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Research Article

Diphtheria Vaccination Coverage and Correlation with Multidimensional Poverty among Children in Nigeria: A Correlational Study from Multiple Indicator Cluster Survey and National Immunization Coverage Survey 2021

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ABSTRACT

Introduction: Nigeria has witnessed recurrent outbreaks of diphtheria in recent time. This study measured the prevalence of DPT vaccination coverage among children aged 12-23 months and its correlation with Multidimensional Poverty Index (MPI) across the 36 Nigeria's states and the federal capital territory.

Methods: State-level data for DPT vaccination coverage rates and multidimensional poverty index were obtained from the 2021 Multiple Indicator Cluster Survey (MICS)/National Immunization Cluster Survey (NICS) and Nigeria Bureau of Statistics respectively. The correlation between MPI and diphtheria vaccination coverage was examined using SPSS V.28 and alpha level was set to 0.05.

Results: DPT vaccination coverage among children aged 12-23 months is suboptimal at 56%. DPT full vaccination coverage is higher in Southern states than Northern states; all states with ≥ 80% coverage are in Southern Nigeria while all states with ≤ 50% coverage are in Northern Nigeria, except for Ogun state (41.3%). Partial DPT vaccination is also higher among Northern states, with Borno State having the highest partial DPT vaccination rate at 27.8%, while Ebonyi State had the lowest (0.4%). States with higher multidimensional poverty index had higher proportions of partially vaccinated and unvaccinated children. There is a statistically significant negative correlation between multidimensional poverty index and DPT full vaccination coverage ($r=-0.534$, $P \leq 0.001$).

Conclusion: DPT vaccination coverage is still low in Nigeria. Northern States had lower vaccination coverage than Southern States. There is a significant negative correlation between DPT vaccination coverage and multidimensional poverty index. This study calls for implementing effective strategies to improve vaccination coverage at a national level, while focusing on States with high levels of multidimensional poverty.

Keywords: Diphtheria; Public health emergency; Nigeria; *Corynebacterium diphtheriae*; Exotoxin; Nigerian Center for Disease Control and Prevention; World Health Organization; UNICEF-Nigeria

Abbreviations: RABV: Rabies Virus; EMA: European Medicines Agency; VAERS: Vaccine Adverse Event Reporting System

INTRODUCTION

Diphtheria constitutes a public health emergency of humongous scale in Nigeria, given its recurrent outbreaks. It is caused by Corynebacterium diphtheriae through the production of an exotoxin that is highly contagious and potentially fatal. The most recent diphtheria outbreak in Nigeria started in December 2022 when the Nigerian Center for Disease Control and Prevention (NCDC) was notified of a suspected diphtheria outbreak in Lagos and Kano states, the most populous states and economic centers based on World Health Organization [1].

As of October 3, 2023, there were 13,204 suspected cases and 8406 confirmed cases [2]. As of September 25, 2023, there were

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453 recorded deaths, accounting for a case-fatality rate of 6.3% [2]. About 73.7% of confirmed cases were among children aged 2-14 years, and 64% of confirmed cases occurred among individuals who were not fully vaccinated for diphtheria [3]. Similarly, the previous diphtheria outbreaks in 2011 had occurred in Borno state, and approximately 64% of its cases were among children aged <10 years, and 98% of cases were among individuals who have never been vaccinated against diphtheria [4].

Diphtheria vaccine is available through a DPT (diphtheria, pertussis, and tetanus) vaccine, which is part of the National Program on Immunization (NPI) in Nigeria. However, its vaccination coverage rate remains suboptimal, with a national coverage of 57% as per the Multiple Indicator Cluster Survey (MICS) that was conducted by the Nigerian National Bureau of Statistics (NBS) and the United Nations International Children's Emergency Fund (UNICEF) in 2021 [5,6]. Generally, diphtheria has a variable case-fatality rate that can be as high as 40% in areas with high poverty levels [1]. According to the Nigerian Bureau of Statistics (NBS) data on multidimensional poverty, states such as Kano, Katsina, Bauchi, Kaduna, Borno, and Yobe, where diphtheria outbreaks occurred, have scored high on Multidimensional Poverty Index (MPI) [7]. MPI is defined as "an index that measures the percentage of households in a country deprived along three dimensions monetary poverty, education, and basic infrastructure services to capture a more complete picture of poverty" World Bank, 2023. Therefore, it reflects people's lived experiences beyond the dimension of income alone [8,9]. To our knowledge, no attempt has been made to examine the diphtheria vaccination coverage in the context of multidimensional poverty in Nigeria. Prior studies have mainly described outbreaks [10], assessed diphtheria vaccine coverage [11,12], and factors associated with the vaccine uptake [13,14]. Similarly, previous studies examined DPT coverage pre-COVID-19 pandemic [12,15] This research aims to;

- Measure the crude and state-specific DPT vaccination coverage during COVID-19 pandemic in Nigeria (36 States and the Federal Capital Territory).
- Examine the correlation between diphtheria vaccination coverage and Multidimensional poverty score.

MATERIALS AND METHODS

Study population

Nigeria is a lower middle-income country, Africa's largest economy and most populous black nation. With an estimated population of 225 million people, Nigeria is the sixth most populous country on the earth, with a median age of 17.2 years [16]. Nigeria has a predominantly young population with approximately half of its population being less than 19 years old [17]. Levels of poverty and literacy varies among Nigerian states, but the Northern states generally have lower literacy and higher poverty levels [18]. Nigeria operates three levels of healthcare delivery, namely: primary, secondary, and tertiary. The primary and secondary levels of healthcare delivery are majorly responsible for vaccine administration; however, tertiary centers have joined to boost vaccine delivery among the population.

Design and data sources

This is a correlational (ecological) study to test the correlation between multidimensional poverty and diphtheria vaccination coverage. Data about multidimensional poverty was obtained from the NBS that computes data on multidimensional poverty index, considering the various dimensions in which Nigerians are deprived, including monetary, educational, and health dimensions across the thirty-six states of Nigeria and the federal capital territory.

Data about DPT vaccination coverage among children aged 12-23 months was obtained from the 2021 Multiple Indicator Cluster Survey and National Immunization Coverage Survey (NICS) report that was co-developed by the NBS and UNICEF [5]. The vaccination coverage estimates were generated using the World Health Organization's Vaccination Coverage Quality Indicator software. This data provides information about the proportion of children aged 12-23 months who have partially or fully completed the DPT vaccine doses in each state in Nigeria.

Sampling

The 2021 MICS used a multi-stage, stratified cluster sampling method to select the sample. The sampling frame was based on Nigeria's 2006 Population and Housing Census. The 36 States of Nigeria and the Federal Capital Territory were the sampling strata, making a total of 37 strata. Each stratum was divided into enumeration areas (EAs), that were further divided into households. At the first sampling stage, a systematic random sampling was used to select the EAs clusters from the list of EAs in each Local Government Area (LGA). In the second sampling stage, a listing of households in each EA was made, and samples of households were selected, using probability proportional to size sampling.

The sample size for the 2021 MICS was calculated to be 1,850 clusters (50 clusters in each state) with 37,000 households (1,000 households from each state). To increase the number of children in the sample and improve the accuracy of the immunization indicators, an additional sample of 337 clusters with 6,740 households was added from the National Immunization Coverage Survey. A total of 128 EAs (MICS=95, NICS=33) were politically inaccessible, and therefore were not included. Overall, the final sample size was 201,942 participants, 29,409 of them were children under the age of 5 years, of which 5652 were in the age category 12 to 23 months. Hence, the final sample size for the current study was 5652 children.

Data collection

Standard MICS questionnaires were administered, and data were collected using the Computer-Assisted Personal Interviewing (CAPI) device. The interviewers asked the mothers or caretakers to show them the vaccination cards that the children received from health facilities. They recorded the vaccination information from the cards into the MICS questionnaire. If the child did not have a vaccination card, the interviewer asked the mother to remember if the child had received each of the vaccinations and how many doses for each one. The response rate among the households in the sample was 98.9% [5].

The survey protocol was approved by the Steering and Review Committees of the NBS in August 2021. The protocol outlined potential risks and strategies to mitigate these risks if they arise. In addition to verbal consent, written assents from children aged 15-17 years old and parental consents were obtained.

Study measures

Diphtheria vaccination: The main outcome for this study is the Diphtheria vaccination coverage. It is defined as the percentage of individuals 12-23 years who were fully vaccinated (have received the DPT1, DPT2, and DPT3 doses) in each geographical state in

Nigeria. Since DPT3 is the last dose of the vaccines, DPT3 coverage rate in this study was used to indicate the proportion of children who completed the vaccines. In this sample, State level Diphtheria full vaccination coverage was measured by the number of children aged 12-23 months who have received the DPT3 vaccine divided by the number of children within that age group in each State. On the other hand, the percentage of children who received their first dose of diphtheria was measured by the number of children aged 12-23 months who have received the DPT1 vaccine divided by the number of children within that age group in each State. Incomplete or partial vaccination was measured by the percentage of children who took less than three doses of DPT, and was calculated by subtracting the percentage of children who received DPT3 from the percentage of children who took DPT1 dose. The percentage of unimmunized children was calculated as 1-the percentage of children who took DPT1 dose.

Multidimensional poverty: The MPI reflects the various deprivations that poor people face regarding health, education, and living standards in Nigeria. MPI was first developed by the United Nations Development Program (UNDP) and Oxford University, using distinct indicators that encompass the three dimensions of deprivations-health, education, and living standards. The Nigerian Bureau of Statistics uses fifteen distinct indicators to examine different areas in which people may experience deprivations. The indicators include nutrition, food security, time to healthcare, school attendance, and years of schooling, school tag, water, water reliability, sanitation, housing materials, cooking fuel, assets, unemployment, underemployment, and security shock.

MPI=Incidence (H) X Intensity (A)

Incidence (H) is the percentage of people who are poor, or the headcount poverty ratio, while Intensity (A) is the average percentage dimensions in which poor people experience deprivation [19]. A person or individual is said to be multidimensionally poor if they experience 30% or more of the weighted deprivations on 0-1 MPI scale.

Data analysis

Categorical variables were summarized using frequency measures and continuous variables were summarized using mean and standard deviation. The overall average vaccination coverage in Nigeria was calculated as the weighted average vaccination coverage in all states. Correlation analysis was used to examine the relationship between states DPT full vaccination coverage rates and their corresponding MPI scores. All statistical analyses were done using SPSS version 28. Alpha level was set to 0.05.

The 2021 MICS sample is not self-weighted, as different sampling fractions were applied in each state. To ensure accurate representation, weights were calculated based on sampling fraction, non-response rates, and adjustment factor for each state (stratum). Details about weight calculations can be found elsewhere [5].

RESULTS

The survey included 5652 children between 12 and 23 months old, of which 2861 (50.6%) were males and 2791 (49.3%) were females. In overall, the percentage of children who received at least one dose of DPT vaccine was 70.3%, of which 80.5% completed the three vaccine doses, 11.4% completed two doses and 8.1% completed only one dose. In overall, 56% of the surveyed children have completed the three doses of DPT vaccine (fully vaccinated). The percentage of children who received partial DPT vaccination by taking only the first or first and second dose was 13.7% details in Figure 1.

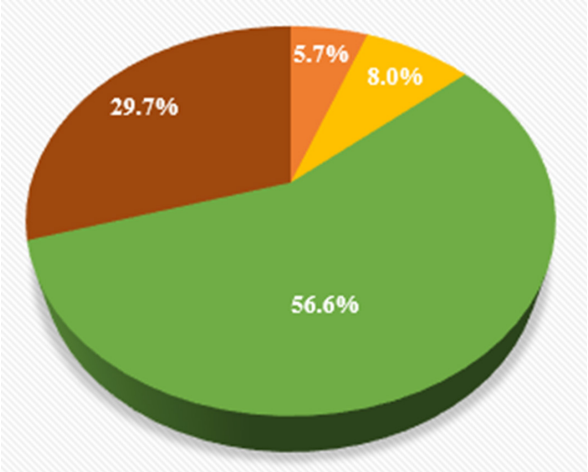

Figure 1: DPT Vaccination coverage status among children (12-23 months) in Nigeria from 2021 multiple indicator cluster survey and national immunization coverage survey. **Note:** (●) Brown-29.7%-unvaccinated,(●): orange: 5.7%-practically vaccinated DPT1 only, (●): yellow-8.0%-partially vaccinated DPT1 and 2only, (●)green: 56.6%-fully vaccinated.

As Figure 2 shows, DPT full vaccination coverage rate in 2021 varies across Nigerian states. The seven states that had 80% full DPT coverage rate or higher were Ebonyi, Enugu, Imo, Ekiti, Lagos, Edo, and Osun, while those with less than 50% full coverage were, Sokoto, Zamfara, Borno, Bauchi, Gombe, Niger, Katsina. The Federal Capital Territory has a DPT full coverage of 79.6%. Ebonyi state has the highest DPT full vaccination coverage (98.7%) while Sokoto state has the lowest (11.5%).

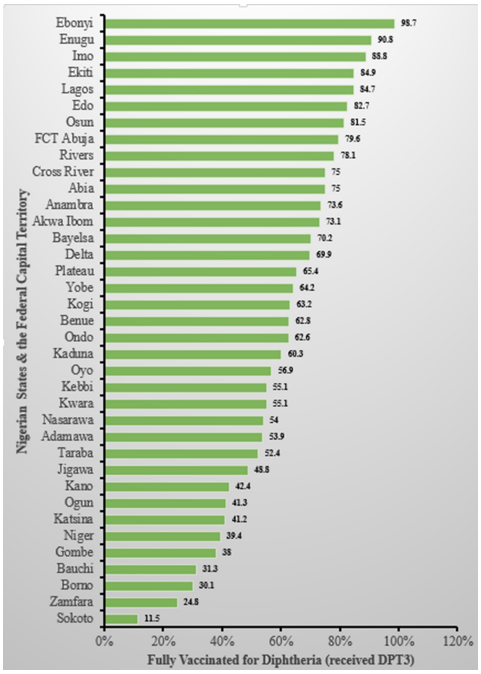

Figure 2: Full diphtheria vaccination coverage rate (dpt3)* across Nigerian states among ages 12-23 months, from 2021 multiple indicator cluster survey/national immunization coverage survey.

Findings regarding un-vaccination showed that Ebonyi (0.9%) and Enugu (1.5%) had the lowest un-vaccination rates, while Sokoto

had the highest (71.2%). Similarly, Ebonyi had the lowest partial (i.e., received less than three doses of DPT) vaccination rates (0.4%), and Borno had the highest (27.8%). Borno, Ogun, Kogi, Niger, and Adamawa States had the highest partial DPT vaccination rates, while Ebonyi, Kebbi, Imo, Bayelsa, and Enugu had the lowest (Figure 3).

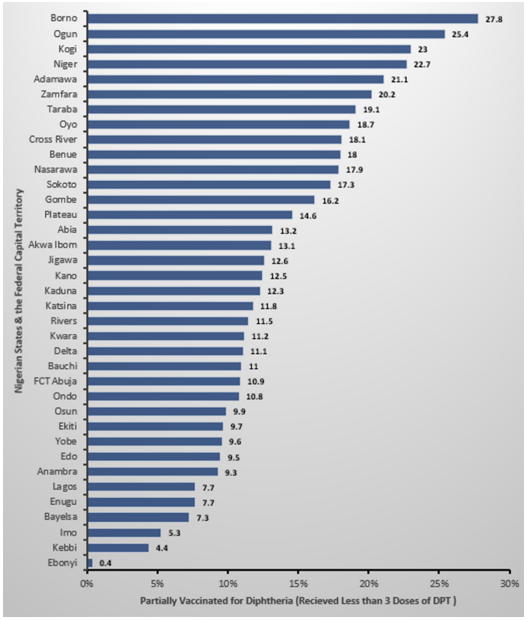

Figure 3: DPT Partial vaccination rates across Nigerian states among ages 12-23 months, from 2021 multiple indicator cluster survey/ national immunization coverage survey.

As Figure 4 showed, multidimensional poverty index was the highest in Sokoto, Bayelsa, Jigawa, Kebbi, and Gombe, and the lowest was in Ondo, Lagos, Abia, Anambra, and Ekiti States. These States with lower MPI had lower proportion of unvaccinated and partially vaccinated children. However, Ebonyi State, despite having a high MPI, had the lowest rate of unvaccinated and partially vaccinated children.

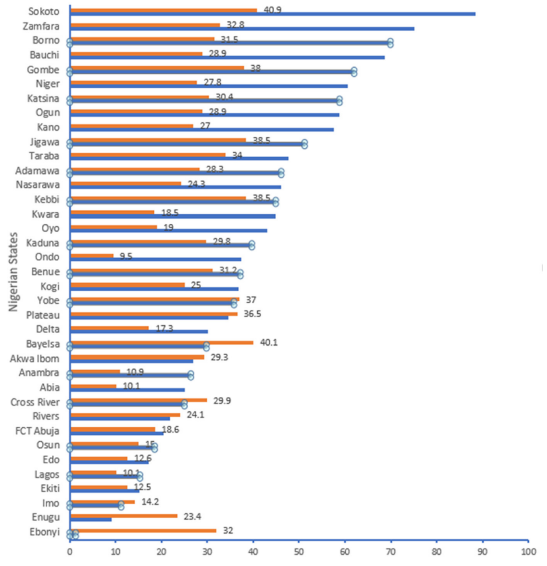

Figure 4: The percentage of children 12-23 months who did not receive or partially received the DPT vaccine and the multidimensional poverty index across the Nigerian states 2021 from multiple indicator cluster survey and national immunization coverage "s". **Note:** (■): DPT unvaccinated or partially vaccinated in percentage, (■): Multidimensional poverty index in percentage.

Figure 5 showed the correlation between DPT full coverage and multidimensional poverty index. There was a statistically significant moderate negative correlation between DPT full vaccination coverage and multidimensional poverty Index (r=-.534, P ≤ 0.001).

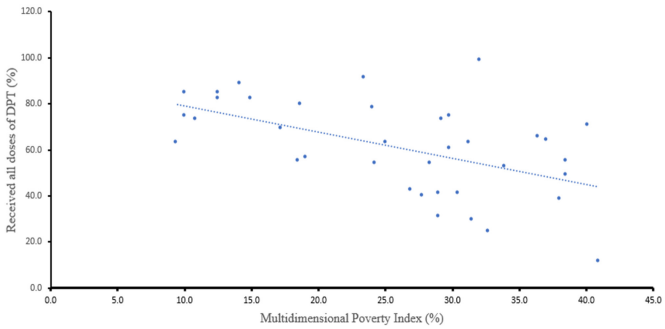

Figure 5: Correlation between dpt3 vaccination rate and multidimensional poverty index among children 12-23 months across Nigerian states from multiple indicator cluster survey and national immunization coverage survey (2021).

DISCUSSION

In overall, 56% of the surveyed children have completed the three doses of DPT vaccine (fully vaccinated). The percentage of children who received at least one dose of the DPT vaccine was 70.3%, of which 80.5% completed the three DPT vaccine doses. The highest DPT full coverage was in Ebonyi, Enugu, Imo, Ekiti, Lagos, Edo, and Osun States, while the lowest was in Sokoto, Zamfara, Borno, Bauchi, Gombe, Niger, Katsina States. Multidimensional poverty index was the highest in Sokoto, Bayelsa, Jigawa, Kebbi, and Gombe, while the lowest in Ondo, Lagos, Abia, Anambra, and Ekiti States. In addition, multidimensional poverty index was negatively correlated with DPT full vaccination coverage. These findings indicate a suboptimal DPT coverage rate during the COVID-19 pandemic across Nigeria's thirty-six States and the federal capital territory, which requires an immediate intervention to improve DPT vaccination coverage to curb the diphtheria recurrent epidemics.

This study finding of suboptimal DPT vaccination coverage among Nigerian children was consistent with previous studies that revealed low vaccination coverage among children in Nigeria [20-22]. The factors highlighted as possible reasons for the low coverage of vaccination in Nigeria included vaccine safety concerns, low maternal education, and poor information about vaccines [21]. Over time, there have been concerns and misconceptions about vaccine safety as some caregivers have attributed vaccine to development of ricket in children and reduced reproductive potential when children become older [23]. The fear that vaccines may result into infertility in adulthood is popular myth that scares the guardians from the vaccines. Previous research indicated poor knowledge regarding vaccine-preventable diseases among the Nigerian mothers from Enugu State [24]. Poor knowledge may also explain the partial vaccination coverage in the States with high partial vaccination coverage as people may not be aware of the importance of completing the vaccine doses.

This study showed variations in DPT vaccination coverage by States. Higher vaccination coverage was observed in Southern than Northern Nigeria's States. These North-South vaccination coverage disparities in Nigeria were previously reported for other national vaccines including Bacillus Calmete-Guerin, measles vaccines,

and oral polio vaccine [25,26]. These variations were previously attributed to socioeconomic status, lower levels of educational attainment, deprivations in health care access, higher levels of insecurity, and lower vaccine literacy [25-29].

Additionally, the interrupted health care access due to the political insecurity and conflicts in the Northern part of Nigeria [30,31] may interpret the difference in vaccination coverage between the two regions. Based on anecdotal evidence, people who live in the Northern States such as Moslems and Fulani had low vaccination coverage rates [23,25,32]. This may in part interpret the recurrent outbreak of vaccine-preventable diseases in those areas [29].

While previous research had investigated the vaccination coverage in the context of socioeconomic factors [33-35] this study was unique in using the multidimensional poverty index as a sustainable development construct that measures various deprivations that people experience and accounts for all those factors. Poor households for instance had higher odds of being unvaccinated or receiving partial vaccination [36]. Similarly, children for parents with higher educational level and income had higher vaccination coverage than those for lower education [22,37-39]. Additionally, accessibility to and affordability of healthcare are more likely to be lower among people with lower socioeconomic class [22] and this may contribute to low vaccination coverage in general [20].

The findings of this study have implications on immunization program planning and implementation in Nigeria. Interventions to scale up vaccination coverage must be multidimensional, accounting for the deprivations that Nigerians encounter in terms of access to health, education, and living standards. There should be an improvement in vaccine education among caregivers since many of them were found to have insufficient knowledge of the importance of vaccination [34]. Additionally, inaccessible roads and long travel time are among the strong factors that may disrupts the vaccination clinics attendance [33]. Improving road networks, widening vaccination networks, and using mobile vaccination service may improve access to vaccination and increase coverage in Nigeria. Since religion has been highlighted as a strong factor for vaccination, it might be helpful if the Nigerian government partners with religious organizations to assist in raising the level of awareness and facilitate immunization delivery to those populations.

This study provided clear insight about the vaccination coverage of Diphtheria through the DPT vaccine, which provides an additional information about pertussis and Tetanus vaccines. In addition, this study is the first to explore the correlation between multidimensional poverty index as a construct of sustainable development and DPT vaccination coverage in Nigeria. However, this study has few limitations. First, underrepresentation due to the political inaccessibility of 27 LGAs in Borno State which is equivalent to nearly 70% of the state's population based on a 2018 census. Though, this did not account for people who moved from insecure to secure LGAs, and the analysis was weighted to account for underrepresentation and missing information. Second, the estimates of vaccination coverage are based on both the card and the mother's report of the child's vaccinations. The latter is subject to recall bias. Nonetheless, maternal reporting of vaccination has previously shown to be a valid reporting approach with low recall bias. Finally, although there was a linear correlation between vaccination coverage and MPI at states' levels, this doesn't necessarily imply a correlation at individual level. There is no information in this study to support that children for families with higher MPI had lower vaccination coverage than for those with Lower MPI for instance. Hence, the correlation between MPI and vaccination coverage is subject to an ecologic fallacy.

CONCLUSION

The overall vaccination coverage in Nigeria was suboptimal. Northern States had lower Diphtheria vaccination coverage than southern States. There is a negative correlation between multidimensional poverty index and DPT full vaccination coverage. Findings from this study may inform the national immunization agencies and nonprofits to deploy a multidimensional approach for improving vaccination coverage among people with lower socioeconomic status, considering the various deprivations they may encounter in their life.

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