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# How the COVID-19 pandemic affected infant vaccination trends in rural and urban communities in Ibadan, Nigeria: a cross-sectional study

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## ABSTRACT

**Objectives** This study compared the infant vaccination trends a year before and a year after the onset of the COVID-19 pandemic in selected urban and rural communities in Ibadan, Nigeria.

**Design** This was a cross-sectional study in which data were extracted from infant vaccination records.

**Setting** Two rural and three urban vaccination centres in primary health clinics at Ibadan Southeast and Olúyòlé local government areas, respectively.

**Participants** Infant vaccination records 1 year before and 1 year after the onset of the COVID-19 pandemic (March 2019–February 2020 and March 2020–February 2021, respectively).

**Outcome measures** Timeliness of vaccination (vaccination taken within 2 weeks of appointment) and vaccination completion according to the Nigerian routine infant vaccination schedule.

**Results** 2000 vaccination records were included in the study (1013 (50.6%) for male infants). 840 (42.0%) of the records were from the rural immunisation clinics. There were 1194 (59.7%) and 806 (40.3%) records from before and after the onset of the COVID-19 pandemic, respectively. Before the pandemic, birth dose vaccines were timelier among infants from urban communities, while vaccines given at 6 weeks were timelier in the rural areas. Following the onset of the pandemic, the rural communities had a higher proportion of infants with timelier and complete vaccination except for the birth dose vaccines. Overall, there was higher vaccination completion before the pandemic, and this was higher in the rural compared with the urban communities both before (54.8% vs 11.7%) and after (23.6% vs 1.0%) the onset of the pandemic.

**Conclusions** A decline in infant vaccination uptake, timeliness and completion persisted 1 year after the COVID-19 pandemic onset, and urban communities were more affected. More efforts are required to ensure optimal infant vaccination, especially in urban communities, to forestall outbreaks of vaccine-preventable diseases.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The comparison of vaccination records a year before and a year after the onset of the COVID-19 pandemic provided a substantial time frame and sizeable vaccination records to understand the dynamics of infant vaccine uptake.
⇒ Consideration was given to both the timeliness and completion of the infant vaccines.
⇒ The comparison of rural and urban vaccine uptake showcased the peculiarities of each settlement type.
⇒ Findings from the other geopolitical zones of Nigeria may be different from those presented here.

## INTRODUCTION

The COVID-19 pandemic had significant impact on systems globally and the health system was not left out. At the onset of the pandemic, measures were instituted to control the spread of the novel virus whose pathogenesis was yet to be understood.[1 2] These measures included restrictions in movement, social distancing, the use of face masks, hand hygiene and confinement or isolation of suspected and confirmed cases, respectively.[3 4] Even though these steps were designed with a positive intention, they subsequently had negative impacts on both the provision and access to healthcare services, including vaccination services.[5] The WHO recommended that routine vaccination services should be continued despite the pandemic with preventive measures instituted in immunisation clinics,[6] but infant vaccine uptake dipped globally during this period.[7] This dip was because people were afraid of visiting the healthcare facilities to avoid infection with COVID-19.[3 8] Restriction in movement also affected the access to vaccination centres and the movement of vaccines and other required consumables.[8–11] Social distancing increased commuters' fare due to the reduction in the number of passengers who could be transported per trip and the extra cost of sanitising the vehicles to prevent transmission. This was an added burden to majority of households whose income reduced or who could not earn a living during this period.[12]

Currently, the world is witnessing the largest decline in infant vaccination in the last 30 years.[7] Routine vaccination was the most disrupted health service during the lockdown period as a result of the pandemic with about 70% of countries reporting either complete or partial disruption.[5] Globally, this disruption was highest in April 2020 with over 4.6 million children missing their third dose of diphtheria, pertussis and tetanus (DPT) vaccine and 4.4 million missing measles-containing vaccine.[13] It is important to note that there was a lot of variation in the severity, pattern and duration of disruption in vaccination uptake across countries. While most of this disruption was in the first 2 months of the pandemic, there were reports of persistence of disruptions many months after the end of lockdown in some countries.[14–16] Also, some country data showed that the decline of vaccine uptake was matched with COVID-19 waves and severity.[14] There was also a report of more decrease in the uptake of vaccines given at older ages like measles vaccine, compared with those given at younger ages in some countries.[14] BCG was the vaccine with the highest dip during the lockdown in Pakistan,[15] but the uptake of the same vaccine did not reduce significantly in Malawi, Haiti, Lesotho, Liberia[14] and Iraq[16] at the same period.

Nigeria is 1 of the 10 countries where 60% of the 25 million children who were either completely unimmunised or partially immunised lived in 2021.[17] The country has been making slow progress in the improvement of infant vaccination coverage, but this progress has not been impressive despite multiple interventions to address the problem.[18] The DPT3 coverage improved from 33% in 2016/2017[19] to 57% in 2019,[20] but this is still lower than the 90% coverage that is required for herd immunity. It is therefore expected that the negative effect of the COVID-19 pandemic can be devastating to the slow progress that has been achieved in vaccination coverage over the decades. The Nigerian government instituted measures to control COVID-19 just like other African countries, and this affected infant vaccination. There was a 12% drop in DPT3 uptake between the first and second quarter of 2020 and 13% drop in measles-containing vaccine uptake at the same time in Nigeria.[21] Prior to the pandemic, Oyo State had the highest number of unvaccinated infants and the second lowest infant vaccination coverage in Southwest Nigeria.[22] Similar to the reports at country level, most co-administered vaccines were at their lowest in April 2020 in Oyo State. Birth dose hepatitis B vaccine (HBV) and BCG were lowest in August of the same year at 56.1% and yellow fever vaccine was 13.0%, while measles vaccine dipped by 12.4%.[23] Also, none of the planned fixed routine immunisation sessions had up to 100% coverage during the pandemic compared with 105% and 101% recorded in September and November 2019, respectively.[23]

There are many questions regarding the disruption of vaccination services because of the COVID-19 pandemic which should be answered because this will guide the focus of the catch-up activities to get the affected children vaccinated. First, there is a dearth of data regarding vaccination activities beyond the lockdown period[14 15] (there was partial lockdown between March and June 2020 in Oyo State), so it is not clear if catch-up was attained or not in many settings. Second, although the pattern of vaccination in the rural and urban settlements is usually different,[24] much literature about vaccine uptake during the pandemic rarely segregate their data, thus occluding the peculiarities of the settlements. Also, misinformation about COVID-19 was reported to be more among rural than urban dwellers,[25] which might have affected their uptake of infant vaccination. Third, there has been little report about the effect of the pandemic on the timeliness of infant vaccination.[14] Delay in vaccination is a form of vaccine hesitancy, threatening the development of herd immunity that can lead to incomplete vaccination. It is important to answer these questions as they will provide more insight into how the COVID-19 pandemic really affected infant vaccination. This study therefore aimed to compare the trend of infant vaccination uptake a year before and a year after the onset of COVID-19 in selected infant vaccination clinics in Ibadan, Southwest Nigeria, and make comparisons between clinics located in the rural and urban communities in Ibadan.

## METHODS

### Study area

The study was carried out in rural and urban areas of Ibadan, a city located in Southwest Nigeria. The city comprises of five urban local government areas (LGAs) and six rural LGAs, respectively.[22] Ibadan Southeast and Olúyòlé LGAs were selected as the urban and rural LGAs, respectively, in this study. There are 18 public primary health centres (PHCs) in Ibadan Southeast LGA with the administrative headquarters at Òrányàn Comprehensive PHC, while Olúyòlé LGA hosts 30 PHCs with administrative house at Adaramagbo PHC. There are more PHCs in Olúyòlé LGA but most of them serve fewer population of infants because the rural communities were less densely populated than the urban communities and they were scattered. More PHCs were thus located in the Olúyòlé LGA to provide easy access for the community members.

### Study population

The study participants were infants who received vaccination 1 year before and 1 year after the onset of the COVID-19 pandemic in the vaccination centres of the PHCs in the two selected LGAs.

### Study design and sampling

The study used a descriptive cross-sectional design. Simple random sampling was used to select three urban infant vaccination clinics, while the two busiest infant vaccination clinics were purposively selected among the rural PHCs because of the comparative lower population of infants being vaccinated in the rural clinics.

## Data source

The data were from the infant vaccination records of the selected clinics. The records extracted spanned from 1 year before, and 1 year after the onset of the COVID-19 pandemic. That is, from March 2019 to February 2020, and March 2020 to February 2021, respectively.

## Training of research assistants

The research assistants were trained by AAA over a 2-day period about the ethics of research and procedures for extracting data correctly from the vaccination records using a proforma. The research assistants rehearsed the data collection process to ascertain that they had mastered the data extraction process.

## Data collection procedures

Data collection lasted for 10 weeks between September and November 2021. Data were extracted from the infant vaccination records of the selected vaccination clinics using a proforma. The name (used for data verification purpose only and deleted before data entry), date of birth, age at registration, sex of the infants and the appointment date for each vaccine were recorded. The vaccination record extracted included those for oral polio vaccine (OPV), BCG, HBV, pneumococcal conjugate vaccine (PCV), pentavalent vaccine (consisted of DPT, HBV and *Haemophilus influenzae* vaccines) (PENTA), inactivated polio vaccine (IPV), measles and yellow fever vaccines. Each proforma was checked for completeness daily during the data collection period. Also, the content of randomly selected proforma was compared with the clinic records to ensure correctness at intervals.

## Data analysis

Data were initially entered into Microsoft Excel and then exported into SPSS V.26[26] for cleaning, sorting and analysis. For this study, vaccine uptake was considered timely when taken within 2 weeks after the due date as described in earlier Nigerian studies.[27 28] On the other hand, vaccine completion was defined as taking one dose each of BCG, HBV, IPV, measles and yellow fever vaccines, three doses of PENTA and four doses of OPV. The primary outcomes were the timeliness of each vaccine and completion of the schedule as defined. These translated to the proportion of infants who had the appropriate vaccines within 2 weeks of their appointment and the proportion of those who completed the required vaccines, respectively. There were some missing data, and complete case analysis (the default method for addressing missing data on SPSS) was used to address it. This method excluded the missing data from the analysis. Association between timeliness and completion of each vaccine with type of settlement and timing of onset of the COVID-19 pandemic were determined using $\chi^2$ test. The timeliness among the settlement types before and after the onset of the pandemic was also presented in diagrams. The level of statistical significance was set at 5%. The Strengthening the Reporting of Observational Studies in Epidemiology cross-sectional reporting guidelines[29] were used in this article.

## Patient and public involvement

This study did not involve the patients' participation directly. The study findings were presented to the public at the Pediatric Association of Nigeria's conference in January 2023.

# RESULTS

Overall, 2000 infant vaccination records were included in the study. Of these, 1013 (50.6%) were males and 840 (42.0%) were from the rural PHCs. There were 1194 (59.7%) records before the COVID-19 pandemic onset consisting of 659 (55.28%) from the urban and 535 (44.8%) from the rural PHCs. Also, there were 806 (40.3%) records after the onset of the pandemic, with 501 (62.2%) from the urban and 305 (37.8%) from the rural PHCs. There were some missing vaccine records with the least missed record being that of the birth dose vaccines (BCG, HBV0 and OPV0) at 6.0%, while measles and yellow fever vaccines had the highest missing values at 8.0%. Table 1 shows that overall, there were significantly less infants vaccinated after the COVID-19 pandemic onset for all vaccines except the birth dose vaccines and IPV. In table 2, the vaccination uptake was segregated according to the settlement type and more infants were vaccinated in the clinics located in the rural settings compared with the urban PHCs before the pandemic except OPV0 which had more uptake in urban settings (97.4% for urban clinics vs 92.0% for rural clinics). BCG uptake was not significantly different in both categories of clinics (95.5% for urban clinics and 100.0% for rural clinics). After the onset of the pandemic, a higher proportion of infants had birth dose vaccines in the urban clinics than the rural clinics but only OPV0 (97.5% for urban clinics vs 93.0% for rural clinics) was statistically significant. All other infant vaccinations were significantly taken in higher proportion at the rural clinics compared with the urban clinics.

Table 3 shows that the overall timeliness of every infant vaccine reduced significantly after the onset of the COVID-19 pandemic. Before the pandemic, the birth dose vaccines (BCG, OPV0 and HBV0) were timelier in the urban clinics than the rural ones as shown in table 4. Also, the vaccines given at 6 weeks (OPV1, PCV1 and PENTA1) were timelier in the rural than the urban clinics. There were no differences in the timeliness of the other vaccines between the two group of clinics. However, after the pandemic, every infant vaccine was timelier in the rural than the urban clinics, except the birth dose vaccines that remained timelier in the urban clinics. Figures 1 and 2 showed the pictorial view of how the timeliness of the BCG, PENTA3 and measles vaccines was before and after the onset of the COVID-19 pandemic for the rural and urban communities, respectively.

Table 1 Association between vaccine uptake and timing of COVID-19 pandemic onset*

| Vaccine | Uptake | Before COVID-19 onset n (%) | After COVID-19 onset n (%) | P value |
|---|---|---|---|---|
| BCG | No | 3 (0.3) | 3 (0.4) | 0.50 |
| | Yes | 1191 (99.7) | 683 (99.6) | |
| HBV0 | No | 84 (7.0) | 40 (5.8) | 0.31 |
| | Yes | 1110 (93.0) | 646 (94.2) | |
| OPV0 | No | 60 (5.0) | 30 (4.4) | 0.52 |
| | Yes | 1134 (95.0) | 656 (95.6) | |
| OPV1 | No | 184 (15.4) | 192 (28.4) | <0.01 |
| | Yes | 1010 (84.6) | 483 (71.6) | |
| PCV1 | No | 184 (15.4) | 192 (28.4) | <0.01 |
| | Yes | 1010 (84.6) | 483 (28.4) | |
| PENTA1 | No | 184 (15.4) | 191 (28.3) | <0.01 |
| | Yes | 1010 (84.6) | 484 (71.7) | |
| OPV2 | No | 268 (22.4) | 226 (33.9) | <0.01 |
| | Yes | 926 (77.6) | 440 (66.1) | |
| PCV2 | No | 268 (22.4) | 227 (32.0) | <0.01 |
| | Yes | 926 (77.6) | 440 (68.0) | |
| PENTA2 | No | 268 (22.4) | 228 (34.2) | <0.01 |
| | Yes | 926 (77.6) | 439 (65.8) | |
| OPV3 | No | 389 (32.6) | 336 (50.4) | <0.01 |
| | Yes | 804 (67.4) | 331 (49.6) | |
| PCV3 | No | 391 (32.8) | 336 (50.4) | <0.01 |
| | Yes | 801 (67.2) | 331 (49.6) | |
| PENTA3 | No | 393 (32.9) | 336 (50.4) | <0.01 |
| | Yes | 801 (67.1) | 331 (49.6) | |
| IPV | No | 607 (50.8) | 356 (53.4) | 0.29 |
| | Yes | 587 (49.2) | 311 (46.6) | |
| Measles | No | 648 (54.3) | 539 (81.7) | <0.01 |
| | Yes | 546 (45.7) | 121 (18.3) | |
| Yellow fever | No | 660 (55.3) | 572 (87.7) | <0.01 |
| | Yes | 533 (44.7) | 88 (13.3) | |

*There were some missing data.
HBV, hepatitis B vaccine; IPV, inactivated polio vaccine; OPV, oral polio vaccine; PCV, pneumococcal conjugate vaccine; PENTA, pentavalent vaccine.

Regarding vaccination completion, more infants in the rural clinics completed their vaccinations before (293 (54.8%) vs 11 (11.7%)) and after (72 (23.6%) vs 5 (1.0%)) the onset of the pandemic (p<0.01 in both cases) as shown in figure 3. The sex of the infants was not associated with the completion of vaccinations overall, before and after the onset of COVID-19 within each settlement.

## DISCUSSION

This study showed that the COVID-19 pandemic affected the uptake of infant vaccination in the study clinics, specifically, the timeliness and completion of the vaccines. There was also variation in these outcomes between the clinics located in the urban and rural communities. The general reduction in the number of infants who were vaccinated after the onset of the pandemic compared with before the pandemic was similar to reports from other countries.[16 24 30] These are important outcomes from this study that can guide infant vaccination policies and programmes in Nigeria to ensure optimal vaccination of infants. It is important to note that the data for this study were obtained from only one geopolitical zone in Nigeria which can limit the application of the results as there may be variations in the findings if data from the other five

**Table 2** Association between vaccine uptake and settlement type before and after the onset of the COVID-19 pandemic in Ibadan, Nigeria*

| | Before COVID-19 onset | | | | After COVID-19 onset | | | |
|---|---|---|---|---|---|---|---|---|
| | | Settlement type | | | | Settlement type | | |
| Vaccine | Uptake | Urban n (%) | Rural n (%) | P value | Uptake | Urban n (%) | Rural n (%) | P value |
| BCG | No | 3 (0.5) | 0 (0.0) | 0.06 | No | 3 (0.7) | 0 (0) | 0.07 |
| | Yes | 656 (95.5) | 535 (100.0) | | Yes | 398 (99.3) | 285 (100.0) | |
| OPV0 | No | 17 (2.6) | 43 (8.0) | <0.01 | No | 10 (2.5) | 20 (7.0) | <0.01 |
| | Yes | 642 (97.4) | 492 (92.0) | | Yes | 391 (97.5) | 265 (93.0) | |
| HBV0 | No | 44 (6.7) | 40 (7.5) | 0.59 | No | 21 (5.2) | 19 (6.7) | 0.43 |
| | Yes | 46 (93.3) | 495 (92.5) | | Yes | 380 (94.8) | 266 (93.3) | |
| OPV1 | No | 173 (26.3) | 11 (2.1) | <0.01 | No | 169 (43.3) | 23 (8.1) | <0.01 |
| | Yes | 485 (73.7) | 524 (97.9) | | Yes | 221 (56.7) | 262 (91.9) | |
| PCV1 | No | 173 (26.3) | 11 (2.1) | <0.01 | No | 169 (43.3) | 23 (8.1) | <0.01 |
| | Yes | 486 (73.7) | 524 (97.9) | | Yes | 221 (56.7) | 262 (91.9) | |
| PENTA1 | No | 173 (26.3) | 11 (2.1) | <0.01 | No | 168 (43.1) | 23 (8.1) | <0.01 |
| | Yes | 486 (73.7) | 524 (97.9) | | Yes | 222 (56.9) | 262 (91.9) | |
| OPV2 | No | 213 (32.3) | 55 (10.3) | <0.01 | No | 181 (47.5) | 45 (15.8) | <0.01 |
| | Yes | 446 (67.7) | 480 (89.7) | | Yes | 200 (52.5) | 240 (84.2) | |
| PCV2 | No | 213 (32.3) | 55 (10.3) | <0.01 | No | 182 (47.6) | 45 (15.8) | <0.01 |
| | Yes | 446 (67.7) | 480 (89.7) | | Yes | 200 (52.4) | 240 (84.2) | |
| PENTA2 | No | 213 (32.3) | 55 (10.3) | <0.01 | No | 182 (47.6) | 46 (16.1) | <0.01 |
| | Yes | 446 (67.7) | 480 (89.7) | | Yes | 200 (52.4) | 239 (83.9) | |
| OPV3 | No | 294 (44.7) | 95 (17.8) | <0.01 | No | 253 (66.1) | 83 (29.2) | <0.01 |
| | Yes | 364 (45.3) | 440 (82.2) | | Yes | 130 (33.9) | 201 (70.8) | |
| PCV3 | No | 296 (45.0) | 95 (17.8) | <0.01 | No | 253 (66.1) | 83 (29.2) | <0.01 |
| | Yes | 362 (55.0) | 439 (82.2) | | Yes | 130 (33.9) | 201 (70.8) | |
| PENTA3 | No | 298 (45.2) | 95 (17.8) | <0.01 | No | 253 (66.1) | 83 (29.2) | <0.01 |
| | Yes | 361 (44.8) | 440 (82.2) | | Yes | 130 (33.9) | 201 (70.8) | |
| IPV | No | 508 (77.1) | 99 (18.5) | <0.01 | No | 268 (70.0) | 88 (31.0) | <0.01 |
| | Yes | 151 (22.9) | 436 (81.5 | | Yes | 115 (30.0) | 196 (69.0) | |
| Measles | No | 433 (65.7) | 215 (40.2) | <0.01 | No | 333 (87.9) | 206 (73.3) | <0.01 |
| | Yes | 226 (34.3) | 320 (59.8) | | Yes | 45 (12.1) | 75 (26.7) | |
| Yellow fever | No | 439 (66.7) | 221 (41.3) | <0.01 | No | 366 (96.6) | 206 (73.3) | 0.92 |
| | Yes | 219 (33.3) | 314 (58.7) | | Yes | 13 (34) | 75 (26.7) | |

*There were some missing data.
HBV, hepatitis B vaccine; IPV, inactivated polio vaccine; OPV, oral polio vaccine; PCV, pneumococcal conjugate vaccine; PENTA, pentavalent vaccine.

geopolitical zones were considered. Also, the data were only from PHCs' records. Those from the secondary and tertiary health facilities may give different results. However, the PHCs are the main access for infant vaccination in Nigeria which makes the data used in this study to be appropriate and important. Despite these limitations, this study presents findings from a large number of vaccination records that spanned over 2 critical years, and brought to fore the details of how the COVID-19 pandemic affected infant vaccination uptake. The study also moved from the traditional focus of just vaccination coverage to vaccination timeliness and completion which are required for optimal vaccination. The comparison of the data between rural and urban clinics added more insights into the peculiarities of the clinic settings as well.

Nigeria was one of the nine countries in Africa where the monthly data of infants who received DPT3 and the first measles-containing vaccine dipped by more than 2 SDs in the second quarter of 2020.[21] This decline in Nigeria was specifically attributed to the difficulty of accessing the vaccination clinics because of the government-instituted movement restrictions,[4] as well as reduction in vaccine

Table 3 Overall timeliness of infant vaccination 1 year before and after the onset of the COVID-19 pandemic in Ibadan, Nigeria*

| Vaccine | Timeliness | Timing in relation to COVID-19 pandemic onset: Before n (%) | After n (%) | P value |
|---|---|---|---|---|
| OPV0 | Delayed | 146 (12.4) | 53 (6.7) | <0.01 |
| | Timely | 1030 (87.6) | 737 (93.3) | |
| HBV0 | Delayed | 139 (11.9) | 50 (6.4) | <0.01 |
| | Timely | 1031 (88.1) | 729 (93.6) | |
| BCG | Delayed | 137 (11.5) | 55 (6.9) | <0.01 |
| | Timely | 1056 (88.5) | 744 (93.1) | |
| OPV1 | Delayed | 150 (13.8) | 143 (23.0) | <0.01 |
| | Timely | 940 (86.2) | 478 (77.0) | |
| PCV1 | Delayed | 149 (13.7) | 143 (23.1) | <0.01 |
| | Timely | 941 (86.3) | 477 (76.9) | |
| PENTA1 | Delayed | 149 (13.7) | 143 (23.1) | <0.01 |
| | Timely | 941 (86.3) | 477 (76.9) | |
| OPV2 | Delayed | 206 (19.8) | 157 (27.6) | <0.01 |
| | Timely | 834 (80.2) | 412 (72.4) | |
| PCV2 | Delayed | 206 (19.8) | 159 (27.9) | <0.01 |
| | Timely | 834 (80.2) | 411 (72.1) | |
| PENTA2 | Delayed | 206 (19.8) | 159 (27.9) | <0.01 |
| | Timely | 834 (80.2) | 411 (72.1) | |
| OPV3 | Delayed | 227 (23.5) | 206 (40.4) | <0.01 |
| | Timely | 737 (76.5) | 304 (59.6) | |
| PCV3 | Delayed | 228 (23.7) | 206 (40.4) | <0.01 |
| | Timely | 736 (76.3) | 304 (59.6) | |
| PENTA3 | Delayed | 229 (23.8) | 206 (40.5) | <0.01 |
| | Timely | 732 (76.2) | 303 (59.5) | |
| IPV | Delayed | 293 (35.2) | 224 (46.5) | <0.01 |
| | Timely | 540 (64.8) | 258 (53.5) | |
| Measles | Delayed | 266 (41.1) | 266 (73.9) | <0.01 |
| | Timely | 381 (58.9) | 94 (26.1) | |
| Yellow fever | Delayed | 272 (42.2) | 283 (79.1) | <0.01 |
| | Timely | 373 (57.8) | 75 (20.9) | |

*There were some missing data.
HBV, hepatitis B vaccine; IPV, inactivated polio vaccine; OPV, oral polio vaccine; PCV, pneumococcal conjugate vaccine; PENTA, pentavalent vaccine.

confidence by both healthcare workers and community dwellers.[31] The lack of confidence was from misinformation about the pandemic and the concerns about safety from contracting the COVID-19 infection from clinic settings. This was similarly reported in the UK.[32] There was however no significant reduction in the uptake of the birth dose vaccines in this study. There were similar reports from other countries like Iraq,[16] Malawi, Haiti, Lesotho and Liberia where BCG uptake was not affected by the pandemic.[14] This was however contrary to the report from Pakistan where the BCG vaccine had the highest dip among vaccines given to infants.[15] The maintenance of the birth dose vaccines in the study communities may be because the infants could easily be vaccinated since the mothers were more likely to still be on admission in the healthcare facility for hours post-delivery, thereby removing the barrier of physical access to the vaccination clinic. It may also be due to the social support that mothers of new infants enjoy in the study area from people in their social circle, who could assist with the infants' vaccination.

**Table 4** Association between vaccine timeliness and settlement type 1 year before and 1 year after the onset of the COVID-19 pandemic in Ibadan, Nigeria*

| | Before COVID-19 onset | | | | After COVID-19 onset | | | |
|---|---|---|---|---|---|---|---|---|
| | | Settlement type | | | | Settlement type | | |
| Vaccine | Timeliness | Urban n (%) | Rural n (%) | P value | Timeliness | Urban n (%) | Rural n (%) | P value |
| BCG | Delayed | 97 (14.7) | 40 (7.5) | <0.01 | Delayed | 35 (7.1) | 20 (6.6) | 0.76 |
| | Timely | 561 (85.3) | 495 (92.5) | | Timely | 459 (92.9) | 285 (93.4) | |
| OPV0 | Delayed | 97 (14.9) | 49 (9.3) | <0.01 | Delayed | 30 (6.2) | 23 (7.6) | 0.43 |
| | Timely | 552 (85.1) | 478 (90.7) | | Timely | 457 (93.8) | 280 (92.4) | |
| HBV0 | Delayed | 90 (14.0) | 49 (9.3) | <0.01 | Delayed | 26 (5.5) | 24 (7.9) | 0.17 |
| | Timely | 553 (86.0 | 478 (90.7) | | Timely | 451 (94.5) | 278 (92.1) | |
| OPV1 | Delayed | 107 (19.3) | 43 (8.0) | <0.01 | Delayed | 120 (36.3.) | 23 (7.9) | <0.01 |
| | Timely | 448 (80.7) | 492 (92.0) | | Timely | 211 (63.7) | 267 (92.1) | |
| PCV1 | Delayed | 106 (19.1) | 43 (8.0) | <0.01 | Delayed | 120 (36.3) | 23 (8.0) | <0.01 |
| | Timely | 449 (80.9) | 492 (92.0) | | Timely | 211 (63.7) | 266 (92.0) | |
| PENTA1 | Delayed | 106 (19.1) | 43 (8.0) | <0.01 | Delayed | 119 (36.0) | 24 (8.3 | <0.01 |
| | Timely | 449 (80.9) | 492 (92.0) | | Timely | 212 (64.0) | 265 (91.7) | |
| OPV2 | Delayed | 108 (21.1) | 98 (18.6) | 0.32 | Delayed | 99 (34.4) | 58 (20.6) | <0.01 |
| | Timely | 405 (78.9) | 429 (81.4) | | Timely | 189 (65.6) | 223 (79.4) | |
| PCV2 | Delayed | 108 (21.1) | 98 (18.6) | 0.32 | Delayed | 100 (34.7) | 59 (20.9 | <0.01 |
| | Timely | 405 (78.9) | 429 (81.4) | | Timely | 188 (65.3) | 223 (79.1) | |
| PENTA2 | Delayed | 108 (21.1) | 98 (18.6) | 0.32 | Delayed | 101 (35.1) | 58 (20.6) | <0.01 |
| | Timely | 405 (78.9) | 429 (81.4) | | Timely | 187 (64.9) | 224 (79.4) | |
| OPV3 | Delayed | 102 (23.0) | 125 (24.0) | 0.61 | Delayed | 132 (52.8) | 74 (28.5) | <0.01 |
| | Timely | 341 (77.0) | 396 (76.0) | | Timely | 118 (47.2 | 186 (71.5) | |
| PCV3 | Delayed | 102 (23.0) | 126 (24.2) | 0.67 | Delayed | 132 (52.8) | 74 (28.5) | <0.01 |
| | Timely | 341 (77.0) | 395 (75.8) | | Timely | 118 (47.2) | 186 (71.5) | |
| PENTA3 | Delayed | 103 (23.4) | 126 (24.2) | 0.78 | Delayed | 132 (53.0) | 74 (28.5) | <0.01 |
| | Timely | 337 (76.6) | 395 (75.8) | | Timely | 117 (47.0 | 186 (71.5) | |
| IPV | Delayed | 167 (53.5) | 126 (24.2) | <0.01 | Delayed | 149 (66.2) | 75 (29.2 | <0.01 |
| | Timely | 145 (46.2) | 395 (75.8) | | Timely | 76 (33.8) | 182 (70.8) | |
| Measles | Delayed | 143 (42.9) | 123 (39.2) | 0.33 | Delayed | 161 (84.7 | 105 (61.8 | <0.01 |
| | Timely | 190 (57.1) | 191 (60.8) | | Timely | 29 (15.3) | 65 (38.2) | |
| Yellow fever | Delayed | 147 (44.5) | 125 (39.7) | 0.21 | Delayed | 177 (94.1) | 106 (62.4) | <0.01 |
| | Timely | 183 (55.5) | 190 (60.3) | | Timely | 11 (5.9) | 64 (37.6) | |

*There were some missing data.
HBV, hepatitis B vaccine; IPV, inactivated polio vaccine; OPV, oral polio vaccine; PCV, pneumococcal conjugate vaccine; PENTA, pentavalent vaccine.

The decline in infant vaccination uptake was reported to be worse in low- and middle-income countries (LMICs) compared with developed countries[33] which may be due to the fragile health systems that the earlier countries have. For example, some developed countries introduced drive-through vaccination centres to reduce contact with people, while some rescheduled appointments to be able to reduce the number of infants presenting at the clinics each time and some redeployed more staff to vaccination clinics.[34 35] These strategies were not feasible in many LMICs as shortages of healthcare workers, heavy clinic schedules and more difficult transportation systems were the order of the day before the onset of the COVID-19 pandemic.

The decrease in infant vaccination uptake however did not persist but was reversed before the end of 2020 in some countries, specifically in Malawi, Haiti, Lesotho, Liberia[14] and the USA (Southern California).[36] This was not the case among the infants from the studied clinics just as reported from France.[37] This underscores the importance of this study which clearly showed that the apathy for infant vaccination had persisted months after

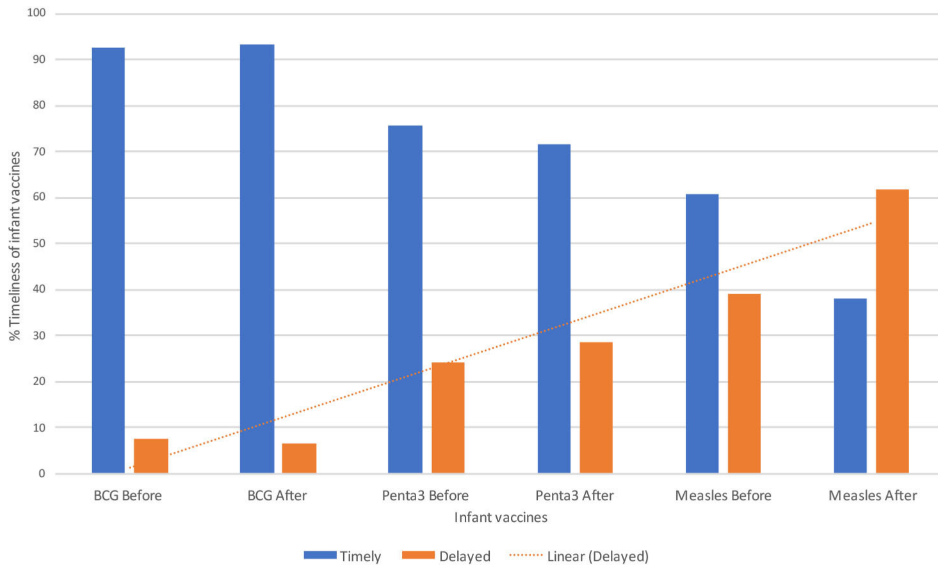


**Figure 1** Infant vaccination timeliness 1 year before and 1 year after the onset of the COVID-19 pandemic in rural communities in Ibadan, Nigeria. Penta, pentavalent vaccine.

the onset of the pandemic. It is therefore imperative to take actions to reverse this trend as Nigeria has made a lot of investments to improve and support infant vaccination in the last few decades. There is a need to be back on track with this improvement.

Generally, infant vaccination coverage has been shown to be better in urban areas compared with the rural ones in Nigeria.[38] This study however showed that a higher proportion of infants were vaccinated in the rural areas for each vaccine (except for the birth dose vaccines) compared with the urban areas before the onset of the pandemic just as reported in an earlier study.[39] This could be because of the concerted efforts to improve vaccination coverage in the rural areas over the years. It could also be because of the urban slum vaccination coverage which is usually abysmally low. This could have reduced the aggregate vaccination coverage in the urban areas. A meta-analysis of vaccination coverage in African countries has reported that the difference between vaccination coverage in rural and urban areas was not significant but there were variations among countries.[24] Disaggregating data from urban areas may provide more details about this coverage and this can help in infant vaccination management.

After the onset of the COVID-19 pandemic, a higher proportion of infants in the rural areas still had their vaccines (except the birth dose vaccines) compared with infants from the urban areas. A similar report by Alhaddad *et al* from Iraq showed that infants from the rural areas were two times likely to take DPT3 compared with infants from urban areas during the pandemic.[16] Reports from Pakistan also showed that there was more

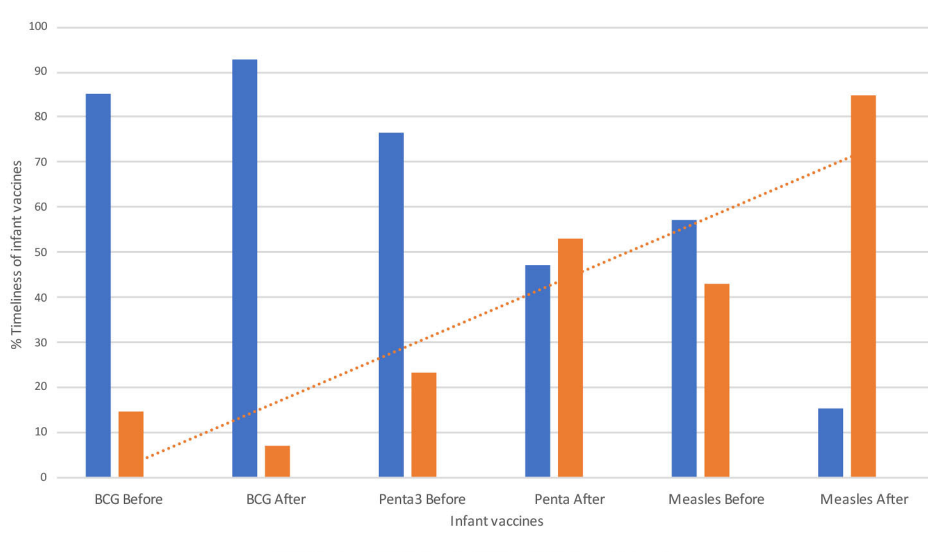


**Figure 2** Infant vaccination timeliness 1 year before and 1 year after the onset of the COVID-19 pandemic in urban communities in Ibadan, Nigeria. Penta, pentavalent vaccine.

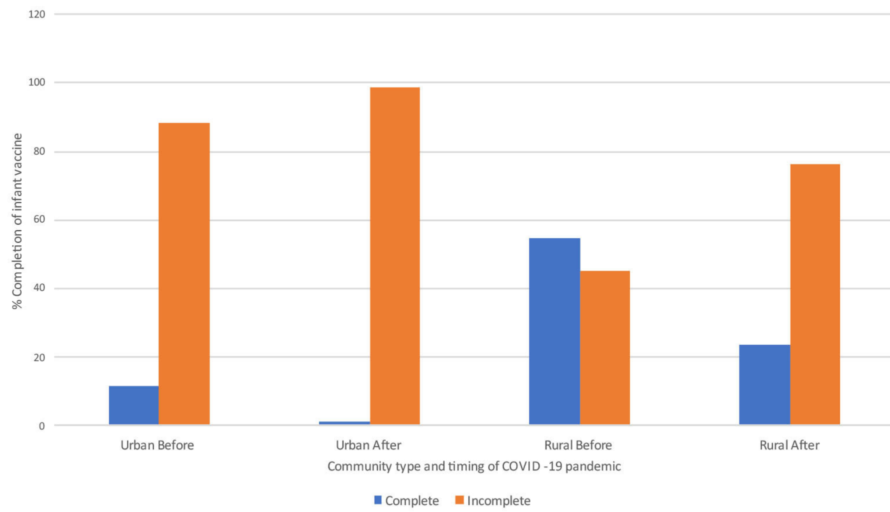


**Figure 3** Completion of infant vaccination 1 year before and 1 year after the onset of the COVID-19 pandemic in selected communities in Ibadan, Nigeria.

enrolment of infants for vaccination after the lockdown in the rural areas and urban slums compared with the urban areas.[15] This may be due to the stricter measures to reduce movement in the urban areas compared with the rural ones. Also, a lot of misinformation was spread in the urban areas on different social media which is likely to be more in urban areas due to the higher proportion of access to smart phones. This however was not supported by a study among African countries that reported that higher spread of misinformation was in the rural areas during the pandemic.[25] The other plausible reason is that those in urban areas have alternative source of vaccination like secondary, tertiary and privately owned health facilities where they can continue infant vaccination after the initial dose. This is however difficult to verify because there is no electronic record base for infant vaccination currently in Nigeria, making harmonisation of the records impossible.

Delay in vaccination is a form of vaccine hesitancy[40] because it can be a precursor for incomplete vaccination and the window of delay exposes the child to infection by vaccine-preventable diseases (VPDs). Vaccination delay is also a threat to herd immunity. Almost every vaccine (except birth dose and yellow fever vaccines) was timelier among the rural infants. This could be because of the distractions that the mothers in the urban areas experience from being employed (especially those working outside the home) and the reduced social support they have compared with the mothers in the rural areas. These could result in delay of infant presentation for vaccination. The reduced timeliness can also explain the reduction in completion rate of infant vaccination, and this worsened after the onset of the pandemic. The reason for this disparity in vaccine timeliness needs further research to adequately understand the problem.

The obvious negative effects of the COVID-19 pandemic in the study clinics were reduced timeliness and completion of infant vaccination. It is very important to take steps to address these problems as it has persisted. The recent outbreak of diphtheria in Nigeria may be connected to these vaccination problems just like the measles outbreak that resulted from the waning of vaccination programmes in some West African countries following the Ebola outbreak.[41] First, it is important to carry community stakeholders along regarding these identified problems.[42] They can pass the message to the populace effectively to get all stakeholders on board and information about vaccine safety should be resounded to improve vaccine confidence. Second, catch-up campaigns, specifically to identify children who have missed their vaccines, should be commenced with the full involvement of the stakeholders in its planning and execution.[43] Third, additional healthcare workers should be hired, and more vaccination clinics are required for adequate coverage if the catch-up campaigns are to be successful.[44] The challenge however is that more funding will be required to make these happen amid other competing health programmes in the country. Also, the ongoing brain drain from healthcare workers seeking greener pastures in developed countries is a threat to these strategies.

In conclusion, the COVID-19 pandemic significantly reduced infant vaccination uptake, timeliness and completion among communities in Ibadan, and the urban communities were most affected. Programmes to identify children who missed their vaccination and ensure catch-up are necessary to forestall the outbreak of VPDs. There should be full involvement of all relevant stakeholders to ensure the success of these programmes.

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**Contributors** AAA and FMB conceptualised and designed the study. AAA supervised the data collection process while FMB analysed the data. Both authors interpreted the results, wrote the manuscript and approved its final draft. FMB is the guarantor and takes full responsibility for the overall content of the manuscript.

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**Patient consent for publication** Not applicable.

**Ethics approval** The study protocol was approved by the Oyo State Ethics Research Committee (AD13/479/2433). Permission to access the vaccination records was obtained from the Oyo State Primary Healthcare Board and the Medical Officers of Health of both Ibadan Southeast and Olúyòlé local government areas.

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**Data availability statement** Data are available in a public, open access repository. The dataset for this study can be found in the Mendeley Data (DOI: 10.17632/n4w7kcyvpk.2).



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