18 years) and emancipated minors, and parental consent for participants younger than 18 years. In addition, we obtained assent for participants aged 10–17 years. The study was reviewed and approved by the ethics committee of the Kinshasa School of Public Health (ESP/CE/37B/2022).

### Data Collection

We used a mobile application (Epicollect 5, Imperial College, London) to administer a structured pretested questionnaire to participants. The questionnaire included sociodemographic characteristics, current and past medical history, COVID-19 vaccination history, exposure to SARS-CoV-2, and COVID-19–related behavioral characteristics. We gave all participants face masks and hand sanitizers and encouraged them to practice physical and social distancing.

### SARS-CoV-2 Antibody Detection

Three to 5 mL of venous blood samples were collected from consented participants in a red-topped plain tube. They were transported at 4°C in cool boxes to Kongo Central Provincial Public Health Laboratory, where they were processed to obtain serum and to make 2-mL aliquots. Aliquots were then transferred in portable freezers to the Institut National de Recherche Biomédicale in Kinshasa and stored at −20°C for downstream analyses.

We used the Wantai SARS-CoV-2 enzyme-linked immunosorbent assay (ELISA) kit (Beijing Wantai Biological Pharmacy Enterprise Co, Ltd), detecting total antibodies (including immunoglobulin G and immunoglobulin M) to the receptor-binding domain of the spike protein. We conducted the assay in a single replicate according to the manufacturer's instructions. We considered a sample positive if the absorbance-to-cutoff ratio was at least 1.1 and negative if this ratio was <1.0. We reran the test in duplicate for samples with borderline results and considered 2 matching results as the final result. The Wantai SARS-CoV-2 total antibody

ELISA kit has a sensitivity of 94.4% and a specificity of 100% [12]. In addition to SARS-CoV-2 antibody testing, we screened all participants for *Plasmodium* infection to rule out acute malaria, which has been reported to induce cross-reactivity to the S1 spike protein through antibody binding to terminal sialic acids of complex glycans [13, 14]. Nested PCR was conducted on DNA extracted from dried blood spots as previously described [15].

#### Statistical Analyses

We extracted data from the Epicollect 5 server, converted into a CSV file, and transferred to Stata 15.1 (StataCorp, College Station, Texas) for analysis. Categorical variables were summarized using proportions with corresponding 95% confidence intervals (CIs), while continuous variables were summarized using the median with interquartile range (IQR). We used the Pearson $\chi^2$ or Fisher exact test to assess the difference in seroprevalence between groups and multivariable logistic regression to assess the association between SARS-CoV-2 seropositivity and key exposures. Key exposures included sex, health district, age, education, household average monthly income, handwashing, face mask wearing, alcohol intake, tobacco intake, contact with a COVID-19 case, comorbidities, reported symptoms, and household size. We adjusted seroprevalence estimates to account for clustering at the household level. Additionally, we corrected the seroprevalence for the test kit error using a Bayesian model described elsewhere [16, 17].

## RESULTS

Out of the 558 randomly selected households from 22 health areas, 489 (87.6%) agreed to participate in the survey. These households comprised 3027 members, of whom 2279 (75.3%) were present on the survey dates. Of the 2279 household members present during recruitment, 2241 (98.3%) were eligible, consented to provide blood samples, and were included. A total of 2210 (98.6%) blood samples were deemed appropriate for serological analyses of which 2197 samples had valid serological results, while 13 samples had borderline results (Figure 1).

Of the 2210 consenting participants, 54.4% were recruited from Matadi health district (Table 1). Female participants represented 59.1%. The median age was 27 years (interquartile range [IQR], 16–45 years). Participants 20–29 years of age were the most represented (20.3%). Half participants had a secondary education level, while 7.2% had no formal education. The median household size was 6 (IQR, 5–8).

Regarding attitudes and practices toward COVID-19, 36.0% of participants reported washing their hands at least 6 times a day, while almost one-fourth reported washing their hands once or twice daily (Table 1). Participants who reported always wearing a face mask represented 3.9%. In contrast, >40% of participants reported rarely wearing a face mask. Almost 93% of participants were nonsmokers, 77.1% reported no alcohol consumption, and 2.1% recalled a known contact with a COVID-19 case.

Nearly 60% of participants experienced at least 1 symptom indicative of COVID-19 within 2 weeks before the survey. Only 9.9% of participants reported at least 1 comorbidity, with hypertension representing 77.7% (Table 2).

The crude SARS-CoV-2 total antibody prevalence was 82.3% (1808/2197; 95% CI, 80.7%–83.8%). Accounting for clustering at the household level increased the seroprevalence to 83.2% (Table 3). The seroprevalence increased further to 88.1% (95% CI, 86.2%–90.1%) after correcting for the laboratory test kit error. Households with at least 1 seropositive case represented 97.9%. The median number of seropositive cases per household was 3 (IQR, 2–5). There was a trend, although not significant, toward decreased household seropositivity with increased household size. Households of >5 members had almost 40% decreased seropositivity odds than households with 1–2 members (adjusted odds ratio [AOR], 0.57 [95% CI, .24–1.38]; $P = .214$). The seroprevalence was slightly higher in Nzanza health district than in Matadi, although not significant in multivariable analysis (83.5% vs 82.9%, $P = .950$). We found a strong association between seropositivity and age in univariable analysis. The odds of seropositivity tended to increase with age, particularly for participants aged 40–49 years (odds ratio [OR], 5.04 [95% CI, 3.06–8.32]; $P = .000$) and 70–79 years (OR, 5.80 [95% CI, 2.13–15.8]; $P = .001$). This association persisted and became stronger in effect size in multivariable analysis for most age groups compared to the age group 5–9 years (Table 3). The lowest seroprevalence was recorded among participants 5–9 years of age (67.7%), while the highest was recorded among those 40–49 years of age (89.4%). Analysis of symptomatic participants showed that participants 70–79 years of age had the highest seroprevalence and were 9 times more likely to be seropositive (100.0%; AOR, 9.03 [95% CI, 1.74–46.9]; $P = .009$) (Supplementary Table 1).

The likelihood of SARS-CoV-2 infection tended to increase with the education level. Participants with university-level education were more likely to be infected with SARS-CoV-2 than those without formal education (OR, 1.97 [95% CI, 1.09–3.58]; $P = .025$) (Table 3). This association decreased in statistical significance in multivariable analysis (AOR, 1.84 [95% CI, .77–4.43]; $P = .173$). In contrast, participants with a primary education level had almost 40% decreased odds of seropositivity compared with those with no formal education (OR, 0.62 [95% CI, .39–.98]; $P = .042$). However, in multivariable analysis, the odds of seropositivity between both categories were similar (AOR, 1.01 [95% CI, .54–1.88]; $P = .984$).

Regarding COVID-19 vaccination status, only 7 participants (0.3%) received the first 2 vaccine shots, and were all seropositive, representing 0.4% of all seropositive participants. Twelve participants received 1 dose of COVID-19 vaccine, of which 10 were seropositive, representing 0.6% of all seropositive participants.

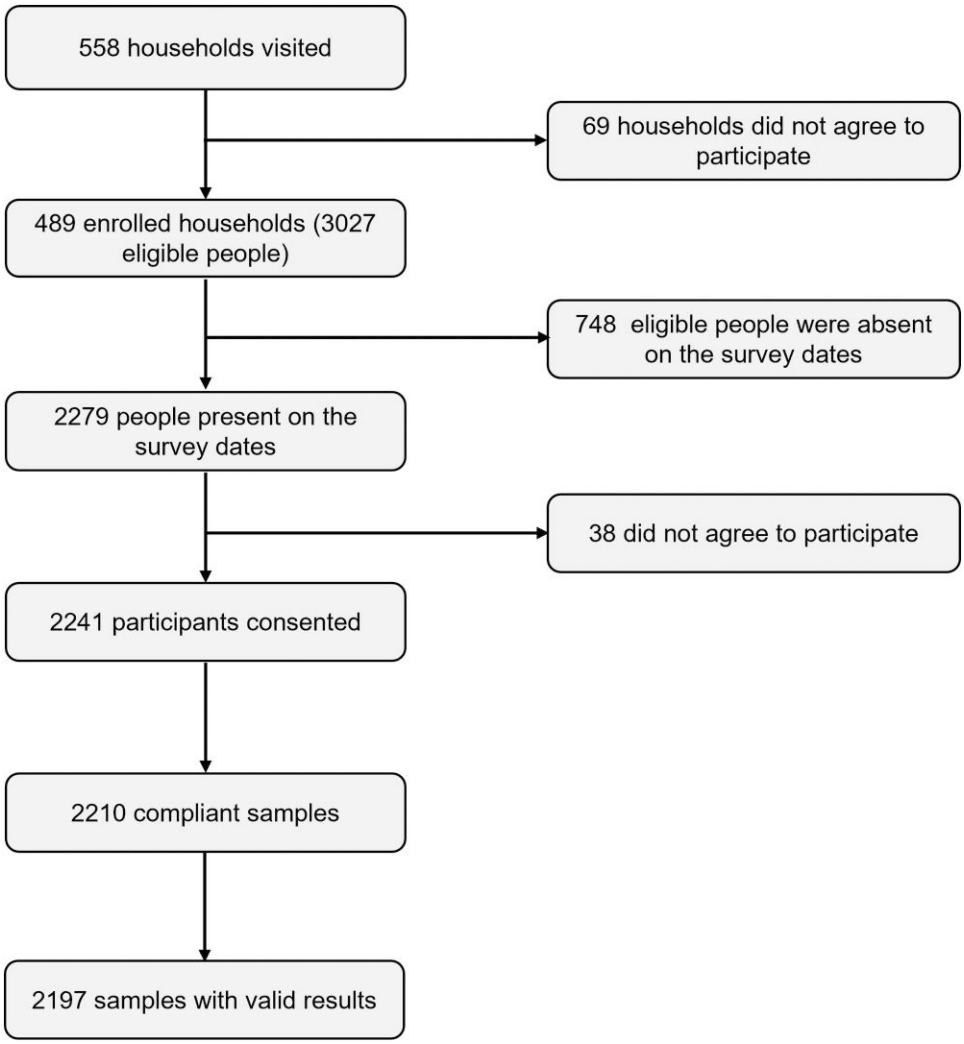


**Figure 1.** Flowchart of participants and households' inclusion.

Of the 1275 participants who reported at least 1 symptom suggestive of COVID-19 within 2 weeks before the survey, 1057 (82.9%) were seropositive and among the 922 participants without any symptom, 751 (81.5%) were seropositive (Table 3). Among the 1808 seropositive participants, 209 (11.5%) presented <2 symptoms and 751 (41.5%) did not report any symptoms. Seropositive participants mostly experienced fever (36.2%), headache (35.8%), coughing (26.2%), chills (23.9%), myalgia (20.5%), fatigue (18.6%), and runny nose (18.4%) (Figure 2).

The overall prevalence of *Plasmodium* infection was 13.1% (95% CI, 11.7%–14.6%). We did not find any statistically significant difference between SARS-CoV-2–seropositive and seronegative participants (13.2% vs 13.4%, $P = .933$).

## DISCUSSION

We conducted a population-based cross-sectional study after the third wave (May–October 2021) of the COVID-19 pandemic in Matadi, before the scale-up of vaccination.

The study provides evidence of a high exposure to SARS-CoV-2. This is the first serological survey conducted on the general population outside the capital city in DRC. The test kit–adjusted SARS-CoV-2 total antibody prevalence of 88.1% (95% CI, 86.2%–90.1%) reflects a marked and sustained community transmission >2 years after the detection of the first case in Matadi.

After extrapolating to the entire population of Matadi (402 397 in 2021), around 354 512 SARS-CoV-2 infections are believed to have occurred by October 2021, while only 3130 cases were reported for the entire Kongo Central province (unpublished data). Previous studies in Africa and Asia have reported similar findings implying underreporting of SARS-CoV-2 infections [4, 5, 7, 18]. This discrepancy can be explained by the limited SARS-CoV-2 testing capacities at the provincial level, the high proportion of infected persons not meeting the case definition, and health services underutilization. Of the 3130 cumulative cases reported by the Kongo Central response team,

**Table 1. Sociodemographic Characteristics of Study Participants (N = 2210)**

| Variable | No. | (%) |
|---|---|---|
| Sex | | |
| Female | 1307 | (59.1) |
| Male | 903 | (40.9) |
| Health district | | |
| Matadi | 1203 | (54.4) |
| Nzanza | 1007 | (45.6) |
| Age, y, median (IQR) | 27 | (16–45) |
| Age group, y | | |
| 5–9 | 212 | (9.6) |
| 10–14 | 247 | (11.2) |
| 15–19 | 292 | (13.2) |
| 20–29 | 449 | (20.3) |
| 30–39 | 316 | (14.3) |
| 40–49 | 258 | (11.7) |
| 50–59 | 211 | (9.5) |
| 60–69 | 144 | (6.5) |
| 70–79 | 60 | (2.7) |
| ≥80 | 21 | (1.0) |
| Education | | |
| No formal education | 159 | (7.2) |
| Primary | 480 | (21.7) |
| Secondary | 1107 | (50.1) |
| Vocational | 178 | (8.1) |
| University | 286 | (12.9) |
| Household size, median (IQR) | 6 | (5–8) |
| No. of rooms per household, median (IQR) | 3 | (2–4) |
| Household average monthly income, USD | | |
| 1–50 | 994 | (45.0) |
| 51–250 | 1062 | (48.1) |
| 251–500 | 127 | (5.7) |
| 501–1000 | 27 | (1.2) |
| Daily handwashing frequency | | |
| <1 time | 548 | (24.8) |
| 1–2 times | 569 | (25.7) |
| 3–4 times | 197 | (8.9) |
| 5–6 times | 101 | (4.6) |
| >6 times | 795 | (36.0) |
| Face mask wearing | | |
| Never | 399 | (18.1) |
| Rarely | 955 | (43.2) |
| Sometimes | 373 | (16.9) |
| Often | 396 | (17.9) |
| Always | 87 | (3.9) |
| Alcohol intake | | |
| No | 1705 | (77.1) |
| Yes | 505 | (22.9) |
| Tobacco intake | | |
| No | 2062 | (93.3) |
| Yes | 148 | (6.7) |
| Contact with a COVID-19 case | | |
| No | 1698 | (76.8) |
| Yes | 46 | (2.1) |
| Don't know | 466 | (21.1) |

Data are presented as No. (%) unless otherwise indicated.

Abbreviations: COVID-19, coronavirus disease 2019; IQR, interquartile range; USD, United States dollars.

**Table 2. Clinical Characteristics of Study Participants (N = 2210)**

| Variables | No. | (%) |
|---|---|---|
| Symptoms suggestive of COVID-19 last 2 wk before the survey | | |
| Absent | 932 | (42.2) |
| Present[a] | 1278 | (57.8) |
| Fever (≥38°C) | 800 | (62.6) |
| Chills | 534 | (41.8) |
| Fatigue | 408 | (31.9) |
| Myalgia | 424 | (33.2) |
| Sore throat | 172 | (13.5) |
| Coughing | 564 | (44.1) |
| Runny nose | 409 | (32.0) |
| Dyspnea | 61 | (4.8) |
| Wheezing | 46 | (3.6) |
| Chest pain | 72 | (5.6) |
| Other respiratory symptoms | 37 | (2.9) |
| Headaches | 785 | (61.4) |
| Nausea/vomiting | 235 | (18.4) |
| Abdominal pain | 237 | (18.5) |
| Diarrhea | 184 | (14.4) |
| Anosmia/ageusia | 72 | (5.6) |
| No. of symptoms | | |
| <2 | 260 | (20.3) |
| 2–4 | 576 | (45.1) |
| >5 | 442 | (34.6) |
| Comorbidity[b] | | |
| Absent | 1990 | (90.1) |
| Present | 220 | (9.9) |
| Hypertension | 171 | (77.7) |
| Stroke | 22 | (10.0) |
| Asthma | 39 | (17.7) |
| Diabetes mellitus | 37 | (16.8) |
| Obesity | 10 | (4.6) |

Abbreviation: COVID-19, coronavirus disease 2019.

[a]Median, 3 (interquartile range, 2–5).

[b]Median, 1.

1383 were recorded during the third wave with a fatality rate of 3.3% (unpublished data), 3 times lower than that recorded in the same province during the first wave (51 deaths for 549 cases [9.3%]). This finding is in keeping with the country-level trend of decreased case fatality rate from 5.1% during the first wave to 2.4% during the third wave, and 0.9% during the fourth wave [2]. The lower-case fatality rates, the lightening of stringent public health measures after the second wave, and the large proportion of mild cases might have influenced the population's perception of COVID-19 risk, resulting in a wide spread of infection.

The seroprevalence in this study was higher than the 76.5% found in Kinshasa, a neighboring province, after the second wave [8]. This finding reflects the population's cumulative exposure during consecutive waves, especially exposure to the SARS-CoV-2 Delta variant, the predominant circulating strain during the third wave [19]. A higher seroprevalence has been reported in India during the same period (97.0%) [20].

**Table 3. Severe Acute Respiratory Syndrome Coronavirus 2 Infection, Sociodemographic, and Clinical Characteristics of Study Participants (N = 2197)**

| Variable | No. | Positive, No. (%)[a] | OR (95% CI) | *P* Value | AOR (95% CI) | *P* Value |
|---|---|---|---|---|---|---|
| Entire study population | 2197 | 1808 (83.2) | … | | … | |
| Sex | | | | | | |
| Female | 1300 | 1075 (83.8) | 1 | | 1 | |
| Male | 897 | 733 (81.7) | 0.94 (.75–1.17) | .555 | 1.16 (.83–1.62) | .387 |
| Health district | | | | | | |
| Matadi | 1195 | 962 (82.9) | 1 | | 1 | |
| Nzanza | 1002 | 846 (83.5) | 1.31 (1.01–1.71) | .042 | 0.99 (.69–1.40) | .950 |
| Age, y | | | | | | |
| 5–9 | 212 | 127 (67.7) | 1 | | 1 | |
| 10–14 | 244 | 191 (85.1) | 2.41 (1.60–3.64) | .000 | 2.18 (1.14–4.17) | .019 |
| 15–19 | 291 | 242 (76.7) | 3.31 (2.19–4.98) | .000 | 3.85 (1.82–8.12) | .000 |
| 20–29 | 447 | 391 (88.7) | 4.67 (3.09–7.06) | .000 | 4.59 (2.20–9.58) | .000 |
| 30–39 | 316 | 269 (80.0) | 3.83 (2.44–6.02) | .000 | 5.61 (2.60–12.1) | .000 |
| 40–49 | 256 | 226 (89.4) | 5.04 (3.06–8.32) | .000 | 5.56 (2.48–12.5) | .000 |
| 50–59 | 209 | 175 (83.0) | 3.44 (2.12–5.58) | .000 | 3.28 (1.48–7.27) | .003 |
| 60–69 | 143 | 121 (83.7) | 3.68 (2.12–6.40) | .000 | 3.71 (1.51–9.13) | .004 |
| 70–79 | 58 | 52 (85.7) | 5.80 (2.13–15.8) | .001 | 9.03 (1.74–46.9) | .009 |
| ≥80 | 21 | 14 (75.0) | 1.34 (.52–3.45) | .547 | 1.32 (.36–4.78) | .675 |
| Education | | | | | | |
| No formal education | 159 | 127 (75.6) | 1 | | 1 | |
| Primary | 476 | 338 (71.0) | 0.62 (.39–.98) | .042 | 1.01 (.54–1.88) | .984 |
| Secondary | 1104 | 940 (87.8) | 1.44 (.93–2.25) | .106 | 0.92 (.48–1.76) | .795 |
| Vocational | 175 | 152 (84.1) | 1.66 (.92–3.01) | .092 | 1.11 (.48–2.58) | .809 |
| University | 283 | 251 (85.3) | 1.97 (1.09–3.58) | .025 | 1.84 (.77–4.43) | .173 |
| Household average monthly income, USD | | | | | | |
| 1–50 | 986 | 814 (81.0) | 1 | | 1 | |
| 51–250 | 1057 | 869 (85.6) | 0.97 (.76–1.26) | .857 | 1.10 (.77–1.57) | .601 |
| 251–500 | 127 | 98 (78.6) | 0.71 (.36–1.43) | .340 | 1.15 (.40–3.27) | .799 |
| 501–1000 | 27 | 27 (100.0) | … | | … | |
| Daily handwashing frequency | | | | | | |
| <1 time | 543 | 447 (80.0) | 1 | | 1 | |
| 1–2 times | 561 | 471 (88.6) | 1.12 (.81–1.56) | .484 | 0.75 (.45–1.26) | .281 |
| 3–4 times | 197 | 148 (80.0) | 0.65 (.43–.97) | .037 | 0.40 (.21–.74) | .003 |
| 5–6 times | 101 | 80 (80.9) | 0.82 (.47–1.41) | .475 | 0.51 (.20–1.31) | .163 |
| >6 times | 795 | 662 (81.9) | 1.07 (.78–1.46) | .674 | 0.70 (.42–1.17) | .173 |
| Face mask wearing | | | | | | |
| Never | 396 | 320 (78.1) | 1 | | 1 | |
| Rarely | 948 | 789 (84.2) | 1.18 (.85–1.63) | .319 | 1.03 (.61–1.74) | .916 |
| Sometimes | 370 | 301 (85.1) | 1.04 (.71–1.51) | .854 | .88 (.48–1.60) | .668 |
| Often | 396 | 331 (84.4) | 1.21 (.82–1.79) | .344 | 1.17 (.60–2.31) | .641 |
| Always | 87 | 67 (84.2) | 0.79 (.42–1.52) | .489 | 0.48 (.20–1.15) | .100 |
| Alcohol intake | | | | | | |
| No | 1692 | 1372 (81.7) | 1 | | 1 | |
| Yes | 505 | 436 (88.6) | 1.47 (1.12–1.93) | .005 | 1.24 (.82–1.87) | .309 |
| Tobacco intake | | | | | | |
| No | 2049 | 1682 (82.9) | 1 | | 1 | |
| Yes | 148 | 126 (87.2) | 1.24 (.78–1.98) | .343 | 0.79 (.44–1.41) | .419 |
| Contact with a COVID-19–confirmed case | | | | | | |
| No | 1686 | 1408 (83.4) | 1 | | 1 | |
| Yes | 46 | 38 (90.9) | 0.94 (.43–2.03) | .871 | 1.44 (.49–4.18) | .500 |
| Don't know | 465 | 362 (81.6) | 0.69 (.52–.92) | .012 | 0.65 (.44–.96) | .033 |
| Comorbidity | | | | | | |
| Absent | 1979 | 1620 (82.7) | 1 | | 1 | |
| Present | 218 | 188 (88.6) | 1.38 (.93–2.05) | .100 | 0.91 (.55–1.49) | .703 |
| No. of symptoms (n = 1275) | | | | | | |
| <2 | 258 | 209 (82.5) | 1 | | 1 | |

**Table 3. Continued**

| Variable | No. | Positive, No. (%)[a] | OR (95% CI) | *P* Value | AOR (95% CI) | *P* Value |
|---|---|---|---|---|---|---|
| 2–4 | 575 | 482 (86.3) | 1.22 (.83–1.78) | .323 | 1.28 (.84–1.95) | .249 |
| >5 | 442 | 366 (94.7) | 1.13 (.76–1.67) | .542 | 1.31 (.84–2.01) | .224 |
| Household size | | | | | | |
| 1–2 | 73 | 65 (85.7) | 1 | | 1 | |
| 3–5 | 704 | 606 (86.4) | 0.76 (.34–1.70) | .506 | 0.70 (.28–1.76) | .452 |
| >5 | 1420 | 1137 (80.2) | 0.49 (.22–1.08) | .079 | 0.57 (.24–1.38) | .214 |

Abbreviations: AOR, adjusted odds ratio; CI, confidence interval; COVID-19, coronavirus disease 2019; OR, odds ratio; USD, United States dollars.

[a]Accounts for clustering at household level.

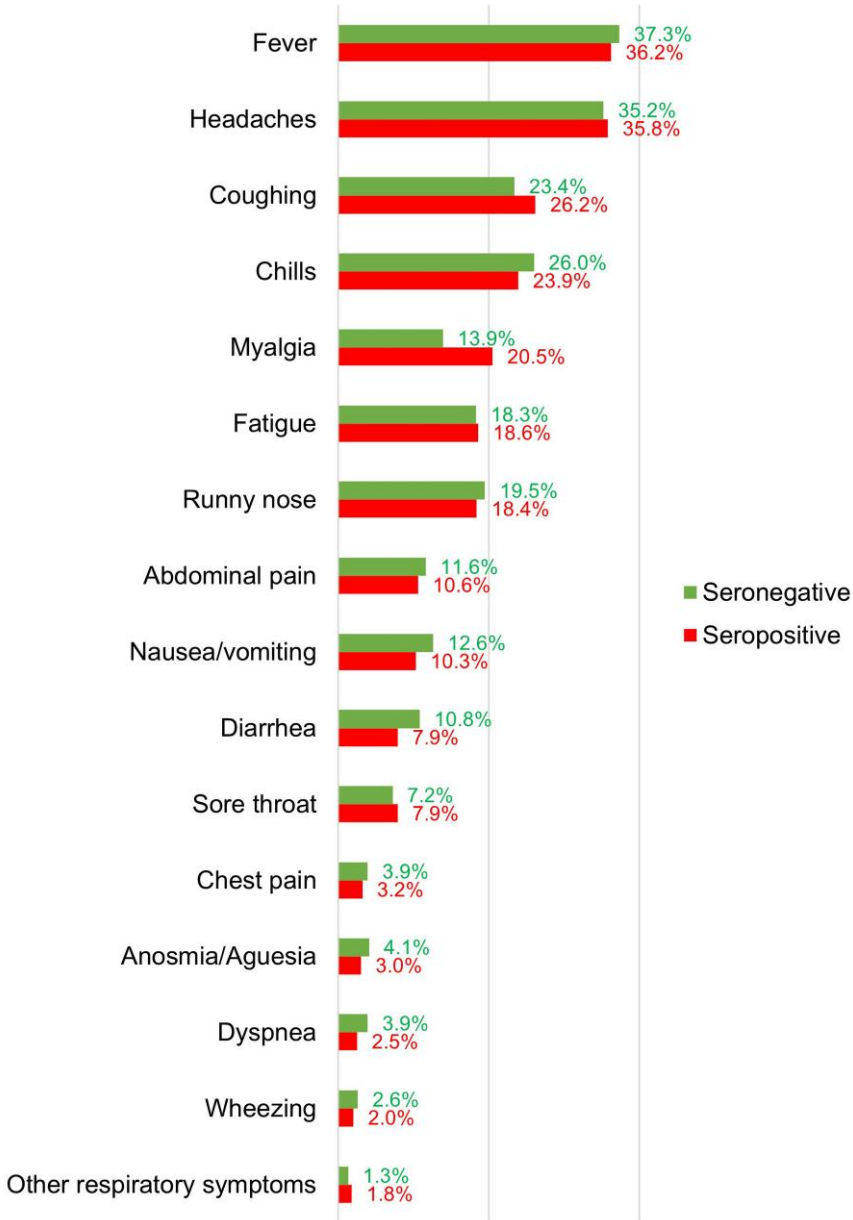


**Figure 2.** Coronavirus disease 2019–compatible symptoms by participants' serological status.

However, the study from India was conducted in a setting with a higher COVID-19 vaccination coverage rate. It used a serological assay that could not discriminate between vaccination and natural infection–induced antibodies [20, 21]. In our study, only 19 of 2210 participants received at least 1 shot of the COVID-19 vaccine. Slightly lower seroprevalence estimates were reported in the Central African Republic (74.1%), South Africa in blood donors (71.1%), and in the general population (60.0% in rural communities vs 70% in urban communities) during similar periods [22–24]. The differences in seroprevalence estimates may be explained by the SARS-CoV-2 infection dynamic, the variability in exposure levels across countries, and the assays' characteristics. Our study and the Central African Republic survey that was conducted a month earlier used a validated commercial ELISA kit detecting total antibodies against the receptor-binding domain of the spike protein [12, 22]. Studies from South Africa included vaccinated participants and used nucleocapsid protein–detecting serological assays to discriminate between vaccination-induced and natural immunity [23, 24]. However, antibodies directed against the SARS-CoV-2 nucleocapsid protein are known to wane over time, inducing underestimation of seroprevalence [25, 26]. Lower seroprevalence estimates have been reported in Nigeria (42.5% in urban areas vs 53.5% in rural areas) and Somalia (44.8%), where less sensitive anti-spike protein–detecting lateral flow assays were used [27, 28].

The seropositivity odds tended to decrease as the household size increased, ruling out the possibility that sampling >1 member per household might have boosted up seroprevalence through infection spreading within household. A similar decreasing trend of seropositivity was reported in a population-based household survey in Nigeria, while in Cameroon an increasing trend was reported [4, 29]. As reported by studies in Africa, Europe, and Asia, we observed a trend of increased seroprevalence with age, with older participants being more likely seropositive [3, 20, 22, 28, 30–32]. The lowest seroprevalence (67.7%) was recorded in participants <10 years of age, while the odds of seropositivity doubled in those aged 10–14 years. This is consistent with previous studies indicating that older children and adults are more likely than children <10 years of age to be infected and facilitate transmission [33, 34].

The likelihood of SARS-CoV-2 infection tended to increase with increasing education levels, especially for participants with university-level education. This finding is in keeping with a report from the Central African Republic [22], and contrasts with a previous study from Portugal [34] in which educational attainment decreased the risk of SARS-CoV-2 infection. Although a higher level of education is more likely associated with knowledge of individual and collective protective measures, compliance with these measures might not be as strict as expected. Moreover, a higher level of education can expand social and professional networks and result in more interactions with potentially infected persons.

Our study has several strengths, including the sampling frame, the large and representative sample size that included participants from all health districts and health areas of Matadi, and the high response rate among eligible participants (98.3%). However, we could not conduct a neutralizing antibody test on positive samples to confirm the protective immunity regarding the very high seroprevalence found. Finally, symptoms suggestive of COVID-19 were collected through participants' interviews, thus increasing the risk of recall bias.

## CONCLUSIONS

Our study revealed a very high population exposure to SARS-CoV-2 in Matadi after the third wave of the COVID-19 epidemic, contrasting with data from epidemiological surveillance. Age was identified as the main risk factor in our study, with the younger age decreasing the odds of seropositivity. Despite the strong correlation between positivity of the commercial ELISA assay used in this study and the virus neutralization; it is challenging to ascertain the protective immunity conferred by such a high level of exposure. Acquired immunity wanes over time and can be challenged by emerging variants. This is supported by the fact that 3 months after the survey, the highly transmissible SARS-CoV-2 Omicron variant spread to DRC and progressively outcompeted the dominant Delta variant. However, prior exposure seems to have protected against the severe form of the disease, as exemplified by the relatively low fatality rate recorded with the Omicron variant (0.9%). Our study underscores the usefulness of serological surveys as complementary to routine surveillance as it provides public health practitioners with relevant information on the magnitude and transmission dynamics of COVID-19 in Matadi. Beyond guiding the implementation or lifting of restrictive social measures, the survey results may be used to efficiently allocate scarce resources such as vaccines or adapt risk communication and community engagement messages to effectively reach persons most at risk of being infected.

### Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

### Notes

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