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Seroprevalence of SARS-CoV-2 antibodies and demographic predictors among asymptomatic individuals in Osun State, Nigeria

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Abstract

Objectives This study assesses the seroprevalence of SARS-CoV-2 antibodies (IgM, IgG, and IgA) among asymptomatic and unvaccinated individuals in Osun State, Nigeria, to quantify hidden infections and inform targeted public health interventions.

Methods A total of 300 participants from diverse socio-demographic backgrounds were tested using ELISA in this cross-sectional study, conducted between February and May 2021.

Results The study revealed a seroprevalence of 58.0%, with notable differences between urban and rural areas, emphasizing the influence of urbanization on virus transmission. No significant associations were found between seropositivity and demographic factors such as age, gender, or occupation, indicating widespread transmission across all groups. However, elevated seroprevalence was observed among married individuals and self-employed workers, suggesting higher exposure in household and occupational settings.

Conclusion These findings underscore the urgent need for tailored public health strategies in low- and middle-income countries, with a focus on urban centers, reducing household transmission, and safeguarding informal workers. The alignment of these results with global trends highlights the critical role of local data in shaping effective public health responses. This study calls for targeted interventions, continuous surveillance, and comparative studies to better manage the current pandemic and prepare for future public health crises. The research provides valuable insights into controlling COVID-19 transmission in similar settings, with significant implications for global health strategies.

Keywords SARS-CoV-2 · Seroprevalence · Asymptomatic Infections · Public Health · Cross-Sectional Studies

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1 Introduction

Coronavirus disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), has led to a pandemic marked by significant mortality and extensive societal disruption [1]. The virus is primarily transmitted through respiratory droplets from presymptomatic, asymptomatic, and symptomatic carriers, with the potential for fomite transmission due to its ability to survive on surfaces [2]. Of particular concern are asymptomatic individuals, who, despite not displaying symptoms, play a substantial role in the transmission dynamics of the virus. These carriers often remain undetected in routine surveillance, yet their contribution to the ongoing spread within communities is undeniable and requires urgent attention [3].

SARS-CoV-2, an RNA virus, is prone to continuous genetic mutations, resulting in new variants, including several classified by the World Health Organization as variants of concern [4]. The highly transmissible Omicron variant and its subvariants have presented ongoing challenges to global public health efforts, including vaccination campaigns [5]. The long-term health impacts of COVID-19, collectively referred to as "long COVID," continue to affect a significant portion of those infected, placing additional strain on healthcare systems [6–8]. Understanding the seroprevalence of SARS-CoV-2 antibodies across different populations is essential for evaluating the extent of past infections, assessing herd immunity levels, and shaping future public health strategies. This is especially crucial in regions like sub-Saharan Africa, where there is limited data on the pandemic's true impact [9].

This study aims to assess the seroprevalence of SARS-CoV-2 antibodies among asymptomatic individuals in Osun State, Nigeria—a region with distinct socio-demographic characteristics and varying levels of urbanization [10, 11]. Focusing on asymptomatic individuals, the research seeks to uncover hidden reservoirs of infection that could significantly contribute to continued transmission within the community. The urgency of this study is underscored by the fact that asymptomatic carriers often remain undetected, yet they play a critical role in the propagation of the virus, making this research timely and crucial for guiding immediate public health interventions.

What distinguishes this study is its emphasis on a frequently overlooked population in seroprevalence research. Concentrating on asymptomatic carriers will provide valuable insights into the unnoticed transmission pathways in a region with limited pandemic-related data. The findings are expected to enhance the global understanding of COVID-19, providing context-specific data that can inform both local and international public health strategies. The insights gained will be particularly relevant to regions with similar socio-demographic and epidemiological profiles, offering a critical tool for assessing and mitigating the spread of the virus. The study will potentially inform targeted public health interventions that will better control the pandemic and prevent future outbreaks.

2 Materials and methods

2.1 Ethical considerations

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Osun State Ministry of Health, Health Planning, Research, and Statistics Department (OSHREC/PRS/569T/186) and the Adeleke University Ethical Approval Committee (AUERC/FOS/MCB/MSc/03). Informed consent forms were distributed and signed by all participants before sample collection.

2.2 Study design

Participants included in the study were asymptomatic individuals from different geographical locations (Oke Baale, Isale Aro, Sabo, Isale Agbara, Osogbo, Asubiaro, Oke Osun, Isale Osun, Ede, Morakinyo, Ife Teaching Hospital (ITH), Ilesa, Ife, Ejigbo, and Iwo) in Osun State, Nigeria. The participant recruitment was carried out between February and May 2021. The sample was selected randomly from these locations, with no stratification by region, though the selection aimed to represent a broad range of socio-demographic backgrounds across both urban and rural areas.

Individuals who exhibited symptoms of COVID-19, had a recent positive COVID-19 test result, or had been vaccinated for COVID-19 were excluded from the study. This exclusion of vaccinated individuals was crucial to isolate the seroprevalence of individuals who had not received the vaccine, thus allowing for a clearer assessment of natural immunity and the extent of past infections within the unvaccinated population.

2.3 Sample collection

A volume of 10 ml of blood sample was collected from participants who were asymptomatic and healthy at the time of collection as part of this cross-sectional study to measure seroprevalence. Using standard venipuncture techniques, blood was drawn and immediately processed to separate the serum, which was then stored at -20 °C until further analysis [12]. To ensure the accuracy and reliability of the samples, quality control measures were implemented at each stage of collection and processing. These included the use of sterile, single-use equipment to prevent cross-contamination, and careful monitoring of the time from sample collection to processing to minimize degradation of the serum. Additionally, all samples were labeled and tracked using a secure and organized system to prevent mix-ups and ensure proper handling.

Alongside blood collection, questionnaires were distributed to study participants to collect their socio-demographic characteristics, including location, age, gender, marital status, and occupation.

2.4 Antibody test

As performed in a similar study [13], the presence of total antibodies (IgM, IgG, and IgA) against SARS-CoV-2 in serum samples was tested using enzyme-linked immunosorbent assay (ELISA) kits according to the manufacturer's instructions [14]. The ELISA for total antibody detection was based on a double-antigen sandwich immunoassay, utilizing mammalian cell-expressed recombinant antigens containing the receptor-binding domain (RBD) of the spike protein of SARS-CoV-2 as the immobilized and HRP-conjugated antigen.

2.5 Statistical and data analysis

Data analysis was conducted entirely in Python using Jupyter Notebook (version 7.4.1). Descriptive statistics were employed to summarize demographic characteristics. Quantitative variables (e.g., age) were expressed as mean ± standard error, and qualitative variables (e.g., gender, occupation) were summarized as frequencies and percentages. The Chi-Square Test of Independence was performed to assess associations between categorical variables (e.g., gender and COVID-19 positivity). A p-value of less than 0.05 was considered statistically significant, with 95% confidence intervals (CI) calculated to determine the strength of associations and 5% error.

Hierarchical clustering analysis was carried out using the `scipy` library to categorize locations based on the frequency and percentage of COVID-19 cases. Additionally, Multivariate Analysis of Variance (MANOVA) was performed using the `statsmodels` package to examine the effect of location on COVID-19 positivity.

To evaluate potential predictors of SARS-CoV-2 seropositivity, a Random Forest classifier was employed. The analysis was performed in Python using the `scikit-learn` package for model implementation, `pandas` for data manipulation, `matplotlib` and `seaborn` for data visualization, and `numpy` for numerical operations. The model was trained and tested using demographic data. The Random Forest classifier was selected due to its robustness in handling complex datasets, its ability to process both categorical and numerical data, and its feature importance ranking, which facilitates identifying the most relevant predictors for the task at hand.

3 Results

3.1 Descriptive statistics

A total of 300 participants were included in the study. The highest number of respondents were from Osogbo (61, 20.3%), followed by Oke Baale (33, 11.0%). The lowest number of respondents was from Oke Osun (3, 1.0%). Most respondents were in the 30–39 age group (76, 25.3%), followed by the 20–29 age group (65, 21.7%). The lowest number of respondents were in the 0–9 age group (3, 1.0%) (Table 1). Female respondents constituted 153 (51.0%) of the sample, while male respondents constituted 147 (49.0%). Most respondents were married (170, 56.7%), followed by single (125, 41.7%), and widow (5, 1.7%). Most respondents were self-employed (120, 40.0%), followed by students (88, 29.3%). The least respondents were retirees (4, 1.3%), and only 1 (0.3%) had no specific occupation.

Table 1 Distribution of COVID-19 seropositivity across age groups

Age (years)	Positive (%)	Negative (%)
0–9	1 (0.6)	2 (1.6)
10–19	32 (18.4)	22 (17.5)
20–29	39 (22.4)	26 (20.6)
30–39	44 (25.3)	32 (25.4)
40–49	28 (16.1)	29 (23.0)
50–59	24 (13.8)	12 (9.5)
60–69	6 (3.4)	3 (2.4)
Total	174 (100)	126 (100)

3.2 COVID-19 seropositivity results

Of the respondents, 174 (58.0%) were reactive for SARS-CoV-2 antibodies, while 126 (42.0%) tested negative. The number of positive cases was highest in Osogbo (32, 18.4%) and lowest in Oke Osun (1, 0.6%) (Table 2). The highest number of positive cases was in the 30–39 age group (44, 25.3%), and the lowest in the 0–9 age group (1, 0.6%). The male gender had slightly higher positive cases (88, 50.6%) than females (86, 49.4%).

Regarding marital status, married individuals had the highest number of positive cases, with 96 (55.2%) testing positive for were reactive for SARS-CoV-2 antibodies. Among single respondents, 74 (42.5%) tested positive, while widowed individuals had the lowest number of positive cases, with only 4 (2.3%) testing positive.

In terms of occupation, self-employed individuals recorded the highest number of reactive cases, with 70 (40.2%) being reactive. Civil servants followed, with 46 (26.4%) being reactive, while students accounted for 53 (30.5%) of the reactive cases. Health workers had the lowest number of antibodies reactions among employed individuals, with only 3 (1.7%) being reactive. Additionally, two retirees (1.1%) were seropositive, while no reactive cases were recorded among those without an occupation. The Chi-Square Test of Independence did not have any significant association of the variables measured with COVID-19 seropositivity (Table 3).

Table 2 Distribution of COVID-19 seropositivity across sudy locations in Osun State, Nigeria

Location	Positive (%)	Negative (%)
Oke Baale	20 (11.5)	13 (10.3)
Isale Aro	13 (7.5)	7 (5.6)
Sabo	9 (5.2)	9 (7.1)
Isale Agbara	10 (5.7)	9 (7.1)
Osogbo	32 (18.4)	29 (23.0)
Asubiaro	18 (10.3)	5 (4.0)
Oke Osun	1 (0.6)	2 (1.6)
Isale Osun	5 (2.9)	1 (0.8)
Ede	12 (6.9)	3 (2.4)
Morakinyo	5 (2.9)	0 (0.0)
Ife Teaching Hospital (ITH)	7 (4.0)	8 (6.3)
Ilesa	11 (6.3)	8 (6.3)
Ife	5 (2.9)	7 (5.6)
Ejigbo	14 (8.0)	11 (8.7)
Iwo	12 (6.9)	14 (11.1)
Total	174 (100)	126 (100)

Table 3 Chi-square test of independence

Variable	Chi-Square (χ^2)	Degrees of Freedom (df)	p-value	Significance
Location	125	121	0.3832	No significant association
Age	42	36	0.227	No significant association
Gender	0	1	1.0	No significant association
Marital Status	6	4	0.1991	No significant association
Occupation	30	25	0.2243	No significant association

3.3 Statistical analysis

3.4 Cluster analysis and MANOVA

Hierarchical clustering analysis dendrogram revealed that Isale Agbara and Oke Baale were grouped together, indicating that these locations exhibited similar positivity rates. Another group was formed by Ede**,** Isale Osun, and Ejigbo**,** which also showed similarities in their COVID-19 positivity patterns, though distinct from the first group. Ilesa, Osogbo, Iwo, and Morakinyo formed another cluster, suggesting that these locations shared similar trends in positivity. The final cluster included Ife, Oke Osun, Asubiaro, Isale Aro, and Sabo, which showed a different pattern of COVID-19 positivity compared to the other locations.

The MANOVA test conducted to assess the effect of Location on COVID-19 positivity rates indicated that Location had a marginally non-significant effect ($F(3, 8) = 3.33$, $p = 0.077$). Although there was some variation in positivity rates between locations, the p-value exceeded the 0.05 significance threshold, suggesting that Location does not have a statistically significant impact on COVID-19 positivity rates in this study (Fig. 1).

3.5 Random forest model

The Random Forest classifier was used to evaluate the predictors of SARS-CoV-2 seropositivity. Age (53%) was found to be the most important predictor, followed by Occupation (35%). Sex contributed less (10%), and Marital Status had the least impact (2%) on the model's predictions (Fig. 2). These results indicate that age and occupation are the primary factors influencing the likelihood of being seropositive in this study. The model achieved an accuracy of 27.03%.

4 Discussion

The seroprevalence of SARS-CoV-2 antibodies observed in this study (58.0%) among asymptomatic individuals in Osun State, Nigeria, provides insights into the silent transmission of COVID-19 in sub-Saharan Africa. This prevalence aligns with findings from other low- and middle-income countries (LMICs), where the virus has spread extensively despite relatively low reported cases and deaths. For example, a seroprevalence study in Kenya reported high seropositivity rates in urban settings, highlighting the potential for underreporting due to limited testing capacity and the substantial role of asymptomatic infections [15]. Globally, variations in seroprevalence reflect differences in testing, reporting, public health measures, and population density. Studies in high-income countries (HICs) reported lower seroprevalence rates early in the pandemic, which increased as the virus spread, particularly before widespread vaccination campaigns [16, 17]. In LMICs, higher seroprevalence is often linked to overcrowded living conditions, high population mobility, and reliance on informal work sectors, making strict containment measures challenging [18, 19].

The results from this study are comparable to seroprevalence rates observed in other regions of Sub-Saharan Africa, such as Cameroon and Nigeria, which similarly highlight the role of asymptomatic individuals in perpetuating community transmission [20, 21]. However, what sets Osun State apart is its unique socio-economic context, with significant urban–rural disparities, varying healthcare access, and a relative reliance on informal employment [22,

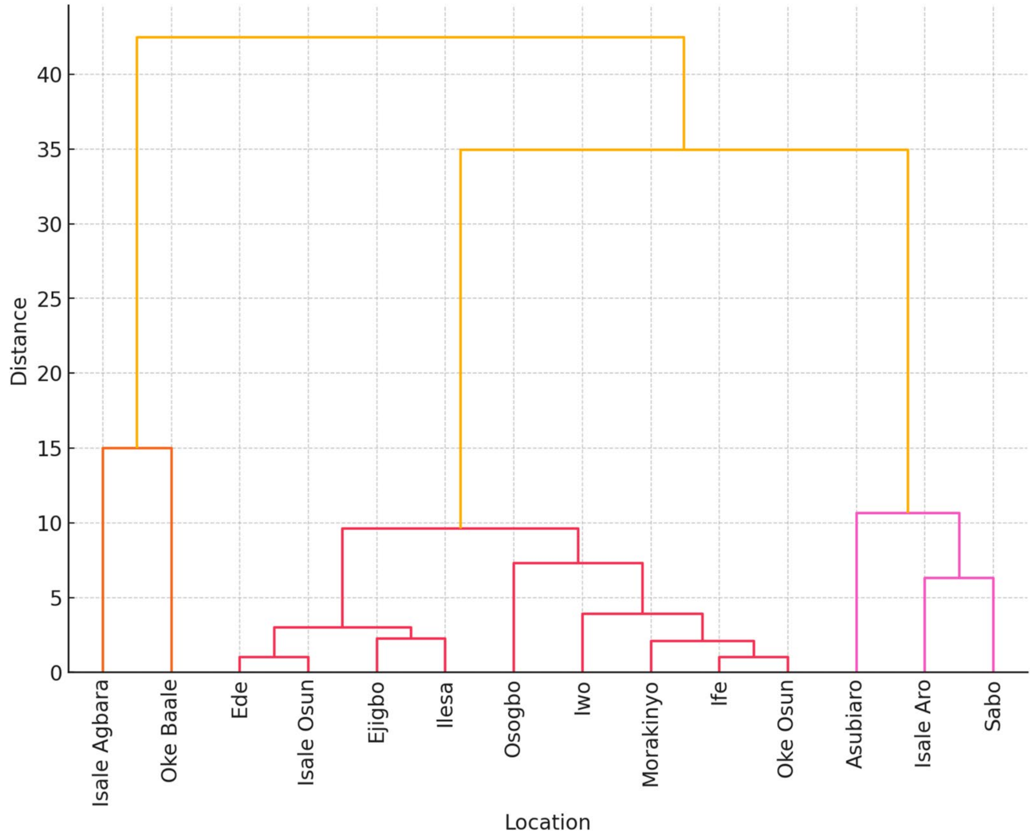

Fig. 1 Hierarchical Clustering of Locations Based on COVID-19 Seropositivity Rates

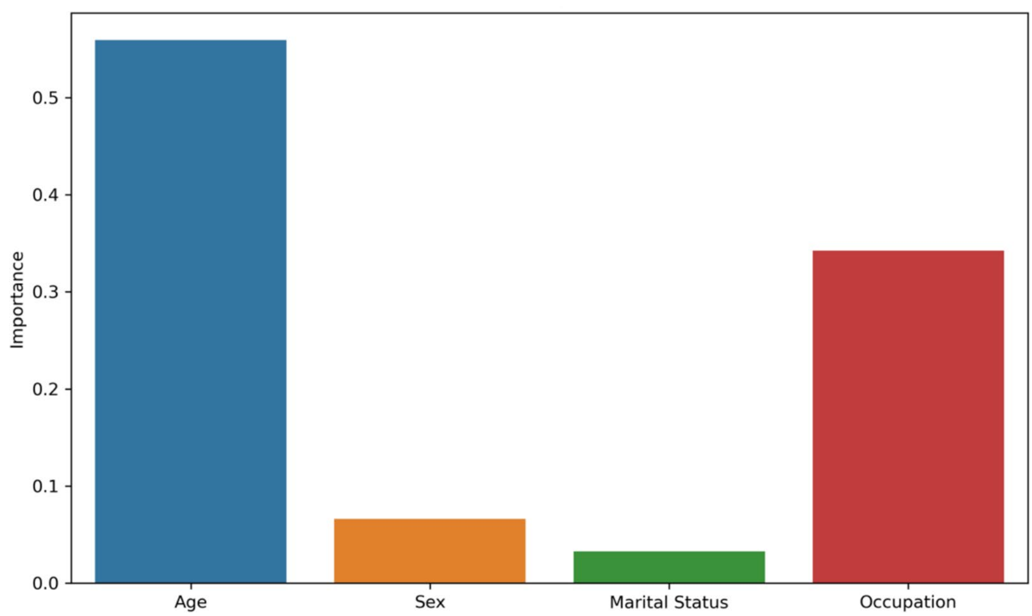

Fig. 2 Feature importance for predicting SARS-CoV-2 seropositivity

23]. These factors may help explain the observed patterns of seroprevalence and contribute to the broader understanding of COVID-19 dynamics in Nigeria.

Interestingly, the seroprevalence among health workers was lower compared to other groups, which may be due to a combination of factors. One explanation is the small sample size of health workers in this study, which may not have fully captured the seroprevalence in this population. Additionally, health workers likely had higher levels of awareness and access to protective measures, such as personal protective equipment (PPE), frequent testing, and adherence to infection control protocols, which could have reduced their exposure. The Random Forest classifier revealed that age and occupation were the most significant predictors of SARS-CoV-2 seropositivity, with sex and marital status contributing less. This highlights that demographic factors such as age and occupation play a critical role in determining the likelihood of being seropositive. Despite the moderate accuracy (27.03%) of the model, this reflects the complexity of predicting seropositivity, which is likely influenced by additional unmeasured factors such as exposure risk and local community behaviors.

The absence of significant associations between seroprevalence and demographic factors such as age, gender, marital status, and occupation in the Chi-Square analysis indicates that COVID-19 transmission is widespread across all demographic groups. This suggests that public health measures in Osun State should be inclusive and address the entire population, not just high-risk groups. Notably, the hierarchical clustering analysis identified distinct groups of locations with similar positivity rates, indicating that geographic factors may influence the spread. Areas like Osogbo, with the highest number of seropositive cases, would benefit from targeted testing campaigns, public health education, and vaccination efforts. Conversely, areas with lower seroprevalence, such as Oke Osun, may reflect effective containment measures or under-detection due to limited healthcare access.

The MANOVA test did not find a significant association between location and COVID-19 positivity rates, suggesting that while there was some geographic variation in positivity rates, it was not statistically significant in this study. However, the geographical variability observed in the clustering analysis emphasizes the importance of tailoring public health interventions to local factors such as population density, mobility, and healthcare access. The findings from this study align with seroprevalence trends observed in urban settings in India and Brazil, where high population density and socio-economic disparities have contributed to widespread transmission [24, 25]. These similarities highlight the need for globally coordinated efforts to address asymptomatic transmission, particularly in LMICs with overburdened healthcare systems. The high seroprevalence rates among self-employed individuals also underscore the vulnerability of informal workers, who often lack workplace protections and healthcare access.

A limitation of this study is the use of the WANTAI SARS-CoV-2 Ab ELISA kit, which was developed based on the original Wuhan strain [14]. This kit may not fully capture antibody responses to newer variants, which could affect the detection of asymptomatic infections associated with those variants. However, this limitation strengthens the argument for a higher proportion of undetected asymptomatic infections, as the kit may have missed infections caused by newer variants with different RBDs.

Public health strategies in Osun State and similar regions should take into account socio-economic factors that drive transmission, such as limited healthcare access, reliance on public transport, and densely populated living conditions. Targeted interventions, such as establishing isolation centers, providing accessible testing facilities, and offering financial support for informal workers, could help mitigate these risks. Furthermore, the significant geographic variability observed in this study suggests that decentralized approaches to pandemic response tailored to local epidemiological and demographic contexts are essential for effective disease control. These findings can directly inform public health interventions in Osun State, supporting targeted testing campaigns, educational programs, and changes in healthcare policy to mitigate COVID-19 transmission and prepare for future public health challenges.

5 Conclusion

This study provides critical insights into the seroprevalence of SARS-CoV-2 antibodies among asymptomatic individuals in Osun State, Nigeria, highlighting the significant role of urbanization, household transmission, and occupational exposure in the spread of COVID-19. The findings emphasize the pervasive nature of the virus across different demographic groups, pointing to the urgent need for comprehensive, inclusive public health strategies. Urban centers, particularly those with high population densities, should be prioritized for targeted interventions such as increased testing, public health education, and vaccination efforts. Additionally, strategies aimed at reducing intra-household transmission and safeguarding informal workers are crucial in mitigating the virus's spread.

Based on these findings, further studies should target asymptomatic populations, particularly in rural areas, to gain a more complete understanding of hidden transmission reservoirs. Additionally, exploring the impact of socio-economic factors, such as household size and occupation, on seroprevalence could further inform tailored interventions. The study's alignment with global trends underscores the importance of context-specific data in guiding public health responses, particularly in LMICs. Continued surveillance is vital to track evolving trends and emerging variants. Research should focus on longitudinal studies to assess long-term immunity and the impact of vaccination in asymptomatic populations. Interventions should also consider the unique needs of informal sectors and rural communities, ensuring equitable healthcare access. This approach will be key in managing the current pandemic and preparing for future public health challenges, with a particular focus on ensuring resilience in LMICs.

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Data availability Data is provided within the manuscript or supplementary information files.

Declarations

Ethics approval and consent to participate Approval was granted by the Osun State Ministry of Health, Health Planning, Research, and Statistics Department (OSHREC/PRS/569T/186) and the Adeleke University Ethical Approval Committee (AUERC/FOS/MCB/MSc/03). Informed consent forms were distributed and signed by all participants before sample collection.

Competing interests The authors declare no competing interests.

References

1. Sharma A, Tiwari S, Deb MK, Marty JL. Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2): a global pandemic and treatment strategies. Int J Antimicrob Agents. 2020;56(2): 106054. https://doi.org/10.1016/j.ijantimicag.2020.106054.
2. Azuma K, Yanagi U, Kagi N, Kim H, Ogata M, Hayashi M. Environmental factors involved in SARS-CoV-2 transmission: effect and role of indoor environmental quality in the strategy for COVID-19 infection control. Environ Health Prev Med. 2020;25(1):66. https://doi.org/10.1186/s12199-020-00904-2.
3. Shaikh N, Swali P, Houben RMGJ. Asymptomatic but infectious—the silent driver of pathogen transmission. A pragmatic review. Epidemics. 2023;44: 100704. https://doi.org/10.1016/j.epidem.2023.100704.
4. Sah R, Rais MA, Mohanty A, et al. Omicron (B.1.1.529) variant and its subvariants and lineages may lead to another COVID-19 wave in the world? An overview of current evidence and counteracting strategies. Int J Surg Open. 2023;55:100625. https://doi.org/10.1016/j.ijso.2023.100625.
5. Chatterjee S, Bhattacharya M, Nag S, Dhama K, Chakraborty C. A detailed overview of SARS-CoV-2 omicron: its sub-variants, mutations and pathophysiology, clinical characteristics, immunological landscape, immune escape, and therapies. Viruses. 2023;15(1):167. https://doi.org/10.3390/v15010167.
6. Davis HE, McCorkell L, Vogel JM, Topol EJ. Author Correction: long COVID: major findings, mechanisms and recommendations. Nat Rev Microbiol. 2023;21(6):408–408. https://doi.org/10.1038/s41579-023-00896-0.
7. Sapna F, Deepa F, Sakshi F, et al. Unveiling the mysteries of long COVID syndrome: exploring the distinct tissue and organ pathologies linked to prolonged COVID-19 symptoms. Cureus. 2023. https://doi.org/10.7759/cureus.44588.
8. Sideratou CM, Papaneophytou C. Persisting shadows: unraveling the impact of long COVID-19 on respiratory, cardiovascular, and nervous systems. Infect Dis Rep. 2023;15(6):806–30. https://doi.org/10.3390/idr15060072.
9. McKay T, Robinson RS, Musungu S, Padi-Adjirackor NA, Angotti N. The missing millions: uncovering the burden of covid-19 cases and deaths in the African Region. Populat Dev Rev. 2024;50(1):7–58. https://doi.org/10.1111/padr.12608.
10. Alao JO, Bejide IO, Komolafe OI, Alao OJ, Oyetunde OB, Oni MO. Prevalence of hepatitis E virus infection among pregnant women attending the ante-natal clinic of a tertiary health care centre. JAMB. 2022. https://doi.org/10.9734/jamb/2022/v22i230438.
11. Odeyemi DA, Alao JO, Kayode TA, Durugbo EU. Assessment of bioaerosol composition and public health implications in high-traffic urban areas of Southwest, Nigeria. Environ Res Commun. 2024;6(12): 121008. https://doi.org/10.1088/2515-7620/ad9e87.

12. O'Connell GC, Alder ML, Webel AR, Moore SM. Neuro biomarker levels measured with high-sensitivity digital elisa differ between serum and plasma. Bioanalysis. 2019;11(22):2087–94. https://doi.org/10.4155/bio-2019-0213.
13. Zhao J, Yuan Q, Wang H, et al. Antibody responses to SARS-CoV-2 in patients with novel coronavirus disease 2019. Clin Infect Dis. 2020;71(16):2027–34. https://doi.org/10.1093/cid/ciaa344.
14. Beijing Wantai Biological Pharmacy Enterprise Co., Ltd. WANTAI SARS-CoV-2 Ab ELISA ELISA for Total Antibody to SARS-CoV-2. Published online 2020. https://www.fda.gov/media/140929/download. Accessed 2 Aug 2024.
15. Uyoga S, Adetifa IMO, Karanja HK, et al. Seroprevalence of anti–SARS-CoV-2 IgG antibodies in Kenyan blood donors. Science. 2021;371(6524):79–82. https://doi.org/10.1126/science.abe1916.
16. Pollán M, Pérez-Gómez B, Pastor-Barriuso R, et al. Prevalence of SARS-CoV-2 in Spain (ENE-COVID): a nationwide, population-based seroepidemiological study. Lancet. 2020;396(10250):535–44. https://doi.org/10.1016/S0140-6736(20)31483-5.
17. Stringhini S, Wisniak A, Piumatti G, et al. Seroprevalence of anti-SARS-CoV-2 IgG antibodies in Geneva, Switzerland (SEROCoV-POP): a population-based study. Lancet. 2020;396(10247):313–9. https://doi.org/10.1016/S0140-6736(20)31304-0.
18. Roelen K, Ackley C, Boyce P, Farina N, Ripoll S. COVID-19 in LMICs: the need to place stigma front and centre to its response. Eur J Dev Res. 2020;32(5):1592–612. https://doi.org/10.1057/s41287-020-00316-6.
19. Nieto-Sanchez C, Dens S, Cisneros J, et al. From risk factors to disease situations: A socio-spatial analysis of COVID-19 experiences in Lima, Peru. Soc Sci Med. 2024;362: 117413. https://doi.org/10.1016/j.socscimed.2024.117413.
20. Nwosu K, Fokam J, Wanda F, et al. SARS-CoV-2 antibody seroprevalence and associated risk factors in an urban district in Cameroon. Nat Commun. 2021;12(1):5851. https://doi.org/10.1038/s41467-021-25946-0.
21. Olayanju O, Bamidele O, Edem F, et al. SARS-CoV-2 seropositivity in asymptomatic frontline health workers in Ibadan, Nigeria. Am J Trop Med Hyg. 2021;104(1):91–4. https://doi.org/10.4269/ajtmh.20-1235.
22. Adeniyi LA, Fatoke MT, Adesoye OP, Folorunso SA, Lawal AA. Assessment of women accessibility to health-care facilities in a typical rural local government area in Nigeria. JFM. 2023;21(2):282–97. https://doi.org/10.1108/JFM-06-2021-0054.
23. Bejide IO, Alao JO, Komolafe IO. Prevalence of hepatitis E virus infection among blood donors in a tertiary healthcare facility in Osun State. Nigeria J Adv Microbiol. 2024;24(11):10–8. https://doi.org/10.9734/jamb/2024/v24i11861.
24. 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):e1390–8. https://doi.org/10.1016/S2214-109X(20)30387-9.
25. Malani A, Shah D, Kang G, et al. Seroprevalence of SARS-CoV-2 in slums versus non-slums in Mumbai, India. Lancet Glob Health. 2021;9(2):e110–1. https://doi.org/10.1016/S2214-109X(20)30467-8.