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Research Article

Response Rates in a COVID-19 Seroepidemiological Survey in Nigeria: Variations by State, Age Group, and Urban-Rural Settings

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Abstract

The COVID-19 pandemic has presented substantial global challenges, necessitating a deep understanding of infection dynamics across diverse populations. Seroepidemiological studies offer valuable insights into these dynamics but depend heavily on obtaining representative samples. This study aimed to assess participant response rates across different age groups and residence settings in Nigeria, focusing on three distinct locations: Lagos, Delta, and Sokoto States. The study utilized a probability sampling procedure, employing a two-stage cluster sampling method to select Enumeration Areas (EAs) and then households with equal probability. Data from the sero-epidemiological survey served as secondary data for analyzing response rates. The American Association for Public Opinion Research (AAPOR) Response Rate 4 (RR4) method was applied. Response rates were calculated, and analyses stratified by age and residence were conducted to examine survey response patterns. In Lagos State, response rates varied significantly across age groups and residence settings. Children aged <2 years had a response rate of 87.9%, but a lower survey response rate of 54.3%. The 2-9 years age group had a high response rate of 97.4% with a survey response rate of 75.5%. Adolescents (10-17 years) showed a response rate of 99.3% and a survey response rate of 83.5%. Adults aged 18-64 years had a response rate of 99.2% and a survey response rate of 86.8%. The 65+ years age group showed a response rate of 96.3% and a survey response rate of 85.9%. Urban areas had a higher response rate (99.1%) compared to rural areas (95.2%), with corresponding survey response rates of 85.5% and 73.1%, respectively. Sokoto State presented lower response rates, particularly among children aged <2 years (4.3%) and the elderly (65+ years) at 19.8%. Urban areas in Sokoto had significant challenges, with an overall response rate of 35.9% and a survey response rate of 4.1%. In contrast, Delta State showed more consistent results, with response rates of 93.2% overall and a survey response rate of 81.8%. The study highlights variations in response and survey response rates across different age groups and residence settings in Lagos, Delta and Sokoto States. These findings underscore the importance of considering demographic and geographic factors when interpreting seroepidemiological data.

Keywords

COVID-19, Seroepidemiology, Response Rates, Age Groups, Residence Settings, Nigeria

1. Introduction

In epidemiological studies, particularly those assessing infectious disease spread and immunity, the participant response rate is a critical factor that directly influences the reliability and generalizability of the findings. High response rates ensure that the sample is representative of the broader population, minimizing biases and enhancing the accuracy of prevalence estimates [1-3]. Conversely, low response rates can lead to skewed data, limiting the applicability of the study results to the general population [4]. In the context of the COVID-19 pandemic, understanding infection dynamics through population-based seroepidemiological studies has been paramount [5]. However, the effectiveness of these studies hinges on achieving adequate response rates across diverse demographic groups and geographical settings.

A larger proportion of individuals infected with SARS-CoV-2 were asymptomatic, meaning they showed no symptoms but could still spread the virus to others [6]. Estimates suggest that asymptomatic cases could account for approximately 5% to 80% of infections, based on an analysis of 21 published reports [7, 8]. Additionally, it was estimated that 6% to 96% of COVID-19 cases were asymptomatic globally [9]. Globally, the detection of SARS-CoV-2 by real-time reverse transcription-polymerase chain reaction (RT-PCR) in a nasopharyngeal swab is the main diagnosis of COVID-19 [10, 11]. The asymptomatic and mildly infected individuals might not be tested, resulting in an underestimated magnitude of SARS-CoV-2 infection in the population. In Nigeria, from 3 January 2020 through 6 December 2023, there have been 267,163 reported confirmed cases and 3,155 deaths of SARS-CoV-2 infections [6].

To control COVID-19, the majority of the population needs to develop immunity against SARS-CoV-2 to suppress viral transmission. It is also very important to detect infected persons early to provide timely intervention and thus break the route of transmission. Hence, relying entirely on the detected cases by RT-PCR could miss out on the asymptomatic and pre-symptomatic infections. Population-based seroepidemiological surveys have been used to estimate the prevalence of both previous and active SARS-CoV-2 infection, i.e., the proportion of the population who have already developed SARS-CoV-2-specific antibodies, which might protect them from subsequent exposures; and those still susceptible to the infection. Hence, seroprevalence and household contact studies in the community become imperative to determine the herd immunity and burden of SARS-CoV-2 infection which will guide the vaccination programme. The validity of findings from such surveys is however dependent on having an adequately large sample that is also representative of the

target population.

The Nigeria COVID-19 seroepidemiological survey was a national household seroprevalence study that involved interviewing the consenting household and the collection of both the nasopharyngeal swab and blood samples to understand the full spectrum of the disease. The surveys were undertaken in 2020 and 2021 in Lagos, Delta and Sokoto States and provided insight into the level of infection. Since by design, participation in the survey is voluntary once an individual's household had been selected based on the sampling frame, attention must be paid to the response rate in the surveys. The response rate is calculated by dividing the number of participants who respond to a survey by either the total number of subjects in the chosen sample or the number of eligible subjects within the sample [12, 13].

High response rates are essential for generating valid, reliable and generalizable results whereas low response rates yield methodological biases with implications for inferences that may be drawn from the survey [14, 15]. This evaluation aimed to assess the participants' response rates across different states, age groups and residence settings within Nigeria to understand the factors affecting participation and the potential biases that could influence the findings from the study.

2. Material and Methods

2.1. Study Area

The surveys were conducted between October 2020 and April 2021 in three states, namely Lagos, Delta and Sokoto representing three of the six geopolitical zones in Nigeria (South-West, South-South, and North-West respectively). Lagos State is located in the South West geopolitical zone of Nigeria, Delta State in the South-South and Sokoto State in the North West zone. Projections for 2018 from the 2006 Population and Housing Census, placed the population of Lagos at 12,531,530; Delta at 5,198,675 and Sokoto States at 5,686,341 [16]. In Lagos State, there were 30 Enumeration Areas (EAs) designated for data collection purposes. Within these 30 EAs, there were a total of 600 households that were selected for the survey while Delta State had 34 EAs designated for the study, from which a total of 680 households were selected for the survey. Similar to Delta, Sokoto State had 34 EAs designated for data collection, from which a total of 680 households were selected for the survey. This structured approach helped ensure that the information gathered was comprehensive and covered a representative sample of the population in the three selected states.

2.2. Study Design and Sample Size

A cross-sectional seroepidemiological survey was conducted in Lagos, Delta and Sokoto States based on the recommendation of WHO as the most appropriate study design [17] to understand multiple unknown characteristics related to the COVID-19 pandemic. In Lagos State, a total of 24 EAs were sampled in urban areas while 6 EAs were sampled in rural areas. In terms of households, 480 were sampled in urban areas and 120 were sampled in rural areas. This distribution reflects the predominantly urban nature of Lagos State, with a higher number of EAs and households selected from urban settings. In Delta State, 26 EAs were sampled in urban areas while 8 EAs were sampled in rural areas. The distribution of households included 506 sampled in urban areas and 157 in rural areas. Like Lagos State, Delta State's distribution emphasized urban areas which might experience different COVID-19 dynamics compared to rural areas. In Sokoto State, the distribution differed from Lagos and Delta. A total of 8 EAs were sampled in urban areas reflecting a smaller urban sample while 26 EAs were sampled in rural areas indicating a more significant focus on rural regions. The household distribution included 102 sampled in urban areas and 465 in rural areas. This distribution recognized Sokoto State's predominantly rural composition considered especially relevant to further explore the epidemiological dynamics of COVID-19 in rural communities. In total, across all the three states, 58 and 40 EAs were sampled in urban and rural areas, respectively. The household distribution comprised 1,088 households sampled in urban areas and 742 households sampled in rural areas (Table 1). Urban-rural sampling proportions were determined based on population density, healthcare accessibility, and anticipated differences in COVID-19 exposure. Urban areas, with higher population densities and mobility, were expected to have greater exposure to the virus, whereas rural areas, with potential healthcare access barriers, were included to capture disparities in participation and infection rates. This stratification ensures that the findings of the study reflect the heterogeneity of the population and provide insights into geographic and demographic differences in response rates.

Table 1. *Distribution of sampled enumeration areas and households by State.*

State	Total EAs sampled for the survey		Number of households sampled for the survey	
	Urban	Rural	Urban	Rural
Lagos	24	6	480	120
Delta	26	8	506	157
Sokoto	8	26	102	465
Total	58	40	1,088	742

2.3. Sampling Methods

A probability sampling procedure was adopted for the survey. A two-stage cluster sampling was used to select EAs and then

households with equal probability to ensure representativeness across diverse populations. The entire master list of EAs for three states was obtained and ordered by geographic location (i.e., by Local Government Areas (LGAs) from North to South of each state). According to urban/rural categorizations of EAs by the National Population Commission of Nigeria, Lagos is 80% urban and 20% rural, Delta is 76% urban and 24% rural and Sokoto is 24% urban and 76% rural, respectively. Since several previous studies have indicated higher seroprevalence in urban compared to rural areas [18-20], urban areas in Lagos and Delta were oversampled in an 80:20 and 76:24 urban: rural ratio to provide a more precise estimate of seroprevalence in urban areas of these states. The EAs in the three states were sampled proportionally to the number of EAs within each local government area The household list generated during the mapping and listing exercise was used as a frame for sampling households for inclusion in the survey. A minimum of 50 and a maximum of 100 households were mapped per EA to have enough households to select for the survey. All the households identified in each EA were assigned a unique serial number within the EA. Systematic sampling was used with the first house selected at random and then every 5^{th} household for a total sample of 25 households per EA in Lagos, 20 households per EA in Delta and a minimum of 17 households per EA in Sokoto State. Age groups were stratified into <2 years, 2-9 years, 10-19 years, and adults to capture variations in susceptibility, exposure, and immune response across different stages of life. Infants and young children (<2 years) were specifically included to assess the potential impact of vertical transmission or early childhood exposure, while the 2-9 years group accounted for school-age children, a demographic often underrepresented in COVID-19 seroprevalence studies. In cases where an EA (Enumeration Area) experienced significant non-response rates, additional households were randomly selected to ensure that the sample size for the EA met the study's target in order to minimize potential biases associated with non-response.

The data and sample collectors used the sampled household list earlier generated to trace the exact household on the list. All members of the selected households who met the inclusion criteria for the survey were identified and interviewed by the data collectors and biological samples such as blood and oral/nasal swabs were collected by the sample collectors.

2.4. Ethical Approval

The study was reviewed and approved by the National Health Research Ethics Committee, the Nigerian Institute of Medical Research Institutional Review Board (NIMR-IRB), the Nigeria Centre for Disease Control and Prevention (NCDC) Research Governance Unit (RGU), the University of Maryland, Baltimore IRB, and the United States Centers for Disease Control and Prevention (CDC) COVID-19 response Human Subjects Review. Furthermore, social approval was also obtained from the respective state ministries of health (SMoH) before the commencement of the survey.

2.5. Data Collection and Management

Consent was obtained using hard-copy of informed consent forms. The questionnaires and specimen data for the three study states were collected on mobile tablet devices using Research Electronic Data Capture (REDCap) in Lagos and Survey CTO in Delta and Sokoto States; secure web-based application software.

2.6. Data Analysis

The household response rates for Lagos, Delta and Sokoto States were calculated using the American Association for Public Opinion Research (AAPOR) Response Rate 4 (RR4) method [21] as the number of complete and incomplete household interviews among all eligible households (plus those estimated to be eligible among those with unknown eligibility [households not located, not attempted or unreachable]). Response rates were calculated as the proportion of households and individuals who participated in the study out of those selected. The AAPOR Response Rate 4 (RR4) was selected as the primary metric for calculating response rates in this study due to its comprehensive nature. Unlike simpler response rate metrics, RR4 accounts for all eligible respondents, including adjustments for unknown eligibility among non-responding households. This method ensures a more accurate and representative measure of participation, particularly in large-scale, population-based surveys where unknown eligibility is common. Additionally, RR4 aligns with international best practices for epidemiological surveys, making the findings comparable with similar studies conducted globally. The decision to use this method was guided by its robustness in addressing potential biases arising from non-response, an essential consideration given the study's goal of deriving reliable survey response estimates. Unweighted and weighted response rates were computed, taking into account the complex sampling design. Descriptive statistics were used to summarize demographic characteristics. Age-stratified and residence-stratified analyses were performed to assess variations in response rates and survey response patterns. Other assumptions considered were relative standard error (RSE, which is the standard error of the survey point estimate divided by the point estimate), an assumed 68% response rate, and an estimated intra-cluster correlation of 0.05. Response rates and survey response rates were reported with their corresponding 95% confidence intervals (CIs). All the analyses in this study were performed using STATA 16.0 Software (StataCorp LLC Statistics/Data Analysis).

3. Results

The results provided in Table 2 presented response rates and related information for the surveys in Lagos, Delta and

Sokoto States. In Lagos State, 600 households were selected, five of the households were not found and/or destroyed. Five hundred and eighty households were occupied and 15 households were vacant for three or more days. About three households had no eligible respondent while 30 of the households refused to participate in the study. In all, 547 households were interviewed and the Household Response Rate (Unweighted) was 94.3%. In Delta State, 663 households were selected, 17 of the households were not found and/or destroyed. Six hundred and forty-six households were occupied. A total of 78 households refused to participate in the study and as a result, 568 households were interviewed and Household Response Rate (Unweighted) was 87.9%. While in Sokoto State, 567 households were selected, four of the households were not found and/or destroyed. Five hundred and forty-one households were occupied and 22 households were vacant for three or more days. Eighteen of the households refused to participate in the study. In all, 523 households were interviewed and Household Response Rate (Unweighted) is 96.7%. (Table 2).

Table 2. *Household response rates for Lagos, Delta and Sokoto States, September 2020 -July 2021.*

	Residence		
Response rates	**Urban (n=1,088)**	**Rural (n=742)**	**Total (N=1,830)**
Lagos			
Households selected	480	120	600
Not found/ destroyed	3	2	5
Inaccessible	0	0	0
Vacant for 3 or more days	8	7	15
Households occupied	469	111	580
No eligible respondent present	2	1	3
Refused to participate	23	7	30
Households interviewed	444	103	547
Household response rate[1] (unweighted)	94.7	92.8	94.3
Delta			
Households selected	506	157	663
Not found/ destroyed	7	10	17
Inaccessible	0	0	0
Vacant for 3 or more days	0	0	0
Households occupied	499	147	646
No eligible respondent present	0	0	0
Refused to participate	45	33	78
Households interviewed	454	114	568
Household response rate[1] (unweighted)	91.0	77.6	87.9
Sokoto			
Households selected	102	465	567
Not found/ destroyed	0	4	4
Inaccessible	0	0	0
Vacant for 3 or more days	13	9	22
Households occupied	89	452	541
No eligible respondent present	0	0	0

	Residence		
Response rates	**Urban (n=1,088)**	**Rural (n=742)**	**Total (N=1,830)**
Refused to participate	8	10	18
Households interviewed	81	442	523
Household response rate[1] (unweighted)	91.0	97.8	96.7

[1]Household response rate was calculated using the American Association for Public Opinion Research (AAPOR) Response Rate 4 (RR4) method: https://www.aapor.org/AAPOR_Main/media/publications/Standard-Definitions20169theditionfinal.pdf

In Lagos State, the overall survey response rates were high across most age groups and settings (Table 3). The age group of 18 to 64 years had the highest overall survey response rate at 86.8% (95% CI: 85.0 – 88.6), with nearly all (99.2%) of the eligible individuals being interviewed. Similarly, the age group of 10 to 17 years also exhibited a strong response, with an overall survey response rate of 83.5% (80.4 – 86.6). Urban areas had a notably high overall survey response rate of 85.5% (84.1 – 86.9) driven by a 99.1% interview rate. In contrast, rural areas had a slightly lower overall survey response rate of 73.1% (68.8 – 77.4), despite an interview rate of 95.2%. The overall survey response rate for the entire study population in Lagos State was 83.6% (82.2 – 85.0). Detailed response rates for individual interviews, swab tests, serology tests, and malaria tests are presented in Table 3.

Table 3. *Individual interview, swab, blood draw and malaria sampling response rates in Lagos State.*

			Unweighted response rate					
Characteristic	**Number eligible**	**Number interviewed**	**Interview[1] (%)**	**Swab[2] (%)**	**Serology[3] (%)**	**Malaria[4] (%)**	**Overall survey response[5]**	**95% CI**
Age								
<2 years	33	29	87.9	82.8	65.5	79.3	54.3	37.3 – 71.3
2-9 years	491	478	97.4	91.0	82.2	90.8	75.5	71.7 – 79.3
10-17 years	549	545	99.3	93.2	89.2	92.8	83.5	80.4 – 86.6
18-64 years	1,435	1,423	99.2	96.4	92.8	96.3	86.8	85.0 – 88.6
65+ years	191	184	96.3	97.3	94.6	97.3	85.9	81.0 – 90.8
Residence								
Urban	2,286	2,266	99.1	95.4	91.5	90.3	85.5	84.1 – 86.9
Rural	413	393	95.2	90.3	81.4	95.2	73.1	68.8 – 77.4
Total	2,699	2,659	98.5	94.7	90.0	94.5	83.6	82.2 – 85.0

[1]Interview response rate = number of individuals interviewed/number of eligible individuals
[2]Swab response rate= number of individuals who provided swab/number of individuals interviewed
[3]Blood draw response rate = number of individuals who provided blood/number of individuals interviewed
[4]Malaria sampling response rate= number of individuals who provided malaria sample/number of individuals interviewed
[5]Overall survey response rate = household response rate*interview response rate*blood draw response rate

In Delta State, the overall survey response rate varied across different age groups and residence settings (Table 4). Notably, the highest response rate was observed in the 65-year-old and above age group, with 97.1% of eligible individuals being interviewed, and the overall survey response rate for this group was 85.3% (1.0 – 87.3). Similarly, the age group of 18 to 64 years showed a high response rate of 91.0%, with an overall survey response rate of 79.9% (64.2 –

83.5). Urban areas had a slightly higher participation rate compared to rural areas, with 95.2% of urban residents interviewed versus 87.7% in rural areas. The overall survey response rate for the entire study population was 81.8% (79.2 – 84.8). Detailed response rates for individual interviews, swab tests, blood draws, and malaria sampling across different age groups and settings are presented in Table 4.

Table 4. *Individual interview, swab, blood draw and malaria sampling response rates in Delta State.*

			Unweighted response rate					
Characteristic	**Number eligible**	**Number interviewed**	**Interview[1] (%)**	**Swab[2] (%)**	**Serology[3] (%)**	**Malaria[4] (%)**	**Overall survey response[5]**	**95% CI**
Age								
<2 years	90	60	66.7	86.7	99.9	86.7	58.5	47.3 – 59.5
2-9 years	196	156	79.6	91.7	99.9	87.2	69.9	58.7 – 75.3
10-17 years	449	405	90.2	94.8	99.9	92.1	79.2	60.4 – 82.6
18-64 years	735	669	91.0	94.9	99.9	93.1	79.9	64.2 – 83.5
65+ years	1590	1,544	97.1	93.5	99.9	93.0	85.3	71.0 – 87.3
Residence								
Urban	2,244	2,136	95.2	92.6	99.8	91.3	83.5	79.1 – 88.7
Rural	816	716	87.7	97.5	99.9	95.5	77.0	65.8 – 78.9
Total	3,060	2,852	93.2	93.8	99.8	92.4	81.8	79.2 – 84.8

[1]Interview response rate = number of individuals interviewed/number of eligible individuals
[2]Swab response rate= number of individuals who provided swab/number of individuals interviewed
[3]Blood draw response rate = number of individuals who provided blood/number of individuals interviewed
[4]Malaria sampling response rate= number of individuals who provided malaria sample/number of individuals interviewed
[5]Overall survey response rate = household response rate*interview response rate*blood draw response rate.

In Sokoto State, the overall survey response rates varied significantly across different age groups and residence settings (Table 5). The lowest response rate was observed in the age group under 2 years, where only 4.3% of the eligible individuals were interviewed, leading to an overall survey response rate of just 4.1% (2.3 – 4.4). In contrast, the age group of 18 to 64 years had a much higher response rate, with 77.3% of eligible individuals being interviewed, resulting in an overall survey response rate of 74.5% (71.0 – 78.6). Urban areas had a notably low overall survey response rate of 4.1% (2.5 – 4.7), primarily due to the low interview rate of 35.9%. In rural areas, the response rate was considerably higher, with 69.0% of eligible individuals interviewed, leading to an overall survey response rate of 54.4% (49.6 – 55.8). The overall survey response rate for the entire study population in Sokoto State was 58.4% (51.2 – 58.9). Detailed response rates for individual interviews, swab tests, blood draws, and malaria sampling are presented in Table 5.

Table 5. *Individual interview, swab, blood draw and malaria sampling response rates in Sokoto State.*

			Unweighted response rate					
Characteristic	**Number eligible**	**Number interviewed**	**Interview[1] (%)**	**Swab[2] (%)**	**Serology[3] (%)**	**Malaria[4] (%)**	**Overall survey response[5]**	**95% CI**
Age								
<2 years	310	9	4.3	99.9	99.9	99.9	4.1	2.3 – 4.4

Characteristic	Number eligible	Number interviewed	Unweighted response rate					
			Interview[1] (%)	Swab[2] (%)	Serology[3] (%)	Malaria[4] (%)	Overall survey response[5]	95% CI
2-9 years	754	453	56.3	94.9	99.8	99.9	54.4	49.7 – 59.3
10-17 years	840	539	60.6	93.9	99.8	99.9	58.4	52.3 – 59.6
18-64 years	1321	1021	77.3	94.4	99.7	99.8	74.5	71.0 – 78.6
65+ years	379	75	19.8	93.3	99.9	99.9	19.1	14.2 – 19.7
Residence								
Urban	1174	421	35.9	96.0	99.5	99.8	4.1	2.5 – 4.7
Rural	2430	1676	69.0	94.0	99.8	99.9	54.4	49.6 – 55.8
Total	3,604	2097	58.2	94.4	99.8	99.9	58.4	51.2 – 58.9

[1]Interview response rate = number of individuals interviewed/number of eligible individuals
[2]Swab response rate= number of individuals who provided swab/number of individuals interviewed
[3]Blood draw response rate = number of individuals who provided blood/number of individuals interviewed
[4]Malaria sampling response rate= number of individuals who provided malaria sample/number of individuals interviewed
[5]Overall survey response rate = household response rate*interview response rate*blood draw response rate

4. Discussion

The study found variations in response rates and survey response rates across different age groups and residence settings in Nigeria, specifically in Lagos, Sokoto, and Delta States. In Lagos State, response rates were higher across all age groups, with the overall response rate being 98.5%, and an overall survey response rate of 83.6% ((80.4 – 86.6)). This could indicate a substantial level of COVID-19 awareness and possibly greater accessibility to health services or stronger engagement in urban areas. In contrast, Sokoto State exhibited the lowest response rates, with an overall response rate of 58.2% and an overall survey response rate of 58.4% (51.2 – 58.9). This may reflect challenges such as lower awareness, geographic barriers, or cultural differences that impact willingness to participate in the study In Delta State, the overall response rate was 93.2%, with an overall survey response rate of 81.8% (79.2 – 84.8), possibly indicating a better engagement than Sokoto but lower than Lagos, potentially due to a mix of urban and rural dynamics.

Among children, particularly those under 2 years of age, the study found the lowest response rates across all states. One possible reason for this observation could be parental hesitance in subjecting young children to testing procedures, concerns about the safety of swabs or serology tests for infants, or difficulties in reaching households with young children. Additionally, logistical challenges, such as ensuring access to families with infants and convincing them to participate, may have contributed to the lower response rates in this age group.

Across all three states, interview response rates were significantly higher than overall survey response rates. This difference can be attributed to the fact that while people might agree to an interview, they may be less inclined to complete additional procedures such as swabs or serology sample collection. The higher interview rates could reflect participants' initial willingness to contribute to the study, but lower survey response rates may be a result of participants' reluctance to provide samples, logistical challenges in coordinating sample collection, or concerns about the purpose and use of the samples. This highlights the need for better communication and trust-building efforts to ensure participants are comfortable with all aspects of the study, including the sample collection process. The lower survey rates might also be due to natural tendency for phobia for nasopharynx invasion and needle prick.

The overall survey response rates revealed a pattern where Lagos and Delta States had higher response rates in urban areas compared to rural areas. However, in Sokoto State, the trend was reversed, with rural areas showing higher response rates than urban areas. This variation could be attributed to several factors, such as differences in access to healthcare services and levels of COVID-19 awareness. Urban residents may have more awareness to public health campaigns and greater access to information, leading to higher participation in Lagos and Delta. In Sokoto, rural residents might have more trust in local community leaders or less perceived risk of the virus, which could explain the higher rural participation. The study revealed notable differences in response rates across different states, age groups, and between urban and rural settings. In Lagos and Delta States, response rates were generally high, reflecting a substantial level of COVID-19

awareness in these areas. In contrast, Sokoto State exhibited lower response rates, particularly among young children and older adults. These findings align with previous studies suggesting that participation rates can be influenced by age and the challenges in engaging participants in less urbanized areas [5, 22]. When looking at survey response rates by age, the differences observed highlight the importance of conducting age-stratified analyses when assessing COVID-19 seroprevalence. As with other studies, younger children and older adults demonstrated lower participation, possibly due to caregiver concerns or health-related limitations [23, 24].

The study also found disparities between interview response rates and overall survey response rates. Interview participation was generally higher, possibly indicating participants' initial willingness to engage, while lower survey completion rates could reflect hesitations or logistical challenges during the study [25]. Finally, urban and rural settings exhibited distinct response patterns. In Lagos and Delta, urban areas had higher response rates compared to rural areas, which could be explained by better healthcare access and more public health outreach. However, Sokoto presented an opposite trend, with rural areas showing higher response rates. This could be due to varying healthcare-seeking behaviours and trust in local health initiatives between urban and rural populations. Understanding these differences is essential for tailoring public health interventions to specific regional needs and ensuring equitable access to testing and vaccination [26-29].

The lower participation observed in Sokoto State and among younger children, could impact the reliability of COVID-19 prevalence estimates. Regions with lower response rates may have underrepresented infection levels, introducing potential bias in seroprevalence data. Understanding this variability is critical for public health planning. Targeted strategies, such as improved community engagement and awareness campaigns are necessary to overcome participation barriers in underserved regions. Enhanced participation would improve data accuracy, enabling more precise targeting of vaccination programs and preventive interventions. These findings show the importance of equitable healthcare strategies to address pandemic-related challenges across diverse settings.

5. Conclusion

This study provides a comprehensive assessment of response rates in a population-based seroepidemiological study of COVID-19 in Nigeria, highlighting differences and challenges of obtaining full participation. The findings underscore the high participation rates in Lagos and Delta States, particularly in urban areas, suggesting substantial engagement and potential COVID-19 awareness. However, the relatively lower response rates in Sokoto State, especially among children under two (2) years and older adults, point to specific challenges. Notably, field reports indicated that many fathers, who are the primary decision-makers in giving consent for their children's participation, had relocated to other states possibly due to economic hardships and the impact of Boko Haram insurgency/insecurity on their livelihoods, particularly farming activities. The response rates have significant public health implications, as they provide insight into the effectiveness of data collection methods and the representativeness of the study population. Improving participation in specific demographics, particularly in states like Sokoto, is crucial for enhancing the accuracy and reliability of seroepidemiological data, which in turn informs public health interventions and policy decisions. Enhanced communication strategies and initiatives to strengthen trust in the research process along with addressing socio-economic barriers, may be required to overcome participation challenges and promote more inclusive and representative data collection in future studies.

6. Study Limitations

This study has several limitations that may affect the interpretation and generalizability of the findings. First, selection bias may be present, as certain groups, particularly young children under 2 years and older adults, were underrepresented due to lower response rates. This could impact the overall representativeness of the data and limit insights into COVID-19 awareness and response across all demographics.

Additionally, geographical and cultural differences across regions likely contributed to the variability in response rates. For example, response rates were generally higher in urban areas and states such as Lagos and Delta but were comparatively lower in Sokoto. These variations may be due to differences in socio-economic conditions, healthcare access, or regional challenges, including insecurity in Sokoto where many families, particularly fathers, had relocated due to threats from Boko Haram. Such factors may have influenced who was available to participate and could introduce variability across states.

Logistical challenges posed further limitations, as remote or rural areas were more difficult to access, which may have reduced the response rates in these locations. Additionally, limitations related to age representation and participation were evident, with lower response rates among children under 2 years and older adults, potentially limiting insights into COVID-19 awareness in these groups. Moreover, while survey responses were essential to the study, some participants may have been influenced by recall bias, particularly in areas with lower literacy levels, leading to potential inaccuracies in the self-reported data. The study context during the COVID-19 pandemic may have also influenced response rates, as some participants might have been hesitant due to concerns about infection or pandemic-related restrictions.

Lastly, in certain regions affected by conflict or socio-political challenges, mistrust of the research process or misunderstanding of study objectives could have contributed to lower participation. These limitations underscore the need

for improved data collection strategies in future studies to ensure more inclusive and representative participation across diverse populations.

Abbreviations

AAPOR	American Association for Public Opinion Research
BMI	Body Mass Index
COVID-19	Coronavirus 2019
EAs	Enumeration Areas
RR4	Response Rate 4

Conflicts of Interest

The authors declare no conflicts of interest.

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