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The COVID-19 Pandemic: Present or Gone, Where Do Adolescents Stand?

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Abstract

Introduction: The initial global response to the SARS-CoV-2 pandemic focused on adults as adolescents mainly had subclinical infections. Adolescents, however, could transmit the virus and hence be a risk to the elderly, young children and immunocompromised. Adolescents are also at risk of long-term complications. This study sought to determine the prevalence of antibodies to SARS-CoV-2 among adolescents in Southern Nigeria, and to determine the association between SARS-CoV-2 seropositivity and age, gender, socioeconomic class, school type and nutritional status. **Methods:** This descriptive cross-sectional study was carried out in Edo state of southern Nigeria. We recruited 270 in-school adolescents aged 10 - 19 years. A WHO-adapted, pre-tested questionnaire was used to obtain data on participant history and risk factors. The questionnaire was interviewer-administered. Adolescents whose parents gave consent were recruited through a multi-stage randomized sampling method. Capillary blood for the assay was collected and analysed using a lateral-flow immunoassay device. The primary outcome was serostatus of the study. The positive predictors of serostatus were finally determined using a multiple logistics regression model. Statistical significance was set at $p < 0.05$. **Results:** The seroprevalence of SARS-CoV-2 was 45.9%. IgM antibodies were found in 5.6% of participants. Older adolescents had higher seropositivity rates than younger adolescents ($\chi^2 = 8.101$, $p = 0.017$). There was no association between gender and seropositivity. Adolescents in public schools were more likely to be seropositive than those in private schools ($\chi^2 = 25.242$, $p = 0.001$). A higher seroprevalence was noticed among study participants in the lower socioeconomic class ($x^2 = 6.928$, p = 0.031), and those in overcrowded classes. ($\chi^2 = 79.303$, $p = 0.001$). **Conclusion:** This study showed a high seroprevalence of SARS-CoV-2 among in-school adolescents. Behavioural change communication on SARS-CoV-2, vaccination of adolescents, and standardization of classrooms are recommended.

Keywords

Pandemic, Adolescents, Seroprevalence, COVID-19

1. Introduction

The novel coronavirus took the world by surprise in December 2019, when several acute atypical respiratory tract infections were noticed in China and subsequently spread globally. [1] It caused a severe multisystemic disease, subsequently named the coronavirus disease 2019 (COVID-19). Within 36 months, 696 million cases and 6.6 million deaths had been reported worldwide from COVID-19 complications. A significant number of these cases (9.4 million) were reported in Africa [2] and Nigeria was not excluded from these complications.

The initial global response was focused on adults particularly in developing countries, as most of the complications were among adults. However as the pandemic progressed, more infections were reported in children and adolescents. [3] These adolescents mainly had asymptomatic or subclinical COVID-19 infections. Despite their subclinical presentations, they could transmit the virus making them a risk to other age groups, especially the elderly, younger children, and immunocompromised. [4] These adolescents are also at risk of long-term complications, particularly the Long COVID which has been seen in adolescents regardless of the severity of the disease. The Global response to the pandemic included travel restrictions (the lockdown), physical distancing, use of face masks, hand hygiene and eventually, vaccination. Many countries including Nigeria excluded adolescents and children from the COVID-19 vaccination Programme. In Nigeria where a quarter of the estimated 213 million population are adolescents, COVID vaccination in this age group is still restricted to those needing it for international travel and education. As of 2021, with increasing vaccination coverage, many countries relaxed the very stringent COVID-19 prevention requirements. The important question of whether COVID-19 had abated, particularly in the important adolescent population who received very little attention, was however left unanswered. Till-date, pockets of cases are still being reported. In Benue State, North-Central Nigeria, 25 new cases have been alluded to by the World Health Organization (WHO). [5] This suggests ongoing transmission.

Factors such as age, gender, socioeconomic status, and nutritional status that have been identified in some studies as being associated with seropositivity have not been comprehensively studied in adolescents. [6] Age and sex-disaggregated data from low and middle-income countries like Nigeria is limited. [7] Data from the United States Centre for Disease Control (CDC) noted that mortality arising from complications in children, was disproportionately higher in adolescents, Africans, and Hispanics. This suggests a need for further research in these subgroups. [8] [9] [10] In this study, we examined the pattern of exposure in Nigerian adolescents as documented by seropositivity and determined its asso-

ciation with age, gender, socioeconomic class, overcrowding, school type and nutritional status.

2. Methods

STUDY DESIGN: This was a cross-sectional study recruiting study participants from 6 secondary schools across 10 wards in Benin City, South-South Nigeria. The study was conducted between August and December 2022. The study population was made up of apparently healthy adolescents aged 10 to 19 years who met the inclusion criteria. Participants were eligible for enrolment if they met the following criteria: they attended one of the participating secondary schools, were between the ages of 10 and 19 years, their parent or legal guardian gave informed consent to participate, and the child gave their assent. Children with a prior COVID-19 positive diagnosis, children whose parents did not give consent and those outside the stipulated age were excluded.

Ethical clearance was obtained from the Health Research and Ethical Committee of the University of Benin Teaching Hospital (UBTH) protocol number: ADM/E22/A/VOL.1457, (see **Appendix 1**) and written permission was obtained from the Edo State Ministry of Education and Edo State Universal Basic Education Board (SUBEB). Participants were assured of confidentiality.

SAMPLING AND DATA COLLECTION: A multistage sampling technique was used. We randomly selected 3 out of the 10 wards in the selected LGA, and 30% of the secondary schools in these wards were randomly selected. The total student population in the 6 selected schools was determined from the school registers, and our sample size of **270** study participants was distributed by proportion among the selected schools. A total of 270 students were recruited.

Sociodemographic data was collected from the study participants using a pretested modified WHO proforma for population-based age-stratified seroepidemiological studies for SARS-CoV-2. [11] [12] The questionnaire was interviewer-administered.

LABORATORY ANALYSIS: Capillary blood samples were collected from the study participants by the research team and analysed using a lateral flow immunoassay device; the Unscience^{R} COVID IgG/IgM rapid test device, an immunochromatographic test for the qualitative detection of IgM and IgG antibodies to SARS CoV2. The manufacturers reported a sensitivity of 98.81% (95% CI: 97.25%, 99.61%), and a specificity of 98.02% (95%CI: 97.05%,98.74%). Test results were classified into one of five categories: Negative, IgG positive alone, IgM positive alone, IgG and IgM positive or invalid. Invalid or ambiguous test kits were discarded, and sample collection from the participant was repeated.

STATISTICAL ANALYSIS: Data obtained was analysed using Statistical Package for Social Sciences (SPSS) spreadsheet version 28. Overcrowding in homes was defined as; a couple plus a child <12 years or two adults (not in a relationship) of the opposite sex sleeping in the same room. [13] [14] while overcrowding in classes was defined as more than 35 students to one teacher in a standard classroom. [15]

The primary outcome was serostatus of the study participants. The relationship between sociodemographic variables and serostatus was analysed using the chi-square test and Fisher's Exact test where applicable.The positive predictors of serostatus were finally determined using a multiple logistics regression model. Statistical significance was set at $p < 0.05$.

3. Results

A total of two hundred and seventy (270) participants between the ages of 10 to 19 years were recruited from both public and private secondary schools. Comparisons of the sociodemographic characteristics of the participants were made based on their school type (Table 1). Adolescents were classified into age groups in line with the WHO classification. [16] Early adolescents accounted for 54.1% (146), middle adolescents 30% (81) and late adolescents 15.9% (43) of the study population. The study participants consisted of 111 (41.1%) males and 159 (58.9%) females, giving a male: female ratio of 1:1.4. There were 112 (41.5%) study participants from the lower socioeconomic class (SEC), 105 (38.9%) from the middle, and 53 (19.6%) from the upper socioeconomic class. None of the participants had received COVID-19 vaccination.

Table 1. Sociodemographic characteristics of study participants.

Sociodemographic characteristics	Frequency		School Type			
	n	%	Public n (%)	Private n (%)	χ^2	*p*
Adolescent group						
Early	146	54.1	65 (44.2)	81 (65.9)	12.997	**0.002***
Middle	81	30.0	52 (35.4)	29 (23.6)		
Late	43	15.9	30 (20.4)	13 (10.5)		
Sex						
Male	111	41.1	61 (40.7)	50 (41.5)	0.020	0.888
Female	159	58.9	86 (59.3)	73 (58.5)		
Socioeconomic Class						
Upper	53	19.6	7 (4.7)	46 (37.4)	106.672	**0.001***
Middle	105	38.9	39 (26.5)	66 (53.7)		
Lower	112	41.5	101 (68.8)	11 (8.9)		
Religion						
Christian	259	95.9	139 (94.6)	120 (97.6)	1.545	0.214
Muslim	11	4.1	8 (5.4)	3 (2.4)		
Overcrowding						
Overcrowded homes	149	55.2	96 (64.4)	53 (35.6)	13.365	**0.001***
Standard Homes	121	44.8	51 (42.1)	70 (57.9)		
Overcrowded Classrooms	134	49.6	113 (84.3)	21 (15.7)	95.788	**0.001***
Standard Classrooms	136	50.4	34 (25)	102 (75)		

χ^2: chi-square test, p: probability. *: $p < 0.05$ (Significant p-value).

Most of the students in public schools 101 (68%) were from low socioeconomic classes compared to those in private schools who were mostly from middle 66 (53.7%) and upper 46 (37.4%) socioeconomic classes. The difference in the socioeconomic class between study participants in public and private schools was statistically significant. (χ^2 = 106,672, p = 0.001).

Overcrowding in homes was defined as; a couple plus a child < 12 years or two adults (not in a relationship) of the opposite sex sleeping in the same room. [13] [14] Overcrowding in classes was defined as more than 35 students to one teacher in a standard classroom. [15] A total of 149 students lived in overcrowded homes, of which 96 (64.4%) were from public schools, while 53 (35.6%) were from private schools. This difference was statistically significant. (χ^2 = 13.365, p = 0.001). There were significantly more overcrowded classrooms in public schools compared to private schools. (χ^2 = 95.788, p = 0.001).

The mean weight and height of students in public schools were significantly higher than those in private schools as shown in Table 2 (t = 2.031, p = 0.043 and 3.302, p < 0.001 respectively).

3.1. Seropositivity of the Study Participants

Of the 270 study participants, 124 (45.9%) were positive for SARS-CoV-2 antibodies; either IgG, IgM, or both, while 146 (54.1%) study participants were seronegative. As seen in Figure 1, 109 were IgG-positive only, 2 were IgM-positive only, and 13 participants were positive for IgG and IgM.

Table 2. The mean anthropometric measures of the study participants.

Anthropometric measure	Type of School						T-test	p-value
	Public Schools		Private Schools		Total			
	Mean	SD	Mean	SD	Mean	SD		
Weight	50.97	11.762	48.07	11.664	50.76	20.859	2.031	**0.043***
Height	161.63	10.427	157.61	9.333	159.80	10.125	3.302	**0.001***
BMI	19.33	3.331	19.17	12.827	19.26	3.387	0.384	0.701

SD: Standard deviation. *: p < 0.05 (Significant p-value).

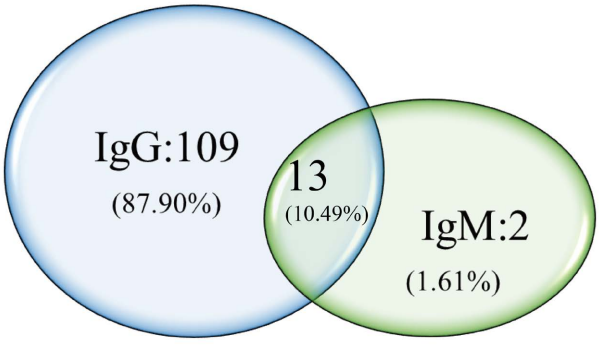

Figure 1. Seropositivity of study participants.

3.2. Relationship between Seropositivity and Sociodemographic Characteristics

There was no statistically significant difference in seropositivity between males and females (χ^2 = 0.059, p = 0.809). Those in the late adolescent group had a higher seroprevalence of 27 (62.8%) compared to those in the middle and early adolescent groups (Table 3). The difference between the groups was statistically significant. (χ^2 = 8.101, p = 0.017). In the same way, a higher seroprevalence of 55.4% was noticed among study participants in the lower socioeconomic class (x^2 6.928 and p = 0.031), and those in overcrowded classes 73.1%. (χ^2 = 79.303, p = 0.001). Students in public schools and overcrowded classes were noted to have a higher seroprevalence, however, overcrowded homes did not affect the serostatus of the study participants. The most identified symptoms in

Table 3. Relationship between sociodemographic factors, nutritional status, overcrowding and seropositivity to SARS-COV-2.

Sociodemographic Variable	Serostatus			
	Negative n (%)	Positive n (%)	χ^2	p
Adolescent group				
Early	89 (61.0)	57 (39.0)	8.101	**0.017***
Middle	41 (50.6)	40 (49.4)		
Late	16 (37.2)	27 (62.8)		
Socioeconomic Class				
Upper	33 (62.3)	20 (37.7)	6.928	**0.031***
Middle	63 (60.0)	42 (40.0)		
Lower	50 (44.6)	62 (55.4)		
Sex				
Male	61 (55.0)	50 (45.0)	0.059	0.809
Female	85 (53.5)	74 (46.5)		
Nutritional Status				
Severe Thinness	1 (50.0)	1 (50.0)	1.779	0.679†
Thin	9 (47.4)	10 (52.6)		
Normal	127 (53.8)	109 (46.2)		
Overweight	9 (69.2)	4 (30.8)		
School				
Public	59 (40.1)	88 (59.9)	25.242	**0.001***
Private	87 (70.7)	36 (29.3)		
Overcrowded class				
No	110 (80.9%)	26 (19.1%)	79.303	**0.001***
Yes	36 (26.9%)	98 (73.1%)		
Overcrowded Homes				
No	66 (54.5)	55 (45.5)	0.000	0.986
Yes	80 (53.7)	69 (46.3)		

†Fisher's exact test. **χ^2:** chi-square test, p: probability, n: number. *: $p < 0.05$ (Significant p-value).

seropositive participants were: headaches (62.5%), fever (44.8%), malaise (33%), joint aches (24%), and chest pain (23%). In assessing risk factors associated with seropositivity, there was no statistically significant correlation between any of the symptoms and seropositivity.

3.3. Independent Predictors of SARS-CoV-2 Seropositivity in Study Participants

Table 4 shows the independent predictors of seropositivity following multivariate analysis. The factors that independently predicted seropositivity were learning in an overcrowded classroom and being from the late adolescent age group.

4. Discussion

This study focused on adolescents, who make up a large percentage of the population and can serve as a reservoir for transmission. The seroprevalence obtained in this study was 45.9%. This suggests a high seropositivity to SARS-CoV-2 among adolescents in this region and is reflective of the significantly high ongoing transmission of SARS-CoV-2 within the study population. A major determinant of seropositivity has been the time interval between waves of the disease and the study period. The high seroprevalence in this study reflects the concurrent waves of the pandemic and the rising cumulative number of people exposed, with successive waves of the disease. IgM antibodies wane in the period following the wave, however IgG antibodies last for months, ranging between 6 to 18 months. The current study assessed both IgM and IgG antibodies, affording an assessment of both the recently and previously infected adolescents. Assessing

Table 4. Independent predictors of SARS-CoV-2 seropositivity.

Variables	AOR	95% C.I.		*p*
		Lower	Upper	
Adolescent group				
Early	1.000			**0.001***
Middle	2,299	1.079	4,897	**0.031***
Late	6.603	2.469	17.465	**0.001***
Overcrowded class				
No	1.000			
Yes	24.623	10.162	59.665	**0.001***
School type				
Private	1.000			0.375
Public	0.665	0.257	1.668	
Socioeconomic Class				
Upper	1.000			0.185
Middle	0.758	0.301	1.910	0.557
Lower	0.395	0.133	1.174	0.095

C.I: confidence interval, AOR: adjusted odd ratio, p: probability. *: $p < 0.05$ (Significant p-value).

both IgG and IgM potentially contributed to the higher seroprevalence observed. [17] This is made obvious when comparing the prevalence reported by Okpala *et al*. [18] in Anambra State, Eastern Nigeria. They reported a seroprevalence of 15.1% among adolescents, one of the lowest that has been reported among adolescents in Nigeria. Their study was done in December 2020, barely a year after the onset of the pandemic. [18] The higher prevalence in the current study is a result of the cumulative effect of multiple previous waves of infection. Kolawole [17] *et al.* on the other hand reported a seroprevalence of 80.5% in adolescents studied between June and August 2021. Their review coincided with the onset of the second wave of the pandemic and most studies done during the pandemic like Kolawole *et al*., have had a higher seroprevalence. The seropositivity in the current study represents prior infection without the bias of a surge of new infections which would no doubt create a spike in seropositivity.

At the time of this study, a small percentage of the study participants had IgM antibodies. The presence of IgM antibodies suggests ongoing (new) infections that show active transmission. Although COVID-19 preventive modes and restrictions had been relaxed in most states and even countries worldwide, we found that there was still significant ongoing transmission during the study period. The presence of active transmission in any community comes with the attendant risk of infection and re-infection in the populace. Okpala and co-workers [18] reported similar evidence of acute infection among their study population six months after the first wave of COVID-19. In both Okpala's study and the present study, there is comparable duration after a major wave of the disease, accounting for the similarity in findings. With the resolution of a wave of disease, the fear of the spread of infection begins to resolve and both general and individual personal protective measures begin to relax. Background pockets of transmission are the facilitators of new waves of the disease. The presence of ongoing local transmission increases the risk for new waves of the disease and puts the population at risk. [19]

We identified an association between the age category of the study participants and seropositivity. Participants in their late adolescence had a higher seroprevalence than those in the early and middle adolescent age group. With advancing age, adolescents are more likely to engage in risk-taking and have less parental control. [20] They are more exposed to the outdoors and crowded environments, and this accounts for the higher prevalence observed in the older adolescent age group. Adolescents in the older age groups are more likely to interact not just with themselves within the school environment but also with other adolescents in the community, as compared with those in the early adolescent age group who are still under close control from parents/guardians and may be more restricted. The findings in this study are in keeping with the cumulative UNICEF age-disaggregated data that showed a higher number of COVID-19 cases among late adolescents than early adolescents. [3] Kolawole *et al.* also reported similar findings, their highest prevalence was in those aged 15 - 19 years. [17] Audu *et al.* in Gombe State also reported a higher prevalence in

adolescents aged 15 - 19 years, when compared to those aged 10 - 14 years. [21]

In the current study, there was no association between gender and seropositivity. This is because both male and female adolescents are exposed to the same environment. Kolawole, Okpala, and Olaleye had similar findings. [17] [18] [22] Our findings are similar to global reports that sex does not significantly influence SARS-CoV-2 seropositivity and transmissibility. The World Health Organization and the African Centre for Disease Control indicated that gender has no role in SARS-CoV-2 seropositivity.

We found no statistically significant difference in seropositivity concerning different nutritional status. Few studies have assessed the relationship between seropositivity and nutritional status. Nwosu *et al* in their study noted higher seroprevalence in obese individuals. [23] Studies have suggested that a positive correlation between obesity and seropositivity may be related to severe illness, which is more common in obese individuals and linked to longer-lasting antibody responses. [23] These findings are further buttressed by Karachaliou *et al* in Spain who demonstrated that obese people had higher positive responses. [24] However, after adjustments were made for the severity of infection, associations were largely diluted. Although Karachaliou *et al.* noted higher seroprevalence among obese individuals, the current study did not have any obese participants and did not observe any relationship between seropositivity and nutritional status. Most of the study participants had normal stature with only a few being overweight or thin. This might account for the lack of significant difference as most of the study population clustered within the normal BMI group.

In the present study, participants in the lower socioeconomic class had higher seropositivity than those in the higher and middle classes. This finding was also reported by Indenbaum in Israel, and Ferreira in Brazil. [25] [26] The higher seropositivity in adolescents of lower socioeconomic class may be linked to higher attendance at public schools by these adolescents. These public schools are often overcrowded, a factor that was noted to independently predict seropositivity in this study. The pattern of housing in overcrowded suburban regions occupied by those in the lower socioeconomic classes may also be a factor. Overcrowding increases the likelihood of transmission via respiratory droplets. Of note was that overcrowding in schools with other students from different homes was even more of a contributor than overcrowding at home with members of the same family. Also, adolescents from the lower socioeconomic class may have limited ability to acquire personal protective materials hence increasing the chances of transmission among them. The role of social distancing and the use of personal protective material in the prevention of SARS-CoV-2 transmission have been alluded to in previous studies.

5. Conclusion and Recommendations

Despite the low reports of COVID-19 in Nigeria, there is a high seroprevalence of SARS-CoV-2 antibodies among adolescents in Benin City. Adolescents in overcrowded classrooms, older adolescents and those from lower socio-economic

classes are more likely to be seropositive. Transmission remains ongoing among the adolescent population who may serve as the source of the infection for their vulnerable parents and other elderly persons in their homes.

There is a need to review the Nigerian COVID-19 immunization policy to include adolescents. Clinicians should maintain a high index of suspicion and include testing for SARS-CoV-2 in adolescents who present with respiratory illness and symptoms simulating post-COVID sequelae.

There should be continued public protective measures to mitigate the spread of the infection and reduce ongoing transmission.

The recommended student: Teacher ratio for classrooms of 1 teacher to 35 students, should be maintained to avoid overcrowded school settings that could set the stage for the spread of infection.

Similar studies should be replicated in a multi-site research to generate representative national data. In addition, more studies should be carried out on the impact of nutrition on SARS-CoV-2 Seropositivity.

6. Limitations

This study was conducted when nations had lifted COVID-19 restrictions, and most communities had relaxed most preventive measures, which could impact the outcome of the study.

Author Contributions

IAE—conceptualization of the study and study design, data collection and entry, sample collection and analysis, interpretation of data, writing of draft and final approval of the version to be published.

AES—conceptualization and review of study design, interpretation of data, revision of draft critically for important intellectual content; and final approval of the version to be published.

EUE—conceptualization and study design, data collection and entry, sample collection and analysis, interpretation of data, revision of draft critically for important intellectual content and final approval of the version to be published.

POA—revision of the draft critically for important intellectual content; and final approval of the version to be published

All authors read and approved the final manuscript.

Ethics Approval and Consent to Participate

This study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The research was reviewed and approved by the University of Benin Teaching Hospital Ethics Health and Research Committee (protocol number: ADM/E22/A/VOL.1457). (Appendix I) Signed informed consent was obtained from caregivers of the study participants after the purpose of the study was explained to them and participation was voluntary.

Conflicts of Interest

The authors declare no conflicts of interest.

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