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Research Article

Determinants of incomplete immunization in children aged 12 to 23 months at sub-national level, Nigeria – a cross-sectional study

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Abstract

Objectives: National immunization coverage rate masks sub-national immunization coverage gaps at the state and local district levels. The study was performed to determine the socio-demographic determinants of incomplete immunization in children at a sub-national level.

Design: Cross-sectional study using the World Health Organization sampling method (2018 Reference Manual).

Setting: Fifty randomly selected clusters (wards) in four districts (two urban and two rural) in Enugu State, Nigeria.

Participants: 1,254 mothers of children aged 12-23 months in July 2020.

Primary and secondary outcome measures: Fully immunized children and not fully immunized children.

Results: Full immunization coverage (FIC) rate in Enugu State was 78.9% (95% CI = 76.5% – 81.1%]). However, stark difference exists in FIC rate in urban versus rural districts. Only 55.5% of children in rural communities are fully immunized compared to 94.5% in urban communities. Significant predictors of incomplete immunization are: children of single mothers (aOR = 5.74, 95% CI = 1.45 – 22.76), children delivered without skilled birth attendant present (aOR = 1.93, 95% CI = 1.24 – 2.99), children of mothers who did not receive postnatal care (aOR = 6.53, 95% CI = 4.17 – 10.22), children of mothers with poor knowledge of routine immunization (aOR = 1.76, 95% CI = 1.09 – 2.87), dwelling in rural district (aOR = 7.49, 95% CI = 4.84 – 11.59), low-income families (aOR = 1.56, 95% CI = 1.17 – 2.81), and living further than 30 minutes from the nearest vaccination facility (aOR = 2.15, 95% CI = 1.31 – 3.52).

Conclusions: Although the proportion of fully-immunized children in Enugu State is low, it is significantly lower in rural districts. Study findings suggest that strategies to improve awareness and geographical accessibility while ensuring functional primary healthcare centers especially in rural underserved district could be effective in achieving the "Reaching Every Districts" immunization coverage targets at every local district.

Strengths and limitations of this study

- Our study highlights critical gap in the global efforts to improve immunization coverage in sub-Saharan Africa by demonstrating stark disparity in immunization uptake in rural districts vis-à-vis urban districts at the subnational level.
- Our study did not comprehensively assess all the factors that could impact vaccine delivery in this context including health system factors such as vaccine availability, health care personnel, and logistics, and paternal factors. Although this was not the primary goal of the study
- This study did not assess uptake of recently introduced vaccines such as Rotavirus vaccine and Pneumococcal Conjugate Vaccine
- This study relied heavily on maternal recall which though demonstrated to be a reliable estimate in other setting in sub-Saharan Africa, which could have introduced differential overestimation or underestimation of immunization coverage in our study.
- Due to deteriorating security situation in the country and the absence of security assurances, this study did not access pockets of historically healthcare-marginalized population in Fulani settlements

Keywords: Immunization, Children, Determinants, Nigeria

Introduction

Immunization, defined as the process that makes a person immune or resistant to an infectious disease, typically by the administration of a vaccine, is one of the most effective interventions in contemporary public health practice [1,2]. Several cost-benefits analyses have consistently placed immunization as one of the most cost-effective health interventions with huge direct and societal benefits [3–8]. Immunization saves about 2-3 million lives every year [1,2], and has successfully led to the elimination of a number of vaccine-preventable diseases in some high-income countries, including polio, diphtheria, and pertussis [3,9]. Indeed, childhood immunization has had a remarkable impact on child morbidity and mortality worldwide with immense positive multiplier effects on the larger communities [3,5,9]

Nigeria is one of the 10 countries (Angola, Brazil, the Democratic Republic of the Congo, Ethiopia, India, Indonesia, Mexico, Nigeria, Pakistan, and the Philippines) that account for over 60% of the children who did not get DPT3 in 2019 [1]. DTP3 coverage is an indicator of how well countries are providing routine immunization services [2]. In 2017, about 20% of the world's infants with incomplete DPT immunization lived in Nigeria [10]. Three million of the estimated 8.9 million infants in the WHO African Region (AFR) who did not receive any measles containing vaccine (MCV-1) in 2015 live in Nigeria [11]. Hence, Nigeria accounts for nearly 40% of the 28,279 confirmed measles cases reported from the WHO African Region in 2016 [12].

The EPI in Nigeria, created in 1979, had a significant impact during the first few years with immunization coverage peaking at 81.5% in 1990 [13–15]. Immunization coverage plummeted to 12.3% in 2003 [15]. Several strategies were deployed in subsequent years to address the low immunization coverage, including routine immunization (RI) strengthening, supplemental immunization activities, global positioning system (GPS) tracker, and several community-level interventions [16]. Despite these efforts, preliminary results of the 2019 National Nutrition and Health Survey (NNHS) suggests a national DTP3 coverage of 67% [17]. However, even the low national immunization coverage rates mask subnational immunization coverage gaps at the state and local district levels [18]. For example, immunization coverage ranged from 5% to 48% across states in northern Nigeria in the 2018 National Demographic and Health Survey [19].

"Reaching every district" (RED) is a World Health Organization (WHO) strategy to achieve 80% immunization coverage in all districts and 90% nationally by 2020 [20]. Despite overall improvements in immunization coverage at the national level [20], geographic variations in the immunization coverage continues to hamper achieving RED targets at most sub-national and district levels [18]. Achieving this geographical parity, however, depends on capturing and understanding local patterns of coverage required to provide optimal, child-focused vaccine delivery services [1,18]. Also, while nationally representative surveys such as the Demographic and Health Survey (DHS) and Multiple Indicator Cluster Survey (MICS) have a standardized data collection procedures across countries that is also consistent content over time [21], presenting immunization coverage at national levels fails to capture the all-important local patterns of coverage required to properly fine-tune vaccine delivery services. Furthermore, relying on sub-national administrative data for assessing immunization system performance and tracking progress towards the RED district-level goals is often fraught with limitations such as missing data and poor data quality [18,22].

This study seeks to identify determinants of incomplete immunization at the sub-national level using Enugu State as point of focus. Enugu State has a high number of unimmunized children[23], and has the lowest proportion of children with complete immunization in the southeast region [24]. Hence, employing the World Health Organization multi-stage sampling methods for community survey [25], this study aims to define identify the sociodemographic determinants of incomplete immunization in children aged 12 to 23 months at a sub-national and local level. Our findings could help tailor strategies and operational plans to address immunization gaps and reach children in every district with life-saving vaccines.

Methods

This was a community-based cross-sectional survey of mothers of children 12–23 months old residing in Enugu State in July 2020. At the time of the study, all children 12–23 months old were considered eligible for sampling. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were used to ensure appropriate reporting of our study's design, conduct, and findings [26].

Study setting

Nigeria is the most populous country in Africa and the sixth most populous in the world [27]. She is located in Western Africa and is divided into six geopolitical regions: Northeast, Northwest, Northcentral, Southsouth, Southeast and Southwest. She has 36 states – the second administrative division, and a federal capital territory in Abuja. Each state is further divided into smaller administrative units called local government areas (LGA) and each LGA is further divided into wards.

Enugu State is one of the 36 states, in Nigeria (**Figure 1**) and one of the five states that make up the southeast geopolitical region in the country. Enugu State is further divided into 17 local government areas (LGA), four of which are predominantly urban (Enugu East, Enugu North, Enugu South, and Nsukka) and the rest are predominantly rural. Enugu State's 2020 projected population is 4,769,916, with most of the population living in urban centres in Enugu and Nsukka [28,29].

Sample size

Using steps described in the WHO Vaccination Coverage Cluster Surveys Reference Manual 2019 [25], we determined the sample size using immunization coverage of 36% obtained for Enugu State in the most recent DHS 2018 [24], significance

level of 5.0%, precision of 5.0%, design effect (DEFF) of 2.5 [30], and an inflation of 15% (to account for non-response). The calculated minimum sample size was 1,183. This was increased to 1,250 to boost the power of the study.

Sampling procedure

A three-stage sampling technique was used. In the first stage, a simple random sampling technique by balloting was used to select four local government areas, two each from the urban and rural areas of the state. In the second stage, a total of 50 clusters based on probability-proportional-to-size of the population; 15 clusters from Enugu East LGA, 15 clusters from Enugu North LGA, and 10 clusters each from Ezeagu LGA and Udenu LGA were randomly selected by balloting. In the third stage, we selected 25 households in each of the 50 clusters (ward) selected in the second stage. The first household in each cluster was selected randomly and subsequent households were selected contiguously in the right direction until the required number of households for that cluster was achieved. From each selected household, one eligible child was selected. If a selected household had more than one eligible child, the youngest child older than 12 months was selected. If a selected household had no eligible child, the next contiguous household was visited, and one eligible child was selected.

Data collection

Data were collected by a team of 14 trained community health workers using structured pre-tested interviewer-administered questionnaires. The questionnaire was constructed from a review of the available literature on immunization surveys in similar contexts [31–33], and tested for acceptability and logical structure in a sample of 20 mothers before the study. The team was trained on the study's objectives, interpreting, and extracting data from health cards/vaccination certificates, sampling techniques, ethical issues including the process of taking informed verbal consent, and administration of the questionnaire. The questionnaire was administered in Igbo (the local language) except for a few non-Igbo speakers who were administered the questionnaire in English. Questions were directed to the mothers, and only the mothers' response was recorded.

Data collected include socio-demographic characteristics of mothers and children including maternal healthcare (MHC) utilization [ante-natal care (ANC), skilled birth attendant (SBA) present at birth, and post-natal care (PNC)] , knowledge of mothers regarding RI, immunization status of children, and reasons for any non-vaccination. If the immunization card was available, immunization information of each inoculation received by the child was recorded. If a child had never received an immunization card or the mother was unable to present the immunization card to the interviewer, the immunization data/information for the child was based on the mother's report.

To evaluate mothers' knowledge of RI and vaccine-preventable diseases (VPDs), the interviewers asked questions on the correct purpose of immunization, different vaccine-preventable diseases, the correct age for receiving the vaccines, and the total number of visits required to complete the recommended vaccination for the child. Responses were evaluated as per the National Primary Healthcare Development Agency (NPHCDA) routine immunization schedule [34]. Correct responses were scored 2 points, incorrect responses 1 point, 'I do not know' 0 (zero) point.

Outcome variable

Children were categorized as fully immunized, partially immunized, or un-immunized (zero-dose) based on the types and doses of antigens received. A "fully immunized child" was defined as a child who had received one dose of BCG, three doses of OPV (excluding OPV given at birth), three doses of Pentavalent vaccine, and one dose of measles vaccine by 12 months of age; a partially immunized child was defined as a child who missed at least any one of the above doses; while an "un-immunized" or "zero-dose" child was defined as a child who had not received any vaccine by 12 months of age [35]. Incomplete immunization, in this study, includes partially immunized children and unimmunized (zero-dose) children. Immunization status was based on mothers' recall and immunization card record (that is, where the mother presents an immunization card, the child's immunization status is based on records in the card, but where an immunization card is not available, the immunization status is based on mothers' recall) as recommended by the World Health Organization [25]. This method has been used in a number of similar studies [31,36], and proven to be a reliable assessment of immunization coverage [37–39].

Data analysis

Data were entered into Microsoft Excel® (Microsoft, Redmond, WA, USA), cleaned and transferred to IBM SPSS® version 27.0 (IBM, Armonk, NY, USA) for statistical analyses. Frequency and percentage were used to describe the data, and Chi-square test was used to test for statistical significance. T-test was used to assess for statistical difference in the mean scores for knowledge of RI. Multivariate logistics regression analyses were performed to estimate adjusted odds ratios with 95 % Confidence Interval (CI) while adjusting for mothers age, marital status, mothers educational status, mothers occupation, religion, ethnic/tribal group, family monthly income, sex of the index child, and source of information on immunization. Aggregate scores for questions on awareness of RI were dichotomized into satisfactory knowledge (10 points and above) and poor knowledge (less than 10 points) prior to inclusion in the regression model. P<0.05 was used to define statistical significance, and all tests were two-tailed.

Results

Socio-demographic characteristics of mothers and children

A total of 1,254 distinct mothers were interviewed with mean (SD) age of 28.7 (4.3) years. Forty-eight percent of mothers were aged 20 – 29 years old, about 89.9% were married, 93.9% had at least secondary education or higher, and about three-quarters (75.5%) were employed. The mean (SD) age of the children was 16.8 (3.3) months, the age ranged from 12 to 23 months, and about half (51.0%) were girls – **Table 1**.

Full immunization coverage (FIC) rate

The FIC rate in Enugu State was 78.9% (95% CI = 76.5% – 81.1%), the partially immunized rate was 15.7% (95% CI = 13.7% – 17.8%), while the unimmunized (zero-dose) rate was 5.4% (95% CI = 4.2% – 6.8%) – **Table 2**. Vaccination coverage rates for Yellow fever vaccine and Vitamin A supplement were 86.2% (95% CI = 84.2% – 88.1%) and 84.4% (82.3% – 86.4%), respectively. DPT3 vaccination coverage rate, which is the Pentavalent-3 coverage rate in this study, was 83.9% (95% CI = 81.7% – 85.9%).

Immunization coverage rates differed based on the rurality-urbanity of communities in the state. FIC rate was 94.5% (95% CI = 92.7% – 96.1%) in urban communities and 55.5% (95% CI = 51.0% – 59.9%) in rural communities. In both urban and rural communities, the proportion of children vaccinated with antigens given at birth and six weeks of age were more than the proportions of children vaccinated with antigens given at later ages.

Of the 1,254 children, 578 possessed immunization cards, indicating an immunization card retention rate of 48.7% (95% CI = 45.9% - 51.6%). About two-fifth of unvaccinated (zero-dose) children were not vaccinated because vaccination sites were too far while another two-fifth reported absence of vaccines in the health facility.

Determinants of immunization status

Table 3 shows results from a bivariate analysis of maternal health care utilization history and knowledge of RI. Use of skilled birth attendants (SBA) during delivery of index child, and reception of postnatal care (at least one postnatal visit) were statistically significant predictors of incomplete immunization. Insufficient knowledge of RI was also statistically significantly associated with incomplete immunization.

Multivariate logistics regression analyses show that single mothers (aOR = 5.74, 95% CI = 1.45 – 22.76), mothers who delivered without SBA (aOR = 1.93, 95% CI = 1.24 – 2.99), mothers who did not receive any postnatal care (aOR = 6.53, 95% CI = 4.17 – 10.22), and mothers with poor knowledge of routine immunization (aOR = 1.76, 95% CI = 1.09 – 2.87) were significant predictors of incomplete immunization – **Table 4**. Community level predictors for incomplete immunization were rural community (aOR = 7.49, 95% CI = 4.84 – 11.59), low-income families (aOR = 1.56, 95% CI = 1.17 – 2.81), and living further than 30 minutes from the nearest vaccination facility (aOR = 2.15, 95% CI = 1.31 – 3.52).

Discussion

This study evaluated immunization coverage data in urban and rural areas of Enugu State and offers a close-up assessment of sociodemographic determinants of incomplete immunization at the sub-national and local level. There are four main findings from this study. First, this assessment of immunization coverage of children aged 12-23 months in 50 randomly selected wards in rural and urban districts (LGA) in Enugu State found FIC rate in Enugu state to be low, below the RED's subnational target of 80% immunization coverage. While the FIC rate in this study is higher than FIC rates reported in other sub-regions in Nigeria [32,40], and Ethiopia [41,42], it is lower than FIC rates reported in Cameroon [36], and Ghana [43]. About one in five (21.1%) children aged 12-23 months in the state were not fully immunized. This finding suggests that even after almost two decades of implementing the RED strategy in Nigeria, some states in the southern region with purportedly high immunization coverage [14], are still yet to meet the (RED's) subnational immunization target. This partially explains why huge investments in immunization activities have had minimal impact on the incidence of vaccine preventable diseases in Enugu State [44].

Secondly, further analysis based on rurality of residence reveals stark disparity in the FIC rate between urban communities and rural communities. Urban communities had a substantially higher FIC rate (94.5%) than rural communities (55.5%). This observation is consistent with findings in other sub-regions in Nigeria [40,45], and Ethiopia [41,42], but differs with findings in Bayelsa State, Nigeria where immunization coverage was higher in the rural community than in the urban community [46]. Our data show that almost half of infants in rural communities miss out on at least one of the critical life-saving BCG, Pentavalent, OPV, and Measles vaccines. This finding underscores the importance of monitoring data at sub-district levels to identify vaccination gaps and tailor operational strategies accordingly.

Thirdly, the low DPT-3 coverage in rural communities (63.0%) points to gaps in RI delivery in those communities and is consistent with a study conducted in another rural community in Enugu[47]. Furthermore, the immunization dropout rate in both urban and rural communities is low, below the 10% cut-off recommended by WHO [48]. The low immunization dropout rate amidst low DPT-1 coverage in rural communities suggests that access to RI in these contexts remains a problem [48], as previous studies have argued[47]. There are many factors responsible for the rural-urban differences in access. For example, vaccination points are more geographically accessible to families in urban communities than in rural communities [10,49,50], rural communities incur higher travel costs to reach vaccination points[50], and rural communities are less aware of the importance of immunization[10,40].

Finally, this study was undertaken to elucidate the socio-demographic predictors of incomplete immunization in children at the sub-national level. Predictors of incomplete immunization identified in this study include marital status, MHC utilization, poor knowledge of routine immunization, poor family income, and geographical accessibility. Children of single mothers are less likely to be fully immunized compared to married mothers. Married mothers are more financially stable and most likely to discuss the health needs of their children, including immunization [43,49]. Also, stigma, psychological trauma, and hardship associated with single motherhood in these context negatively impacts access to health and vaccination [43,49]. MHC utilization also significantly predicts incomplete immunization. Mothers who give birth using SBA are more likely to have them fully immunized than mothers who did not use SBA. Likewise, mothers who receive PNC care are more likely to have their children fully immunized. This is consistent with several studies in other LMICs that demonstrate that increased health communications on immunization during MHC utilization significantly impacts childhood immunization [49,51]. However, given that the sequence of MHC utilization is ANC-SBA-PNC, the absence of a significant effect for ANC in this study does not imply that adequate ANC attendance does not impact RI. Instead, our data suggest that other factors such as accessibility to health facilities could have a stronger impact on RI than adequately attending ANC [52].

Strengths and limitations

Our study extends the body of knowledge on immunization uptake in rural areas vis-à-vis urban areas at the subnational level, our results can be generalized to similar contexts in Nigeria and beyond, and provides important evidence to policymakers and program managers for improving immunization coverage. However, our study is not without limitations. First, the effects of health system factors including vaccine availability, health care personnel, and logistics [53,54], which are known to influence uptake of immunization coverage were not adequately explored. Also, paternal factors that may influence the completion of immunization were not also evaluated [49]. However, the primary goal of this study was not to

assess the effect of these factors. Secondly, new vaccines recently introduced into the Nigeria RI schedule (specifically, Rotavirus vaccine and Pneumococcal Conjugate Vaccine (PCV)) were not explored [55,56]. Thirdly, although maternal recall has been shown to be a reliable estimate of maternal recall in Senegal, Ethiopia, and Tanzania [37–39], there is little evidence that it is a reliable coverage measure in Nigeria. A similar study in Osun State showed that agreement between the mothers' recall and immunization card assessment was low [32]. This (maternal recall) could have also biased our estimates. Finally, pockets of hard-to-reach Fulani settlements that have been shown to have poor immunization coverage were not included in our sample [57]. Due to the deteriorating security situation in the country and the absence of security assurances, we could not send data collectors to these settlements.

Policy implications

Our study findings have policy implications for vaccination delivery in low- and middle-income countries laboring to improve national and subnational immunization coverage. First, innovative solutions to improve geographical accessibility are undoubtedly needed to achieve RED targets at local levels. For example, Sibeudu et al have suggested providing RI services in marketplaces on local market days [50]. Implementing such ingenious solutions while ensuring functional primary healthcare centers in every ward could reduce the existing urban-rural immunization coverage gap. Additionally, our study findings also suggest that strategies aimed at improving MHC utilization, especially in underserved rural communities, could be effective in achieving the RED national and sub-national targets [51]. Furthermore, comprehensive sensitization campaigns on immunization programmes should strengthened in rural communities to improve the effectiveness of immunization programme [44]. Finally, educational and reminder interventions that leverage on existing mobile phone technology obtainable in almost all rural communities in Nigeria could improve immunization awareness, timeliness, and coverage [58,59].

Conclusions

The FIC rate in rural communities in Enugu State is below the RED target of 80 % for all antigens by 2020. About one in two children in rural communities in Enugu State is not fully immunized. Determinants of full immunization are single motherhood, maternal healthcare utilization, family income, rural residence, and geographical proximity to health facilities. Providing routine immunization services in marketplaces on local market days could improve rural access to RI while ensuring that there is a functional primary healthcare center in every ward could reduce the existing urban-rural immunization coverage disparity. Mobile phone educational and reminder interventions could improve immunization awareness, timeliness, and coverage.

List of abbreviations

ANC	Antenatal care
BCG	Bacille Calmette Guerin
DEFF	Design effect
DPT	Diphtheria-Pertussis-Tetanus
EPI	Expanded program on immunization
FIC	Full immunization coverage
GVAP	Global Vaccine Action Plan
LMIC	Low- and middle-income countries
MHC	Maternal Healthcare
OPV	Oral polio vaccine
PNC	Postnatal care
RI	Routine immunization
SBA	Skilled birth attendant
TT	Tetanus toxoid
UNICEF	United Nations Children's Fund
VPD	Vaccine preventable diseases
WHO	World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Ethical Committee of the Enugu State University Teaching Hospital – Reference number: ESUTHP/C-MAC/RA/034/Vol1/264. Permission was also obtained from the State Ministry of Health, Enugu.

Informed verbal consent was obtained from each mother before participating in the study. Verbal consent was deemed appropriate and approved by the ethics committee. Informed verbal consent consisted of a description of the objectives of the study, assurance of confidentiality of personal information, and a specific request for permission to conduct the interview. Consent was obtained in Igbo (the local language) except for a few non-Igbo speaker whose consent was obtained in English. Where the mother was less than 18 years, consent to participate in the study was obtained from the husband (if mother was married) or from the mother's mother/father (if the mother was single).

Children with zero or incomplete immunization were referred to the nearest health center for vaccination. All patient identifiers were removed prior to statistical analysis.

Consent for publication

Not applicable

Availability of data and materials

The dataset generated and analyzed in this study is freely available from the corresponding author on reasonable request or directly from the data repository, Zenodo, http://doi.org/10.5281/zenodo.4294847

Competing interests

None declared.

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Author contributions

PE and YA conceptualized the study, oversaw its conduct, analyzed the data, interpreted the results, drafted the original article, and reviewed the final draft. UJA, CLA, SAA, and LOL contributed to the collection and analysis of the data, interpretation of the results, and review of the final draft. All authors read and approved the final manuscript.

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Authors' information (optional)

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Table 1: Socio-demographic characteristics of mother and children in Enugu State, Nigeria, July 2020

Socio-demographic characteristics	Frequency (N = 1,254)	Proportion (%)
Mothers' age		
– < 20 years	54	4.3%
– 20 – 29 years	602	48.0%
– ≥ 30 years	598	47.7%
Marital status		
– Single	50	4.0%
– Currently Married	1127	89.9%
– Divorced/Widowed	77	7.1%
Mothers' education		
– Primary or lower	77	6.1%
– Secondary or higher	1177	93.9%
Mothers' working status		
– Stay-at-home/Housewife	307	24.5%
– Working mom	947	75.5%
Religion		
– Christian	1,214	96.8%
– Islam/Muslim	20	1.6%
– African Traditional Religion	20	1.6%
Family monthly income		
– < N80,000 (Approx. USD 200)	960	76.6%
– ≥ N80,000	294	23.4%
Ethnic group		
– Igbo	1201	95.8%
– Others	53	4.2%
Sex/gender of child		
– Female	640	51.0%
– Male	614	49.0%
Birth order of child		
– First born	347	27.7%
– Second or third	625	49.8%
– Others	282	22.5%
Residence/Community		
– Rural	503	40.1%
– Urban	751	59.9%
Walking distance to nearest health facility		
– < 30-minutes' walk	546	43.5%
– ≥ 30-minutes' walk	708	56.5%
Source of information on Immunization (more than source applies)		
– Hospital/Health facility	913	72.8%
– Family/friends	789	62.9%
– Church/Mosque	328	26.2%
– TV, Radio, and social media	193	15.4%

Table 2: Immunization coverage for routine immunization (RI) antigens in Enugu State, Nigeria, July 2020

RI Antigen	State-wide Coverage N = 1,254 n, (%, [95% CI])	Coverage in Urban communities N = 751 n, (%, [95% CI])	Coverage in Rural communities N = 503 n, (%, [95% CI])
Antigens administered at birth			
– BCG ##	1,136 (90.6%, [88.8% – 92.1%])	741 (98.7%, [97.6% – 99.4%])	395 (78.5%, [74.7% – 82.0%])
Antigens administered at 6 weeks			
– OPV 1	1,137 (90.7%, [88.9% – 92.2%])	742 (98.8%, [97.7% – 99.5%])	395 (78.5%, [74.7% – 82.0%])
– Penta 1	1,136 (90.6%, [88.8% – 92.1%])	738 (98.3%, [97.1% – 99.1%])	398 (79.1%, [75.2% – 82.7%])
Antigens administered at 10 weeks			
– OPV 2	1,083 (86.4%, [84.3% – 88.2%])	741 (98.7%, [97.6% – 99.4%])	342 (68.0%, [63.7% – 72.1%])
– Penta 2	1,090 (86.9%, [84.9% – 88.7%])	736 (98.0%, [96.7% – 98.9%])	354 (70.4%, [66.2% – 74.3%])
Antigens administered at 14 weeks			
– OPV 3 ##	1,042 (83.1%, [80.9% – 85.1%])	740 (98.5%, [97.4% – 99.3%])	302 (60.0%, [55.6% – 64.3%])
– Penta 3 ##	1.052 (83.9%, [81.7% – 85.9%])	735 (97.9%, [96.6% – 98.8%])	317 (63.0%, [58.6% – 67.3%])
Antigens administered at 9 months			
– Measles ##	1,101 (87.8%, [85.9% – 89.6%])	716 (95.3%, [93.6% – 96.7%])	385 (76.5%, [72.6% – 80.2%])
– Yellow fever	1,081 (86.2%, [84.2% – 88.1%])	720 (95.9%, [94.2% – 97.2%])	361 (71.8%, [67.6% – 75.7%])
Supplements			
– Vitamin A	1,059 (84.4%, [82.3% – 86.4%])	721 (96.0%, [94.3% – 97.3%])	338 (67.2%, [62.9% – 71.3%])
Immunization status ##			
– Fully immunized	989 (78.9%, [76.5% – 81.1%])	710 (94.5%, [92.7% – 96.1%])	279 (55.5%, [51.0% – 59.9%])
– Partially immunized	197 (15.7%, [13.7% – 17.8%])	34 (4.5%, [3.2% – 6.3%])	163 (32.4%, [28.3% – 36.7%])
– Unimmunized (Zero-dose)	68 (5.4%, [4.2% – 6.8%])	7 (0.9%, [0.4% – 1.9%])	61 (12.1%, [9.4% – 15.3%])

Vaccines included in the definition of immunization status (Fully immunized child vs Partially immunized vs Unimmunized)

Table 3: Maternal health care utilization history and knowledge of routine immunization in Enugu State, Nigeria 2020

Characteristics	Fully immunized (n = 989)	Not fully immunized (n = 265)	Crude Odds ratio (95% CI)	p-value
MOTHERS' HEALTH CARE UTILIZATION HISTORY				
Use of Skilled birth attendants (SBA)				
– Yes (Hospital)	309 (84.7%)	56 (15.3%)	1.70 (1.23 – 2.35)	0.001
– No (TBA, Home delivery)	680 (76.5%)	209 (23.5%)		
Attended ante-natal care (ANC)				
– ≥ Four ante-natal visits	762 (77.8%)	217 (22.2%)	0.74 (0.53 – 1.05)	0.091
– < Four ante-natal visits	227 (82.5%)	48 (17.5%)		
Tetanus toxoid (TT) injection during pregnancy				
– ≥ 2 TT injections	784 (79.0%)	209 (21.0%)	1.03 (0.74 – 1.43)	0.888
– < 2 TT injection	205 (78.5%)	56 (21.5%)		
Attended post-natal care (PNC)				
– Yes	866 (89.2%)	105 (10.8%)	10.73 (7.87 – 14.63)	< 0.001
– No	123 (43.5%)	160 (56.5%)		
MOTHERS' AWARENESS OF ROUTINE IMMUNIZATION				
What do vaccines do to your child's body?				
– Vaccines help prevent illness	937 (78.5%)	256 (21.5%)	0.63 (0.31 – 1.30)	0.210
– Other responses **	44 (88.0%)	6 (12.0%)		
– I do not know **	8 (72.7%)	3 (27.3%)		
Mention any disease(s) children's vaccines can prevent				
– Mentioned Four (4) or more diseases	481 (90.6%)	50 (9.4%)	4.07 (2.92 – 5.68)	< 0.001
– Less than four (4) diseases **	502 (70.1%)	214 (29.9%)		
– I do not know **	6 (85.7%)	1 (14.3%)		
At what age does child immunization start?				
– Just after birth	858 (84.6%)	156 (15.4%)	4.58 (3.37 – 6.22)	< 0.001
– Stated other dates (1 week, 1 month, etc.) **	95 (50.3%)	94 (49.7%)		
– I do not know **	36 (70.6%)	15 (29.4%)		
When does a child complete his/her immunization?				
– 9 to 15 months	930 (79.6%)	238 (20.4%)	1.79 (1.11 – 2.88)	0.016
– < 6 months OR > 15 months **	51 (67.1%)	25 (32.9%)		
– I do not know **	8 (80.0%)	2 (20.0%)		
What is the age/schedule for each vaccine?				
– Correct schedule for three or more vaccines	952 (83.3%)	191 (16.7%)	9.97 (6.52 – 15.24)	< 0.001
– Other responses **	26 (26.3%)	73 (73.7%)		
– I do not know **	11 (91.7%)	1 (8.3%)		
How many HF visits are required for full immunization?				
– At least 5 or 6 visits	686 (80.4%)	167 (19.6%)	1.33 (1.00 – 1.76)	0.049
– < 5 visits **	183 (88.0%)	25 (12.0%)		
– I do not know **	120 (62.2%)	73 (37.8%)		
Scores for Knowledge of routine immunization				
– Mean Score (± Std Dev)	10.71 (1.61)	9.63 (1.82)	1.07 (0.83 – 1.32) ##	< 0.001

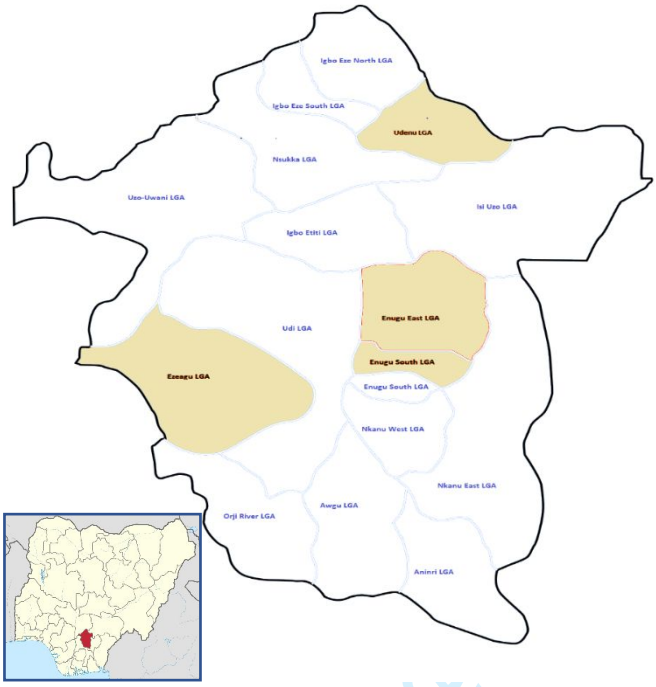
** These responses were combined for estimation of Crude OR. | ## Mean difference (95% CI) | Abbreviations: HF, Health Facility

Table 4: Determinants of immunization status of children aged 12-23 months in Enugu State, Nigeria, July 2020

Socio-demographic Characteristics	Reference	Adjusted OR	95% CI	p-value
INDIVIDUAL LEVEL FACTORS				
Mothers' age				
– < 20 years	20 – 29 years	0.17	0.03 – 1.06	0.058
– ≥ 30 years	20 – 29 years	0.87	0.57 – 1.34	0.534
Marital status				
– Single	Married	5.74	1.45 – 22.76	0.013
– Divorced/Widowed	Married	1.35	0.60 – 3.07	0.468
Mothers' educational status				
– Primary education or lower	Secondary education or higher	0.64	0.26 – 1.56	0.383
Mother's working status				
– Working mom	Stay-at-home/Housewife	1.08	0.63 – 1.85	0.327
Religion of family				
– Islam/Muslim	Christian	1.53	0.27 – 8.62	0.627
– African traditional	Christian	2.21	0.44 – 11.13	0.335
Sex of the child				
– Male	Female	0.98	0.66 – 1.45	0.914
Child's birth order				
– Second/third child	First child	1.52	0.78 – 2.98	0.220
– Fourth and later children	First child	1.34	0.48 – 3.74	0.577
MHC UTILIZATION & KNOWLEDGE OF RI				
Antenatal care (ANC)				
– < 4 ANC visits	≥ 4 ANC visits	1.52	0.71 – 3.22	0.472
Maternal tetanus toxoid (TT)				
– < 2 doses	≥ 2 doses	0.93	0.41 – 2.10	0.864
Use of Skilled birth attendants (SBA)				
– No	Yes	1.93	1.24 – 2.99	0.003
Postnatal care (PNC)				
– No	Yes	6.53	4.17 – 10.22	< 0.001
Mothers' knowledge of RI				
– Poor	Satisfactory	1.76	1.09 – 2.87	0.022
COMMUNITY LEVEL FACTORS				
Area of residence				
– Rural	Urban	7.49	4.84 – 11.59	< 0.001
Family monthly income level				
– < N80,000 (Approx. USD 200)	≥ N80,000 (Approx. USD 200)	1.56	1.17 – 2.81	< 0.001
Distance to nearest vaccination point				
– ≥ 30 minutes' walk	< 30 minutes' walk	2.15	1.31 – 3.52	0.003

Figure 1: Study Area: Enugu East LGA, Enugu North LGA, Ezeagu LGA, and Udenu LGA in Enugu State, Nigeria.

(Insert shows the location of Enugu State (coloured burgundy)).



Source: https://www.researchgate.net/figure/Map-of-Enugu-State-showing-the-locations-of-the-17-local-government-areas-Ukabia-2010_fig4_261949564.

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2,3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	3,4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	5
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	5
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5
		(*b*) Report category boundaries when continuous variables were categorized	5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	6,7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6
Generalisability	21	Discuss the generalisability (external validity) of the study results	7
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Determinants of incomplete immunization in children aged 12 to 23 months at sub-national level, Nigeria – a cross-sectional study

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Research Article

Determinants of incomplete immunization in children aged 12 to 23 months at sub-national level, Nigeria – a cross-sectional study

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Abstract

Objectives: National immunization coverage rate masks sub-national immunization coverage gaps at the state and local district levels. The study was performed to determine the socio-demographic determinants of incomplete immunization in children at a sub-national level.

Design: Cross-sectional study using the World Health Organization sampling method (2018 Reference Manual).

Setting: Fifty randomly selected clusters (wards) in four districts (two urban and two rural) in Enugu State, Nigeria.

Participants: 1,254 mothers of children aged 12-23 months in July 2020.

Primary and secondary outcome measures: Fully immunized children and not fully immunized children.

Results: Full immunization coverage (FIC) rate in Enugu State was 78.9% (95% CI = 76.5% – 81.1%]). However, stark difference exists in FIC rate in urban versus rural districts. Only 55.5% of children in rural communities are fully immunized compared to 94.5% in urban communities. Significant predictors of incomplete immunization are: children of single mothers (aOR = 5.74, 95% CI = 1.45 – 22.76), children delivered without skilled birth attendant present (aOR = 1.93, 95% CI = 1.24 – 2.99), children of mothers who did not receive postnatal care (aOR = 6.53, 95% CI = 4.17 – 10.22), children of mothers with poor knowledge of routine immunization (aOR = 1.76, 95% CI = 1.09 – 2.87), dwelling in rural district (aOR = 7.49, 95% CI = 4.84 – 11.59), low-income families (aOR = 1.56, 95% CI = 1.17 – 2.81), and living further than 30 minutes from the nearest vaccination facility (aOR = 2.15, 95% CI = 1.31 – 3.52).

Conclusions: Although the proportion of fully-immunized children in Enugu State is low, it is significantly lower in rural districts. Study findings suggest the need for innovative solutions to improve geographical accessibility and reinforce the importance of reporting vaccination coverage at local district level to identify districts for more targeted interventions.

Strengths and limitations of this study

- The estimates presented in the study for the sub-national level are potentially more accurate than previous estimates.
- We adhered to the guidelines in WHO Vaccination Coverage Cluster Surveys Reference Manual 2019, thus enabling greater comparability with future studies using the same method.
- Due to the observational cross-sectional design, we cannot establish a causal relationship between the determinants and vaccination.
- This study considerably relied on maternal recall which can lead to overestimation or underestimation of immunization coverage estimates.
- We were unable to access pockets of historically healthcare-marginalized population in one of the settlements due to security concerns.

Keywords: Routine immunization, Children, Determinants, Nigeria

Introduction

Immunization, defined as the process that makes a person immune or resistant to an infectious disease, typically by the administration of a vaccine, is one of the most effective interventions in contemporary public health practice [1,2]. Several cost-benefits analyses have consistently placed immunization as one of the most cost-effective health interventions with huge direct and societal benefits [3–8]. Immunization saves about 2-3 million lives every year [1,2], and has successfully led to the elimination of a number of vaccine-preventable diseases in some high-income countries, including polio, diphtheria, and pertussis [3,9]. Indeed, childhood immunization has had a remarkable impact on child morbidity and mortality worldwide with immense positive multiplier effects on the larger communities [3,5,9].

Nigeria is one of the 10 countries (Angola, Brazil, the Democratic Republic of the Congo, Ethiopia, India, Indonesia, Mexico, Nigeria, Pakistan, and the Philippines) that account for over 60% of the children who did not get DPT3 in 2019 [1]. DTP3 coverage is an indicator of how well countries are providing routine immunization services [2]. In 2017, about 20% of the world's infants with incomplete DPT immunization lived in Nigeria [10]. Three million of the estimated 8.9 million infants in the WHO African Region who did not receive any measles containing vaccine in 2015 live in Nigeria [11]. Hence, Nigeria accounts for nearly 40% of the 28,279 confirmed measles cases reported from the WHO African Region in 2016 [12].

The Expanded Program on Immunization in Nigeria, created in 1979, had a significant impact during the first few years with immunization coverage peaking at 81.5% in 1990 [13–15]. Immunization coverage plummeted to 12.3% in 2003 [15], due to a myriad of factors including low government commitment to EPI policy, over-centralization in the administration of EPI at the federal level, collapse of the primary healthcare service upon which EPI services were delivered, and vaccination refusal mostly due to religious beliefs in the northern part of the country [15]. Several strategies were deployed in subsequent years

to address the low immunization coverage, including routine immunization strengthening, supplemental immunization activities, global positioning system tracker, and several community-level interventions [16]. Despite these efforts, preliminary results of the 2019 National Nutrition and Health Survey suggests a national DTP3 coverage of 67% [17]. However, even the low national immunization coverage rates mask subnational immunization coverage gaps at the state and local district levels [18]. For example, immunization coverage ranged from 5% to 48% across states in northern Nigeria in the 2018 National Demographic and Health Survey (DHS) [19].

The Immunization Agenda 2030 (IA2030) is a global strategy led by the World Health Organization (WHO) to ensure every child is protected by full immunization, regardless of location, age, socioeconomic status, or gender-related barriers by 2030 [20]. Despite overall improvements in immunization coverage at the national level [21], geographic variations in the immunization coverage persists at most sub-national and district levels [18]. Achieving geographical parity, however, depends on capturing and understanding local patterns of coverage required to provide optimal, child-focused vaccine delivery services [1,18]. Also, while nationally representative surveys such as the Demographic and Health Survey (DHS) and Multiple Indicator Cluster Survey (MICS) have a standardized data collection procedures across countries that is also consistent over time [22], presenting immunization coverage at national levels fails to capture the all-important local patterns of coverage required to properly fine-tune vaccine delivery services. Furthermore, relying on sub-national administrative data for assessing immunization system performance and tracking progress is often fraught with limitations such as missing data and poor data quality [18,23].

This study seeks to identify determinants of incomplete immunization at the sub-national level using Enugu State as point of focus. Enugu State has a high number of unimmunized children[24], and has the lowest proportion of children with complete immunization in the southeast region [25]. Hence, employing the World Health Organization multi-stage sampling methods for community survey [26], this study aims to identify the sociodemographic determinants of incomplete immunization in children aged 12 to 23 months at a sub-national and local level. Our findings could help tailor strategies and operational plans to address immunization gaps and reach children in every district with life-saving vaccines.

Methods

This was a community-based cross-sectional survey of mothers of children 12–23 months old residing in Enugu State in July 2020. At the time of the study, all children 12–23 months old were considered eligible for sampling. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were used to ensure appropriate reporting of our study's design, conduct, and findings [27].

Study setting

Nigeria is the most populous country in Africa and the sixth most populous in the world [28]. She is located in Western Africa and is divided into six geopolitical regions: Northeast, Northwest, Northcentral, Southsouth, Southeast and Southwest. She has 36 states – the second administrative division, and a federal capital territory in Abuja. Each state is further divided into smaller administrative units called local government areas (LGA) and each LGA is further divided into wards.

Enugu State is one of the 36 states in Nigeria (**Figure 1**) and one of the five states that make up the southeast geopolitical region in the country. Enugu State is further divided into 17 LGAs, four of which are predominantly urban (Enugu East, Enugu North, Enugu South, and Nsukka) and the rest are predominantly rural. Enugu State's 2020 projected population is 4,769,916, with most of the population living in urban centres in Enugu and Nsukka [29,30].

Sample size

Using steps described in the WHO Vaccination Coverage Cluster Surveys Reference Manual 2019 [26], we determined the sample size using immunization coverage of 36.0% obtained for Enugu State in the most recent 2018 Nigeria DHS [25], significance level of 5.0%, precision of 5.0%, design effect of 2.5 [31], and an inflation of 15% (to account for non-response). The calculated minimum sample size was 1,183 which was increased to 1,250 to boost the power of the study.

Sampling procedure

A three-stage sampling technique was used. In the first stage, a simple random sampling technique by balloting was used to select four local government areas, two each from the urban and rural areas of the state. In the second stage, a total of 50 clusters based on probability-proportional-to-size of the population; 15 clusters from Enugu East LGA, 15 clusters from Enugu North LGA, and 10 clusters each from Ezeagu LGA and Udenu LGA were randomly selected by balloting. In the third stage, we selected 25 households in each of the 50 clusters (ward) selected in the second stage. The first household in each cluster was selected randomly and subsequent households were selected contiguously in the right direction until the required number of households for that cluster was achieved. From each selected household, one eligible child was selected. If a selected household had more than one eligible child, the youngest child older than 12 months was selected. If a selected household had no eligible child, the next contiguous household was visited, and one eligible child was selected.

Data collection

Data were collected by a team of 14 trained community health workers (CHW) using structured pre-tested interviewer-administered questionnaires. The questionnaire was constructed from a review of the available literature on immunization surveys in similar contexts [32–34], and tested for acceptability and logical structure in a sample of 20 mothers before the study. The team was trained on the study's objectives, interpreting, and extracting data from health cards/vaccination certificates, sampling techniques, walking distance estimation using Google® Maps mobile app, ethical issues including the process of taking informed verbal consent, and administration of the questionnaire. The questionnaire was administered in Igbo (the local language) except for a few non-Igbo speakers who were administered the questionnaire in English. Questions were directed to the mothers, and only the mothers' responses were recorded.

Data collected include socio-demographic characteristics of mothers and children including maternal healthcare (MHC) utilization [ante-natal care (ANC), skilled birth attendant (SBA) present at birth, and post-natal care (PNC)] , knowledge of mothers regarding RI, immunization status of children, and reasons for any non-vaccination. If the immunization card was available, immunization information of each inoculation received by the child was recorded. If a child had never received an immunization card or the mother was unable to present the immunization card to the interviewer, the immunization data/information for the child was based on the mother's report.

Google® Map mobile app was used on smartphones to estimate the walking distance from each study participant's house to the nearest vaccination center in all but four clusters (in Ezeagu LGA). In these four clusters, we first identified the nearest routine childhood vaccination point in each cluster and then estimated the walking distance from this nearest vaccination facility to each household included in the study. To evaluate mothers' knowledge of routine immunization and vaccine-preventable diseases, the interviewers asked questions on the correct purpose of immunization, different vaccine-preventable diseases, the correct age for receiving the vaccines, and the total number of visits required to complete the recommended vaccination for the child. Responses were evaluated as per the National Primary Healthcare Development Agency routine immunization schedule [35]. Correct responses were scored 2 points, incorrect responses 1 point, 'I do not know' 0 (zero) point.

Outcome variable

Children were categorized as fully immunized, partially immunized, or un-immunized (zero-dose) based on the types and doses of antigens received. A "fully immunized child" was defined as a child who had received one dose of BCG, three doses of OPV (excluding OPV given at birth), three doses of Pentavalent vaccine, and one dose of measles vaccine by 12 months of age; a partially immunized child was defined as a child who missed at least any one of the above doses; while an "un-immunized" or "zero-dose" child was defined as a child who had not received any vaccine by 12 months of age [36]. Incomplete immunization, in this study, includes partially immunized children and unimmunized (zero-dose) children. Immunization status was based on mothers' recall and immunization card record (that is, where the mother presents an immunization card, the child's immunization status is based on records in the card, but where an immunization card is not available, the immunization status is based on mothers' recall) as recommended by the World Health Organization [26]. This method has been used in a number of similar studies [32,37], and proven to be a reliable assessment of immunization

coverage [38–40]. Vitamin A and Yellow fever vaccines were not included in determining complete immunization status for this study.

Data analysis

Data were entered into Microsoft Excel® (Microsoft, Redmond, WA, USA), cleaned and transferred to IBM SPSS® version 27.0 (IBM, Armonk, NY, USA) for statistical analyses. Frequency and percentage were used to describe the data, and Chi-square test was used to test for statistical significance. T-test was used to assess for statistical difference in the mean scores for knowledge of routine immunization. Multivariate logistics regression analyses were performed to estimate adjusted odds ratios with 95 % Confidence Interval (CI) while adjusting for mothers age, marital status, mothers educational status, mothers occupation, religion, ethnic/tribal group, family monthly income, sex of the index child, and source of information on immunization. Aggregate scores for questions on awareness of routine immunization were dichotomized into satisfactory knowledge (10 points and above) and poor knowledge (less than 10 points) prior to inclusion in the regression model. $P<0.05$ was used to define statistical significance, and all tests were two-tailed.

Patient and Public Involvement

No patients were involved in developing the research question and study design or in the implementation of the study design, the interpretation of the results and writing of the manuscript. There are no plans to share the study with patients.

Results

Socio-demographic characteristics of mothers and children

A total of 1,254 distinct mothers were interviewed with mean (SD) age of 28.7 (4.3) years. Forty-eight percent of mothers were aged 20 – 29 years old, about 89.9% were married, 93.9% had at least secondary education or higher, and about three-quarters (75.5%) were employed. The mean (SD) age of the children was 16.8 (3.3) months, the age ranged from 12 to 23 months, and about half (51.0%) were girls – **Table 1**.

Full immunization coverage (FIC) rate

The FIC rate in Enugu State was 78.9% (95% CI = 76.5% – 81.1%), the partially immunized rate was 15.7% (95% CI = 13.7% – 17.8%), while the unimmunized (zero-dose) rate was 5.4% (95% CI = 4.2% – 6.8%) – **Table 2**. Vaccination coverage rates for Yellow fever vaccine and Vitamin A supplement were 86.2% (95% CI = 84.2% – 88.1%) and 84.4% (82.3% – 86.4%), respectively. DPT3 vaccination coverage rate, which is Pentavalent-3 coverage rate in this study, was 83.9% (95% CI = 81.7% – 85.9%).

Immunization coverage rates differed based on the rurality-urbanity of communities in the state. FIC rate was 94.5% (95% CI = 92.7% – 96.1%) in urban communities and 55.5% (95% CI = 51.0% – 59.9%) in rural communities. In both urban and rural communities, the proportion of children vaccinated with antigens given at birth and six weeks of age were more than the proportions of children vaccinated with antigens given at later ages.

Of the 1,254 children, 578 possessed immunization cards, indicating an immunization card retention rate of 48.7% (95% CI = 45.9% - 51.6%). About two-fifth of unvaccinated (zero-dose) children were not vaccinated because vaccination sites were too far while another two-fifth reported absence of vaccines in the health facility (**Supplement 1**).

Determinants of immunization status

Table 3 shows results from a bivariate analysis of maternal health care utilization history and knowledge of routine immunization. Use of skilled birth attendants (SBA) during delivery of index child, and reception of postnatal care (at least one postnatal visit) were statistically significant predictors of incomplete immunization. Student t-test we used for the comparison of mean score of knowledge of routine immunization demonstrated that insufficient knowledge of routine immunization was also statistically significantly associated with incomplete immunization.

Multivariate logistic regression model was statistically significant, $\chi^2(25) = 24.217$, p = 0.002. The model explained 57.0% (Nagelkerke R^2) of the variance in immunization status and correctly classified 90.7% of cases. Single mothers (aOR = 5.74, 95% CI = 1.45 – 22.76), mothers who delivered without SBA (aOR = 1.93, 95% CI = 1.24 – 2.99), mothers who did not receive any postnatal care (aOR = 6.53, 95% CI = 4.17 – 10.22), and mothers with poor knowledge of routine immunization (aOR = 1.76, 95% CI = 1.09 – 2.87) were significant predictors of incomplete immunization – **Table 4**. Community level predictors for incomplete immunization were rural community (aOR = 7.49, 95% CI = 4.84 – 11.59), low-income households (aOR = 1.56, 95% CI = 1.17 – 2.81), and living further than 30 minutes walking distance from the nearest vaccination facility (aOR = 2.15, 95% CI = 1.31 – 3.52).

Discussion

This study evaluated immunization coverage data in urban and rural areas of Enugu State and offers a close-up assessment of sociodemographic determinants of incomplete immunization at the sub-national and local level. There are four main findings from this study. First, this assessment of immunization coverage of children aged 12-23 months in 50 randomly selected wards in rural and urban districts (LGA) in Enugu State found FIC rate in Enugu state to be low, below the RED's subnational target of 80% immunization coverage. While the FIC rate in this study is higher than FIC rates reported in other sub-regions in Nigeria [33,41], and Ethiopia [42,43], it is lower than FIC rates reported in Cameroon [37], and Ghana [44]. The FIC rate is also substantially different from the FIC rate reported for Enugu State (36.4%) in the latest (2018) Nigeria DHS [25]. This could possibly be due some improvements in routine immunization coverage utilization likely occurred over the period (recall the 2018 DHS was conducted in 2017) driven by recent State Government efforts to boost vaccination coverage in the state [24], and differences in the sampling approach between the two surveys [25,26]. About one in five (21.1%) children aged 12-23 months in the state were not fully immunized. This suggests that even after almost two decades of implementing the RED strategy in Nigeria, some states in the southern region with purportedly high immunization coverage [14], did not yet meet the (RED's) subnational immunization target. This partially explains why huge investments in immunization activities have had minimal impact on the incidence of vaccine preventable diseases in Enugu State [45].

Secondly, further analysis based on rurality of residence reveals stark disparity in the FIC rate between urban communities and rural communities. Urban communities had a substantially higher FIC rate (94.5%) than rural communities (55.5%). This observation is consistent with findings in other sub-regions in Nigeria [41,46], and Ethiopia [42,43], but differs with findings in Bayelsa State, Nigeria where immunization coverage was higher in the rural community than in the urban community [47]. Our data show that almost half of infants in rural communities miss out on at least one of the critical life-saving BCG, Pentavalent, OPV, and Measles vaccines. This finding underscores the importance of monitoring data at sub-district levels to identify vaccination gaps and tailor operational strategies accordingly.

Thirdly, the low DPT-3 coverage in rural communities (63.0%) points to gaps in routine immunization delivery in those communities and is consistent with a study conducted in another rural community in Enugu[48]. Furthermore, the immunization dropout rate in both urban and rural communities is low, below the 10% cut-off recommended by WHO [49]. The low immunization dropout rate amidst low DPT-1 coverage in rural communities suggests that access to routine immunization services in these contexts remains a problem [49], as previous studies have argued[48]. There are many factors responsible for the rural-urban differences in access. For example, vaccination points are more geographically accessible to families in urban communities than in rural communities [10,50,51], rural communities incur higher travel costs to reach vaccination points[51], and rural communities are less aware of the importance of immunization[10,41].

Finally, predictors of incomplete immunization at the district level identified in this study include marital status, MHC utilization, poor knowledge of routine immunization, poor family income, and geographical accessibility. Children of single mothers are less likely to be fully immunized compared to married mothers. Married mothers are more financially stable and most likely to discuss the health needs of their children, including immunization [44,50]. Also, stigma, psychological trauma, and hardship associated with single motherhood in these context negatively impacts access to health and vaccination [44,50]. MHC utilization also significantly predicts incomplete immunization. Mothers who give birth using SBA are more likely to have them fully immunized than mothers who did not use SBA. Likewise, mothers who receive PNC care are more

likely to have their children fully immunized. This is consistent with several studies in other LMICs that demonstrate that increased health communications on immunization during MHC utilization significantly impacts childhood immunization [50,52]. However, given that the sequence of MHC utilization is ANC-SBA-PNC, the absence of a significant effect for ANC in this study does not imply that adequate ANC attendance does not impact routine immunization. Instead, our data suggest that other factors such as accessibility to health facilities could have a stronger impact on routine immunization than adequately attending ANC [53].

Strengths and limitations

Our study extends the body of knowledge on immunization uptake in rural areas vis-à-vis urban areas at the subnational level, our results can be generalized to similar contexts in Nigeria and beyond and provides important evidence to policymakers and program managers for improving immunization coverage. However, our study is not without limitations. First, the effects of health system factors including vaccine availability, health care personnel, and logistics [54,55], which are known to influence uptake of immunization coverage were not adequately explored. Also, paternal factors that may influence the completion of immunization were not also evaluated [50]. However, the primary goal of this study was not to assess the effect of these factors. Secondly, new vaccines recently introduced into the Nigeria routine immunization schedule (specifically, Rotavirus vaccine and Pneumococcal Conjugate Vaccine (PCV)) were not explored [56,57]. Thirdly, although maternal recall has been shown to be a reliable estimate of maternal recall in Senegal, Ethiopia, and Tanzania [38–40], there is little evidence that it is a reliable coverage measure in Nigeria. A similar study in Osun State showed that agreement between the mothers' recall and immunization card assessment was low [33]. This (maternal recall) could have also biased our estimates. Finally, pockets of hard-to-reach Fulani settlements that have been shown to have poor immunization coverage were not included in our sample [58]. Due to the deteriorating security situation in the country and the absence of security assurances, we could not send data collectors to these settlements.

Policy implications

Our study findings have policy implications for vaccination delivery in low- and middle-income countries laboring to improve national and subnational immunization coverage. Innovative solutions to improve geographical accessibility are undoubtedly needed to achieve IA2030 targets at local levels. Also, our study found that mothers who used MHC services were significantly more likely to have full immunized children suggesting that improving MHC utilization, especially in underserved rural communities, might be an effective strategy in achieving the IA2030 national and sub-national targets [52]. However, further studies, preferably randomized controlled trials, are needed to confirm if strategies aimed at improving MHC utilization actually improve immunization rate. Lastly, our study demonstrates the importance of reporting vaccination coverage at the local/district level to draw attention to regional inequities at that level and identify regions/districts for more targeted interventions.

Conclusions

The FIC rate in rural communities in Enugu State is below the RED target of 80 % for all antigens by 2020. About one in two children in rural communities in Enugu State is not fully immunized. Determinants of full immunization are single motherhood, maternal healthcare utilization, family income, rural residence, and geographical proximity to health facilities.

List of abbreviations

ANC	Antenatal care
BCG	Bacille Calmette Guerin
DPT	Diphtheria-Pertussis-Tetanus
EPI	Expanded program on immunization
FIC	Full immunization coverage
MHC	Maternal Healthcare
OPV	Oral polio vaccine
PNC	Postnatal care
SBA	Skilled birth attendant
TT	Tetanus toxoid
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Ethical Committee of the Enugu State University Teaching Hospital – Reference number: ESUTHP/C-MAC/RA/034/Vol1/264. Permission was also obtained from the State Ministry of Health, Enugu.

Informed verbal consent was obtained from each mother before participating in the study. Verbal consent was deemed appropriate and approved by the ethics committee. Informed verbal consent consisted of a description of the objectives of the study, assurance of confidentiality of personal information, and a specific request for permission to conduct the interview. Consent was obtained in Igbo (the local language) except for a few non-Igbo speaker whose consent was obtained in English. Where the mother was less than 18 years, consent to participate in the study was obtained from the husband (if mother was married) or from the mother's mother/father (if the mother was single).

Children with zero or incomplete immunization were referred to the nearest health center for vaccination. All patient identifiers were removed prior to statistical analysis.

Consent for publication

Not applicable

Availability of data and materials

The dataset generated and analyzed in this study is freely available from the corresponding author on reasonable request or directly from the data repository, Zenodo, http://doi.org/10.5281/zenodo.4294847

Competing interests

None declared.

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Author contributions

PE and YA conceptualized the study, oversaw its conduct, analyzed the data, interpreted the results, drafted the original article, and reviewed the final draft. UJA, CLA, SAA, and LOL contributed to the collection and analysis of the data, interpretation of the results, and review of the final draft. All authors read and approved the final manuscript.

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Authors' information (optional)

Not applicable

Caption for Figure 1

Figure 1: Map of Nigeria above showing Enugu State and Map of Enugu state showing the study area (four LGAs).

Adapted from image culled from Ugoyibo OV, Amaechi IF, Obinna AC. Evaluation of Groundwater Pollution Sources in Enugu North LGA of Enugu State , Nigeria. IJSAR J Environ Earth Phys Sci. 2015;2(3):54–69.

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Table 1: Socio-demographic characteristics of mother and children in Enugu State, Nigeria, July 2020

Socio-demographic characteristics	Frequency (N = 1,254)	Proportion (%)
Mothers' age		
– < 20 years	54	4.3%
– 20 – 29 years	602	48.0%
– ≥ 30 years	598	47.7%
Marital status		
– Single	50	4.0%
– Currently Married	1127	89.9%
– Divorced/Widowed	77	7.1%
Mothers' education		
– Primary or lower	77	6.1%
– Secondary or higher	1177	93.9%
Mothers' working status		
– Stay-at-home/Housewife	307	24.5%
– Working mom	947	75.5%
Religion		
– Christian	1,214	96.8%
– Islam/Muslim	20	1.6%
– African Traditional Religion	20	1.6%
Family monthly income **		
– < N40,000 (Approx. US $100)	544	43.4%
– N40,000 – N79,999	416	33.2%
– N80,000 – N119,999	256	20.4%
– ≥ N120,000	38	3.0%
Ethnic group		
– Igbo	1201	95.8%
– Others	53	4.2%
Sex/gender of child		
– Female	640	51.0%
– Male	614	49.0%
Birth order of child		
– First born	347	27.7%
– Second or third	625	49.8%
– Others	282	22.5%
Residence/Community		
– Rural	503	40.1%
– Urban	751	59.9%
Walking distance to nearest health facility		
– < 30-minutes' walk	546	43.5%
– ≥ 30-minutes' walk	708	56.5%
Source of information on Immunization (more than source applies)		
– Hospital/Health facility	913	72.8%

– Family/friends	789	62.9%
– Church/Mosque	328	26.2%
– TV, Radio, and social media	193	15.4%

** 1 USD = N400.00 on the Currency exchange market in July 2020; www.oanda.com

Table 2: Immunization coverage for routine immunization (RI) antigens in Enugu State, Nigeria, July 2020

RI Antigen	State-wide Coverage N = 1,254 n, (%, [95% CI])	Coverage in Urban communities N = 751 n, (%, [95% CI])	Coverage in Rural communities N = 503 n, (%, [95% CI])
Antigens administered at birth			
– BCG ##	1,136 (90.6%, [88.8% – 92.1%])	741 (98.7%, [97.6% – 99.4%])	395 (78.5%, [74.7% – 82.0%])
Antigens administered at 6 weeks			
– OPV 1	1,137 (90.7%, [88.9% – 92.2%])	742 (98.8%, [97.7% – 99.5%])	395 (78.5%, [74.7% – 82.0%])
– Penta 1	1,136 (90.6%, [88.8% – 92.1%])	738 (98.3%, [97.1% – 99.1%])	398 (79.1%, [75.2% – 82.7%])
Antigens administered at 10 weeks			
– OPV 2	1,083 (86.4%, [84.3% – 88.2%])	741 (98.7%, [97.6% – 99.4%])	342 (68.0%, [63.7% – 72.1%])
– Penta 2	1,090 (86.9%, [84.9% – 88.7%])	736 (98.0%, [96.7% – 98.9%])	354 (70.4%, [66.2% – 74.3%])
Antigens administered at 14 weeks			
– OPV 3 ##	1,042 (83.1%, [80.9% – 85.1%])	740 (98.5%, [97.4% – 99.3%])	302 (60.0%, [55.6% – 64.3%])
– Penta 3 ##	1.052 (83.9%, [81.7% – 85.9%])	735 (97.9%, [96.6% – 98.8%])	317 (63.0%, [58.6% – 67.3%])
Antigens administered at 9 months			
– Measles ##	1,101 (87.8%, [85.9% – 89.6%])	716 (95.3%, [93.6% – 96.7%])	385 (76.5%, [72.6% – 80.2%])
– Yellow fever	1,081 (86.2%, [84.2% – 88.1%])	720 (95.9%, [94.2% – 97.2%])	361 (71.8%, [67.6% – 75.7%])
Supplements			
– Vitamin A	1,059 (84.4%, [82.3% – 86.4%])	721 (96.0%, [94.3% – 97.3%])	338 (67.2%, [62.9% – 71.3%])
Immunization status ##			
– Fully immunized	989 (78.9%, [76.5% – 81.1%])	710 (94.5%, [92.7% – 96.1%])	279 (55.5%, [51.0% – 59.9%])
– Partially immunized	197 (15.7%, [13.7% – 17.8%])	34 (4.5%, [3.2% – 6.3%])	163 (32.4%, [28.3% – 36.7%])
– Unimmunized (Zero-dose)	68 (5.4%, [4.2% – 6.8%])	7 (0.9%, [0.4% – 1.9%])	61 (12.1%, [9.4% – 15.3%])

Vaccines included in the definition of immunization status (Fully immunized child vs Partially immunized vs Unimmunized)

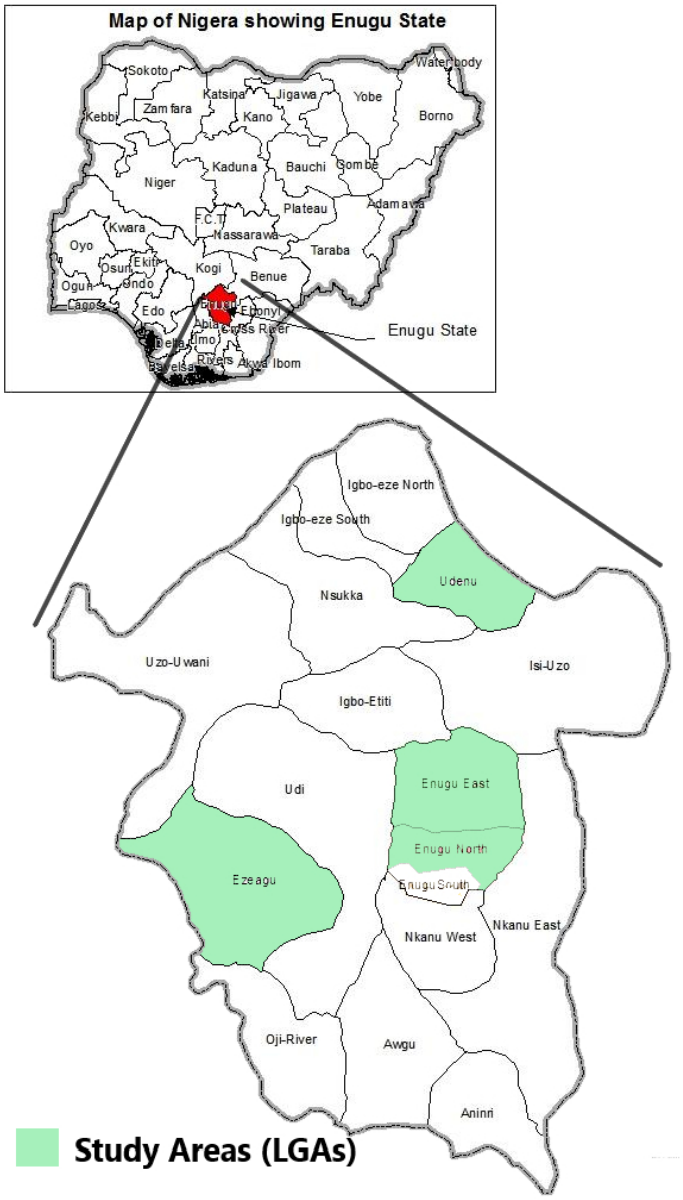
Table 3: Maternal health care utilization history and knowledge of routine immunization in Enugu State, Nigeria 2020

Characteristics	Fully immunized (n = 989)	Not fully immunized (n = 265)	Crude Odds ratio (95% CI)	p-value
MOTHERS' HEALTH CARE UTILIZATION HISTORY				
Use of Skilled birth attendants (SBA)				
– Yes (Hospital)	309 (84.7%)	56 (15.3%)	1.70 (1.23 – 2.35)	0.001
– No (TBA, Home delivery)	680 (76.5%)	209 (23.5%)		
Attended ante-natal care (ANC)				
– ≥ Four ante-natal visits	762 (77.8%)	217 (22.2%)	0.74 (0.53 – 1.05)	0.091
– < Four ante-natal visits	227 (82.5%)	48 (17.5%)		
Tetanus toxoid (TT) injection during pregnancy				
– ≥ 2 TT injections	784 (79.0%)	209 (21.0%)	1.03 (0.74 – 1.43)	0.888
– < 2 TT injection	205 (78.5%)	56 (21.5%)		
Attended post-natal care (PNC)				
– Yes	866 (89.2%)	105 (10.8%)	10.73 (7.87 – 14.63)	< 0.001
– No	123 (43.5%)	160 (56.5%)		
MOTHERS' AWARENESS OF ROUTINE IMMUNIZATION				
What do vaccines do to your child's body?				
– Vaccines help prevent illness	937 (78.5%)	256 (21.5%)	0.63 (0.31 – 1.30)	0.210
– Other responses **	44 (88.0%)	6 (12.0%)		
– I do not know **	8 (72.7%)	3 (27.3%)		
Mention any disease(s) children's vaccines can prevent				
– Mentioned Four (4) or more diseases	481 (90.6%)	50 (9.4%)	4.07 (2.92 – 5.68)	< 0.001
– Less than four (4) diseases **	502 (70.1%)	214 (29.9%)		
– I do not know **	6 (85.7%)	1 (14.3%)		
At what age does child immunization start?				
– Just after birth	858 (84.6%)	156 (15.4%)	4.58 (3.37 – 6.22)	< 0.001
– Stated other dates (1 week, 1 month, etc.) **	95 (50.3%)	94 (49.7%)		
– I do not know **	36 (70.6%)	15 (29.4%)		
When does a child complete his/her immunization?				
– 9 to 15 months	930 (79.6%)	238 (20.4%)	1.79 (1.11 – 2.88)	0.016
– < 6 months OR > 15 months **	51 (67.1%)	25 (32.9%)		
– I do not know **	8 (80.0%)	2 (20.0%)		
What is the age/schedule for each vaccine?				
– Correct schedule for three or more vaccines	952 (83.3%)	191 (16.7%)	9.97 (6.52 – 15.24)	< 0.001
– Other responses **	26 (26.3%)	73 (73.7%)		
– I do not know **	11 (91.7%)	1 (8.3%)		
How many HF visits are required for full immunization?				
– At least 5 or 6 visits	686 (80.4%)	167 (19.6%)	1.33 (1.00 – 1.76)	0.049
– < 5 visits **	183 (88.0%)	25 (12.0%)		
– I do not know **	120 (62.2%)	73 (37.8%)		
Scores for Knowledge of routine immunization				
– Mean Score (± Std Dev)	10.71 (1.61)	9.63 (1.82)	1.07 (0.83 – 1.32) ##	< 0.001

** These responses were combined for estimation of Crude OR. | ## Mean difference (95% CI) | Abbreviations: HF, Health Facility

Table 4: Determinants of immunization status of children aged 12-23 months in Enugu State, Nigeria, July 2020

Socio-demographic Characteristics	Reference	Adjusted OR	95% CI	p-value
INDIVIDUAL LEVEL FACTORS				
Mothers' age				
– < 20 years	20 – 29 years	0.17	0.03 – 1.06	0.058
– ≥ 30 years	20 – 29 years	0.87	0.57 – 1.34	0.534
Marital status				
– Single	Married	5.74	1.45 – 22.76	0.013
– Divorced/Widowed	Married	1.35	0.60 – 3.07	0.468
Mothers' educational status				
– Primary education or lower	Secondary education or higher	0.64	0.26 – 1.56	0.383
Mother's working status				
– Working mom	Stay-at-home/Housewife	1.08	0.63 – 1.85	0.327
Religion of family				
– Islam/Muslim	Christian	1.53	0.27 – 8.62	0.627
– African traditional	Christian	2.21	0.44 – 11.13	0.335
Sex of the child				
– Male	Female	0.98	0.66 – 1.45	0.914
Child's birth order				
– Second/third child	First child	1.52	0.78 – 2.98	0.220
– Fourth and later children	First child	1.34	0.48 – 3.74	0.577
MHC UTILIZATION & KNOWLEDGE OF RI				
Antenatal care (ANC)				
– < 4 ANC visits	≥ 4 ANC visits	1.52	0.71 – 3.22	0.472
Maternal tetanus toxoid (TT)				
– < 2 doses	≥ 2 doses	0.93	0.41 – 2.10	0.864
Use of Skilled birth attendants (SBA)				
– No	Yes	1.93	1.24 – 2.99	0.003
Postnatal care (PNC)				
– No	Yes	6.53	4.17 – 10.22	< 0.001
Mothers' knowledge of RI				
– Poor	Satisfactory	1.76	1.09 – 2.87	0.022
COMMUNITY LEVEL FACTORS				
Area of residence				
– Rural	Urban	7.49	4.84 – 11.59	< 0.001
Household monthly income				
– < N80,000 (Approx. USD 200)	≥ N80,000 (Approx. USD 200)	1.56	1.17 – 2.81	< 0.001
Distance to nearest vaccination point				
– ≥ 30 minutes' walk	< 30 minutes' walk	2.15	1.31 – 3.52	0.003



Map of Nigeria above showing Enugu State and Map of Enugu state showing the study area (four LGAs). Adapted from image culled from Ugoyibo OV, Amaechi IF, Obinna AC. Evaluation of Groundwater Pollution Sources in Enugu North LGA of Enugu State , Nigeria. IJSAR J Environ Earth Phys Sci. 2015;2(3):54–69.

56x85mm (300 x 300 DPI)

Supplement 1: Reasons mothers of zero-dose (unvaccinated) children gave for not vaccinating their children

Reasons	Frequency N = 68	Proportion (%)
◦ I was busy with other things	1	1.5%
◦ Child was too sick to receive vaccines	3	4.4%
◦ I did not know the schedule for vaccination	8	11.8%
◦ There were no vaccines in our health facility	26	38.2%
◦ My religion forbids vaccination	1	1.5%
◦ Vaccination site is too far	29	42.6%

Study Interview guide

Determinants of incomplete immunization in children aged 12 to 23 months in Enugu, Nigeria – a cross-sectional study

INSTRUCTIONS

1. Seek permission from the mother to participate before you commence. If mother is < 18 years old, seek permission of the husband (if mother is < 18 years old and married) or mother's mother/father (if mother is < 18years old and single)
2. If more than two children in the age bracket, only interview for the youngest child more than 12 months of age
3. Always be polite and courteous throughout the interview. NEVER Shout. NEVER Criticize.
4. Please complete ONE questionnaire for one/each child

Section A: Sociodemographic Data

1. **Local Government Area:** _____
2. **Cluster or Ward:** _____
3. **Mother's age**
   a. < 20 yrs
   b. 20 – 24 yrs
   c. 25 – 29 yrs
   d. 30 – 34 yrs
   e. ≥ 35 yrs
4. **Marital status**
   a. Single
   b. Married
   c. Divorced
   d. Widow
5. **Mother's education**
   a. None
   b. Primary
   c. Secondary
   d. Tertiary
6. **Mother's Occupation**
   a. Stay-at-home/Housewife
   b. Farmer
   c. Civil Servant
   d. Trader
   e. Artisan
7. **Tribe/Ethnicity**
   a. Igbo
   b. Hausa/Fulani
   c. Yoruba

d. Igala
e. Others

8. Family religion

a. Christian
b. Islam/Muslim
c. African Traditional Religion

9. Family monthly income

a. < N 40,000
b. N40,000 to N79,999
c. N80,000 to N119,999
d. ≥ N120,000

10. Sex of child

a. Female/Girl
b. Male/Boy

11. Birth order in the family

a. First born
b. Second or third born
c. Others

Section B: Prevalence & Determinants

1. **Has your child been vaccinated?**

A. YES
B. NO

>> If YES to Q1 above, when was your child vaccinated?

A. At the appropriate age
B. Later than appropriate date

2. **Please where is the Immunization card? Is the mother able to provide the card**?

A. YES
B. NO

>> If mother is NOT able to provide the card, Why?

A. Mother cannot find it during interview
B. Mother lost card before interview, i.e. could not find the card before the day of interview
C. Mother was not given any immunization card at health centre

3. **How many antenatal care visits did you attend while pregnant for this child?**

A. None, I did not attend any antenatal clinic
B. Only one visit
C. Two visits
D. Three visits
E. Four visits or more

4. **How many TT injections did you receive during pregnancy?**

A. None, I did not receive any TT injection

B. One injection
C. Two or more injections

12. Where did you deliver this child?

A. In a hospital
B. With Traditional birth attendants (TBA)
C. At home

5. **Did you attend any post-natal care consultation after delivering this child?**

A. YES
B. NO

6. **Where did you hear of vaccination**? (Please tick all that apply)

A. Hospital/Health facility
B. Family/friends
C. Church/Mosque
D. TV
E. Radio
F. Social media (Facebook, Twitter, WhatsApp, Instagram)

7. **What does vaccination do to your child's body?**

A. Vaccination prevent illnesses in children
B. Vaccines treat illnesses in children like drugs
C. Vaccines provide nutrients to children like food
D. I do not know

8. **Please mention any disease vaccination can prevent:**
(Use this list to assess mothers' response: Tuberculosis, Diphtheria, Whooping cough, Tetanus, Poliomyelitis, Hepatitis B virus infection, Measles, Pneumococcal pneumonia)

A. Mother mentions four (4) or more diseases
B. Mother mentions three (3) or fewer diseases
C. I do not know any diseases vaccination can prevent

9. **When do you start to vaccinate a child?**

A. Just after birth
B. 1 week after birth
C. 2 weeks after birth
D. 1 month after birth
E. Anytime
F. I do not know

10. **When does a child complete his routine vaccination?**

A. 6 months
B. 9 months
C. 12 months (1 year)
D. 15 months
E. 2 years
F. 5 years
G. I do not know

11. **Do you know the right age or schedule for routine vaccination of infants?**
(Use vaccination schedule on the paper titled, 'NPHCDA routine immunization schedule' to assess mothers' response)
    A. Mother mentions correct schedule for three (3) or more vaccines
    B. Mother mentions correct schedule for one or two vaccines
    C. I do not know

12. **How many visits are needed to complete the immunization for a child**
    A. One (1) visit
    B. 2 or 3 visits
    C. 5 or 6 visits
    D. I do not know

13. **Using the Google Map app on your phone, how far is the nearest vaccination centre to this house?**
    A. Less than 30 mins walk
    B. About or more 30 mins' walk

Section C: Immunization status

If you answered YES to Question 1 above, which of these vaccines has he/she received?

Step 1: FIRST, ask the mothers to know how many vaccinations she can recall, and tick accordingly

Step 2: Then, cross check with the Vaccination/Immunization Card, and tick accordingly

S/n	Vaccine	Age	1). Mothers recall		2). Immunization Card	
			YES	NO	YES	NO
1	BCG	At birth				
2	OPV-1	6 weeks				
3	OPV-2	10 weeks				
4	OPV-3	14 weeks				
5	Pentavalent – 1	6 weeks				
6	Pentavalent – 2	10 weeks				
7	Pentavalent – 3	14 weeks				
8	Vitamin A	6 months				
9	Measles vaccine	9 months				
10	Yellow fever	9 months				

** The END **

Thank the mother profusely …. Daalu nnukwu / Thank you very much!!

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2,3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	3,4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	5
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	5
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5
		(*b*) Report category boundaries when continuous variables were categorized	5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	6,7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6
Generalisability	21	Discuss the generalisability (external validity) of the study results	7
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Factors associated with incomplete immunization in children aged 12 to 23 months at sub-national level, Nigeria – a cross-sectional study

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Research Article

Factors associated with incomplete immunization in children aged 12-23 months at sub-national level, Nigeria – a cross-sectional study

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Word Count

Abstract: 297 words (Max, 300) | **Text:** 3,861 words (Max, 4,000) | **Table/figures:** 4 + 1 (Max, 5) | **References:** 60 (Max, NA)

Abstract

Objectives: National immunization coverage rate masks sub-national immunization coverage gaps at the state and local district levels. The objective of the current study was to determine the socio-demographic factors associated with incomplete immunization in children at a sub-national level.

Design: Cross-sectional study using the World Health Organization sampling method (2018 Reference Manual).

Setting: Fifty randomly selected clusters (wards) in four districts (two urban and two rural) in Enugu State, Nigeria.

Participants: 1,254 mothers of children aged 12-23 months in July 2020.

Primary and secondary outcome measures: Fully immunized children and not fully immunized children.

Results: Full immunization coverage (FIC) rate in Enugu State was 78.9% (95% CI = 76.5% – 81.1%]). However, stark difference exists in FIC rate in urban versus rural districts. Only 55.5% of children in rural communities are fully immunized compared to 94.5% in urban communities. Significant factors associated with incomplete immunization are: children of single mothers (aOR = 5.74, 95% CI = 1.45 – 22.76), children delivered without skilled birth attendant present (aOR = 1.93, 95% CI = 1.24 – 2.99), children of mothers who did not receive postnatal care (aOR = 6.53, 95% CI = 4.17 – 10.22), children of mothers with poor knowledge of routine immunization (aOR = 1.76, 95% CI = 1.09 – 2.87), dwelling in rural district (aOR = 7.49, 95% CI = 4.84 – 11.59), low-income families (aOR = 1.56, 95% CI = 1.17 – 2.81), and living further than 30 minutes from the nearest vaccination facility (aOR = 2.15, 95% CI = 1.31 – 3.52).

Conclusions: Although the proportion of fully-immunized children in Enugu State is low, it is significantly lower in rural districts. Study findings suggest the need for innovative solutions to improve geographical accessibility and reinforce the importance of reporting vaccination coverage at local district level to identify districts for more targeted interventions.

Strengths and limitations of this study

- The estimates presented in the study for the sub-national level are potentially more accurate than previous estimates.
- We adhered to the guidelines in WHO Vaccination Coverage Cluster Surveys Reference Manual 2019, thus enabling greater comparability with future studies using the same method.
- Due to the observational cross-sectional design, we cannot establish a causal relationship between these factors and vaccination.
- This study considerably relied on maternal recall which can lead to overestimation or underestimation of immunization coverage estimates.
- We were unable to access pockets of historically healthcare-marginalized population in one of the settlements due to security concerns.

Keywords: Routine immunization, Vaccination coverage, Children, Nigeria

Introduction

Immunization, defined as the process that makes a person immune or resistant to an infectious disease, typically by the administration of a vaccine, is one of the most effective interventions in contemporary public health practice [1,2]. Several cost-benefits analyses have consistently placed immunization as one of the most cost-effective health interventions with huge direct and societal benefits [3–8]. Immunization saves about 2-3 million lives every year [1,2], and has successfully led to the elimination of a number of vaccine-preventable diseases in some high-income countries, including polio, diphtheria, and pertussis [3,9]. Indeed, childhood immunization has had a remarkable impact on child morbidity and mortality worldwide with immense positive multiplier effects on the larger communities [3,5,9].

Nigeria is one of the 10 countries (Angola, Brazil, the Democratic Republic of the Congo, Ethiopia, India, Indonesia, Mexico, Nigeria, Pakistan, and the Philippines) that account for over 60% of the children who did not get DPT3 in 2019 [1]. DTP3 coverage is an indicator of how well countries are providing routine immunization services [2]. In 2017, about 20% of the world's infants with incomplete DPT immunization lived in Nigeria [10]. Three million of the estimated 8.9 million infants in the WHO African Region who did not receive any measles containing vaccine in 2015 live in Nigeria [11]. Hence, Nigeria accounts for nearly 40% of the 28,279 confirmed measles cases reported from the WHO African Region in 2016 [12].

The Expanded Program on Immunization in Nigeria, created in 1979, had a significant impact during the first few years with immunization coverage peaking at 81.5% in 1990 [13–15]. Immunization coverage plummeted to 12.3% in 2003 [15], due to a myriad of factors including low government commitment to EPI policy, over-centralization in the administration of EPI at the federal level, collapse of the primary healthcare service upon which EPI services were delivered, and vaccination refusal mostly due to religious beliefs in the northern part of the country [15]. Several strategies were deployed in subsequent years

to address the low immunization coverage, including routine immunization strengthening, supplemental immunization activities, global positioning system tracker, and several community-level interventions [16]. Despite these efforts, preliminary results of the 2019 National Nutrition and Health Survey suggests a national DTP3 coverage of 67% [17]. However, even the low national immunization coverage rates mask subnational immunization coverage gaps at the state and local district levels [18]. For example, immunization coverage ranged from 5% to 48% across states in northern Nigeria in the 2018 National Demographic and Health Survey (DHS) [19].

The Immunization Agenda 2030 (IA2030) is a global strategy led by the World Health Organization (WHO) to ensure every child is protected by full immunization, regardless of location, age, socioeconomic status, or gender-related barriers by 2030 [20]. Despite overall improvements in immunization coverage at the national level [21], geographic variations in the immunization coverage persists at most sub-national and district levels [18]. Achieving geographical parity, however, depends on capturing and understanding local patterns of coverage required to provide optimal, child-focused vaccine delivery services [1,18]. Also, while nationally representative surveys such as the Demographic and Health Survey (DHS) and Multiple Indicator Cluster Survey (MICS) have a standardized data collection procedures across countries that is also consistent over time [22], presenting immunization coverage at national levels fails to capture the all-important local patterns of coverage required to properly fine-tune vaccine delivery services. Furthermore, relying on sub-national administrative data for assessing immunization system performance and tracking progress is often fraught with limitations such as missing data and poor data quality [18,23].

This study seeks to identify the factors associated with incomplete immunization at the sub-national level using Enugu State as point of focus. Enugu State has a high number of unimmunized children[24], and has the lowest proportion of children with complete immunization in the southeast region [25]. Hence, employing the World Health Organization multi-stage sampling methods for community survey [26], this study aims to identify the sociodemographic factors associated with incomplete immunization in children aged 12 to 23 months at a sub-national and local level. Our findings could help tailor strategies and operational plans to address immunization gaps and reach children in every district with life-saving vaccines.

Methods

This was a community-based cross-sectional survey of mothers of children 12–23 months old residing in Enugu State in July 2020. The study considered all children 12–23 months old eligible for sampling, and used the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines to ensure appropriate reporting of its study's design, conduct, and findings [27].

Study setting

Nigeria is the most populous country in Africa and the sixth most populous in the world [28]. She is located in Western Africa and is divided into six geopolitical regions: Northeast, Northwest, Northcentral, Southsouth, Southeast and Southwest. She has 36 states – the second administrative division, and a federal capital territory in Abuja. Each state is further divided into smaller administrative units called local government areas (LGA) and each LGA is further divided into wards.

Enugu State is one of the 36 states in Nigeria (**Figure 1**) and one of the five states that make up the southeast geopolitical region in the country. Enugu State is further divided into 17 LGAs, four of which are predominantly urban (Enugu East, Enugu North, Enugu South, and Nsukka) and the rest are predominantly rural. Enugu State's 2020 projected population is 4,769,916, with most of the population living in urban centres in Enugu and Nsukka [29,30].

Sample size

Using steps described in the WHO Vaccination Coverage Cluster Surveys Reference Manual 2019 [26], we determined the sample size using immunization coverage of 36.0% obtained for Enugu State in the most recent 2018 Nigeria DHS [25], significance level of 5.0%, precision of 5.0%, design effect of 2.5 [31], and an inflation of 15% (to account for non-response). The calculated minimum sample size was 1,183 which we increased to 1,250 to boost the power of the study.

Sampling procedure

We used a three-stage sampling technique. In the first stage, we used a simple random sampling technique by balloting to select four local government areas: two each from the urban and rural areas of the state. In the second stage, we randomly selected (by balloting) a total of 50 clusters based on probability-proportional-to- population: 15 clusters from Enugu East LGA, 15 clusters from Enugu North LGA, and 10 clusters each from Ezeagu LGA and Udenu LGA. In the third stage, we selected 25 households in each of the 50 clusters (ward). In each cluster, we selected the first household randomly and subsequent households contiguously in the right direction until we achieved the required number of households for that cluster. From each selected household, we selected one eligible child. If a selected household had more than one eligible child, we selected the youngest child older than 12 months. If a selected household had no eligible child, we visited the next contiguous household, and selected one eligible child.

Data collection

A team of 14 trained community health workers (CHW) collected the data using structured pre-tested interviewer-administered questionnaires. We constructed the questionnaire from a review of the available literature on immunization surveys in similar contexts [32–34], and tested it for acceptability and logical structure in a sample of 20 mothers before the study. Prior to the survey, we trained the team on the study's objectives, interpreting, and extracting data from health cards/vaccination certificates, sampling techniques, walking distance estimation using Google® Maps mobile app, ethical issues including the process of taking informed verbal consent, and administration of the questionnaire. We administered the questionnaire in Igbo (the local language) except for a few non-Igbo speakers whom we administered the questionnaire in English. The research team directed the questions to the mothers and recorded only their responses.

Data we collected include socio-demographic characteristics of mothers and children including maternal healthcare (MHC) utilization [ante-natal care (ANC), skilled birth attendant (SBA) present at birth, and post-natal care (PNC)], knowledge of mothers regarding RI, immunization status of children, and reasons for any non-vaccination. If the immunization card was available, we recorded immunization information of each inoculation the child received. If a child had never received an immunization card or the mother was unable to present the immunization card to the interviewer, the immunization data/information for the child was based on the mother's report.

We used Google® Map mobile app on smartphones to estimate the walking distance from each study participant's house to the nearest vaccination center in all but four clusters (in Ezeagu LGA). In these four clusters, we first identified the nearest routine childhood vaccination point in each cluster and then estimated the walking distance from this nearest vaccination facility to each household included in the study. To evaluate mothers' knowledge of routine immunization and vaccine-preventable diseases, the interviewers asked questions on the correct purpose of immunization, different vaccine-preventable diseases, the correct age for receiving the vaccines, and the total number of visits required to complete the recommended vaccination for the child. We evaluated the responses as per the National Primary Healthcare Development Agency routine immunization schedule [35]. We coded correct responses as 2 points, incorrect responses 1 point, 'I do not know' 0 (zero) point.

Outcome variable

We categorized children as fully immunized, partially immunized, or un-immunized (zero-dose) based on the types and doses of antigens received. We defined a "fully immunized child" as a child who had received one dose of BCG, three doses of polio vaccine (excluding OPV given at birth), three doses of pentavalent vaccine, and one dose of measles vaccine by 12 months of age. Likewise, we defined a partially immunized child as a child who missed at least any one of the above doses, and an "un-immunized" or "zero-dose" child as a child who had not received any vaccine by 12 months of age [36]. Incomplete immunization, in this study, includes partially immunized children and unimmunized (zero-dose) children. Immunization status was based on mothers' recall and immunization card record (that is, where the mother presents an immunization card, the child's immunization status is based on records in the card, but where an immunization card is not available, the immunization status is based on mothers' recall) as recommended by the World Health Organization [26]. A number of other

studies have used this method [32,37], which has proven to be a reliable assessment of immunization coverage [38–40]. We did not include Vitamin A and Yellow fever vaccines in determining complete immunization status for this study.

Data analysis

We entered the data into Microsoft Excel® (Microsoft, Redmond, WA, USA), cleaned and transferred to IBM SPSS® version 27.0 (IBM, Armonk, NY, USA) for statistical analyses. We used frequency and percentage to describe the data, and Chi-square test to test for statistical significance. We used t-test to assess for statistical difference in the mean scores for knowledge of routine immunization. We conducted multivariate logistics regression analyses to estimate adjusted odds ratios with 95 % Confidence Interval (CI) while adjusting for mothers age, marital status, mothers educational status, mothers occupation, religion, ethnic/tribal group, family monthly income, sex of the index child, and source of information on immunization. We dichotomized aggregate scores for questions on awareness of routine immunization into satisfactory knowledge (10 points and above) and poor knowledge (less than 10 points) prior to inclusion in the regression model. We used $P<0.05$ to define statistical significance, and all tests were two-tailed.

Patient and Public Involvement

No patients nor the public were involved in developing the research question and study design or in the implementation of the study design, the interpretation of the results and writing of the manuscript. There are no plans to share the study with patients, will share with the public through open access publishing.

Results

Socio-demographic characteristics of mothers and children

We interviewed 1,254 distinct mothers with mean (SD) age of 28.7 (4.3) years. Forty-eight percent of mothers were aged 20 – 29 years old, about 89.9% were married, 93.9% had at least secondary education or higher, and about three-quarters (75.5%) were employed. The mean (SD) age of the children was 16.8 (3.3) months, the age ranged from 12 to 23 months, and about half (51.0%) were girls – **Table 1**.

Full immunization coverage (FIC) rate

The FIC rate in Enugu State was 78.9% (95% CI = 76.5% – 81.1%), the partially immunized rate was 15.7% (95% CI = 13.7% – 17.8%), while the unimmunized (zero-dose) rate was 5.4% (95% CI = 4.2% – 6.8%) – **Table 2**. Vaccination coverage rates for Yellow fever vaccine and Vitamin A supplement were 86.2% (95% CI = 84.2% – 88.1%) and 84.4% (82.3% – 86.4%), respectively. DPT3 vaccination coverage rate, which is Pentavalent-3 coverage rate in this study, was 83.9% (95% CI = 81.7% – 85.9%).

Immunization coverage rates differed based on the rurality-urbanity of communities in the state. FIC rate was 94.5% (95% CI = 92.7% – 96.1%) in urban communities and 55.5% (95% CI = 51.0% – 59.9%) in rural communities. In both urban and rural communities, the proportion of children vaccinated with antigens given at birth and six weeks of age were more than the proportions of children vaccinated with antigens given at later ages. Of the 1,254 children, 578 possessed immunization cards, indicating an immunization card retention rate of 48.7% (95% CI = 45.9% - 51.6%). About two-fifth of unvaccinated (zero-dose) children were not vaccinated because vaccination sites were too far while another two-fifth reported absence of vaccines in the health facility (**Supplement 1**).

Factors associated with immunization status

Table 3 shows results from a bivariate analysis of maternal health care utilization history and knowledge of routine immunization. Use of skilled birth attendants (SBA) during delivery of index child, and reception of postnatal care (at least one postnatal visit) were statistically significant factors associated with incomplete immunization. Insufficient knowledge of routine immunization was also statistically significantly associated with incomplete immunization.

Multivariate logistic regression model was statistically significant, $\chi^2(25) = 24.217$, p = 0.002. The model explained 57.0% (Nagelkerke R^2) of the variance in immunization status and correctly classified 90.7% of cases. Single mothers (aOR = 5.74, 95% CI = 1.45 – 22.76), mothers who delivered without SBA (aOR = 1.93, 95% CI = 1.24 – 2.99), mothers who did not receive any postnatal care (aOR = 6.53, 95% CI = 4.17 – 10.22), and mothers with poor knowledge of routine immunization (aOR = 1.76, 95% CI = 1.09 – 2.87) were significant factors associated with incomplete immunization – **Table 4**. Community level factors associated with incomplete immunization were rural community (aOR = 7.49, 95% CI = 4.84 – 11.59), low-income households (aOR = 1.56, 95% CI = 1.17 – 2.81), and living further than 30 minutes walking distance from the nearest vaccination facility (aOR = 2.15, 95% CI = 1.31 – 3.52).

Discussion

This study evaluated immunization coverage data in urban and rural areas of Enugu State and offers a close-up assessment of sociodemographic factors associated with incomplete immunization at the sub-national and local level. There are four main findings from this study. First, this assessment of immunization coverage of children aged 12-23 months in 50 randomly selected wards in rural and urban districts (LGA) in Enugu State found FIC rate in Enugu state to be low, below the RED's subnational target of 80% immunization coverage. About one in five (21.1%) children aged 12-23 months in the state were not fully immunized. This suggests that even after almost two decades of implementing the RED strategy in Nigeria, some states in the southern region with purportedly high immunization coverage [14] did not yet meet the (RED's) subnational immunization target. This partially explains why huge investments in immunization activities have had minimal impact on the incidence of vaccine preventable diseases in Enugu State [41].

The FIC rate in this study is higher than FIC rates reported in other sub-regions in Nigeria [33,41], and Ethiopia [42,43], and lower than FIC rates reported in Cameroon [37] and Ghana [44]. The FIC rate is also substantially higher than the FIC rate reported for Enugu State (36.4%) in the latest (2018) Nigeria DHS [25]. There are three possible reasons for this difference. The first reason relates to the definition of FIC: FIC was defined for DHS as having received one dose of BCG, one dose of measles, three doses of DPT, and three doses of OPV vaccines ([25], pg. 224). FIC for this study was likewise defined as in DHS, but for OPV, we defined as three doses of polio vaccine instead, that is either three doses of OPV or two doses of OPV and one dose of IPV [42], in line with the Polio Endgame Strategy 2019-2023 [43]. To illustrate how the difference in FIC definition drives the overall rates, we calculated FIC by applying our definition to the DHS data which shows that FIC rates in the current study and DHS are within 11 percentage points when our definition of FIC is used (**Supplement 2**). Additionally, difference in the sampling approaches used in our study and DHS, and the resulting differences in the characteristics of the sample could explain some of the difference. A comparison of demographic characteristics of our sample with that of the DHS sample (in Enugu state) shows that mothers in our sample are more educated and more likely to be working (**Supplement 3**). It is reasonable to expect a higher FIC among these mothers [10,34]. Strikingly, children in our sample are of lower birth order than in the DHS and disproportionately from rural area. It appears that higher vaccination rates among younger more educated and working mothers is less than offset by lower vaccination rate among children of lower birth order and those from rural areas. Finally, a portion of the difference could be due to the State Government's recent efforts to boost vaccination coverage in the state since the 2018 Nigeria DHS [24].

Secondly, further analysis based on rurality of residence reveals stark disparity in the FIC rate between urban communities and rural communities. Urban communities had a substantially higher FIC rate (94.5%) than rural communities (55.5%). This observation is consistent with findings in other sub-regions in Nigeria [44,45], and Ethiopia [46,47], but differs with findings in Bayelsa State, Nigeria where immunization coverage was higher in the rural community than in the urban community [48]. Our data show that almost half of infants in rural communities miss out on at least one of the critical life-saving BCG, Pentavalent, Polio, and Measles vaccines. This finding underscores the importance of monitoring data at sub-district levels to identify vaccination gaps and tailor operational strategies accordingly.

Thirdly, the low DPT-3 coverage in rural communities (63.0%) points to gaps in routine immunization delivery in those communities and is consistent with a study conducted in another rural community in Enugu [49]. Furthermore, the immunization dropout rate in both urban and rural communities is low, below the 10% cut-off recommended by WHO [50].

The low immunization dropout rate (< 10.0%) and the low DPT-1 coverage in rural communities (78.5%) together suggests that access to routine immunization services in these contexts remains a problem [50], as a previous study have suggested [49]. There are many factors responsible for the rural-urban differences in access. For example, vaccination points are more geographically accessible to families in urban communities than in rural communities [10,51,52], rural communities incur higher travel costs to reach vaccination points[52], and rural communities are less aware of the importance of immunization[10,44].

Finally, marital status, MHC utilization, poor knowledge of routine immunization, poor family income, and geographical accessibility were associated with incomplete immunization at the district level. Children of single mothers are less likely to be fully immunized compared to married mothers. Married mothers are more financially stable and most likely to discuss the health needs of their children, including immunization [51,53]. Also, stigma, psychological trauma, and hardship associated with single motherhood in these context negatively impacts access to health and vaccination [51,53]. MHC utilization also significantly predicts incomplete immunization. Mothers who give birth using SBA are more likely to have them fully immunized than mothers who did not use SBA. Likewise, mothers who receive PNC care are more likely to have their children fully immunized. This is consistent with several studies in other LMICs that demonstrate that increased health communications on immunization during MHC utilization was significantly associated with childhood immunization [51,54]. However, given that the sequence of MHC utilization is ANC-SBA-PNC, the absence of a significant effect for ANC in this study does not imply that adequate ANC attendance is not associated with routine immunization. Instead, our data suggest that other factors such as accessibility to health facilities could have a stronger association with routine immunization than adequately attending ANC [55].

Strengths and limitations

Our study extends the body of knowledge on immunization uptake in rural areas vis-à-vis urban areas at the subnational level, our results can be generalized to similar contexts in Nigeria and beyond and provides important evidence to policymakers and program managers for improving immunization coverage. However, our study is not without limitations. First, health system factors including vaccine availability, health care personnel, and logistics [56,57], which are known to influence uptake of immunization coverage were not adequately explored. Also, paternal factors that may influence the completion of immunization were not evaluated [51]. However, the primary goal of this study was not to assess the effect of these factors. Secondly, new vaccines recently introduced into the Nigeria routine immunization schedule (specifically, Rotavirus vaccine and Pneumococcal Conjugate Vaccine (PCV)) were not explored [58,59]. Thirdly, although maternal recall has been shown to be a reliable estimate of maternal recall in Senegal, Ethiopia, and Tanzania [38–40], there is little evidence that it is a reliable coverage measure in Nigeria. A similar study in Osun State showed that agreement between the mothers' recall and immunization card assessment was low [33]. This (maternal recall) could have also biased our estimates. Finally, pockets of hard-to-reach Fulani settlements that have been shown to have poor immunization coverage were not included in our sample [60]. Due to the deteriorating security situation in the country and the absence of security assurances, we could not send data collectors to these settlements.

Policy implications

Our study findings have policy implications for vaccination delivery in low- and middle-income countries attempting to improve national and subnational immunization coverage. Innovative solutions to improve geographical accessibility are undoubtedly needed to achieve IA2030 targets at local levels. Also, our study found that mothers who used MHC services were significantly more likely to have full immunized children suggesting that improving MHC utilization, especially in underserved rural communities, might be an effective strategy in achieving the IA2030 national and sub-national targets [54]. However, further studies, preferably randomized controlled trials, are needed to confirm if strategies aimed at improving MHC utilization actually improve immunization rate. Lastly, our study demonstrates the importance of reporting vaccination coverage at the local/district level to draw attention to regional inequities at that level and identify regions/districts for more targeted interventions.

Conclusions

The FIC rate in rural communities in Enugu State is below the RED target of 80% for all antigens by 2020. About one in two children in rural communities in Enugu State is not fully immunized. Socio-demographic factors associated with full immunization at the sub-national level are single motherhood, maternal healthcare utilization, family income, rural residence, and geographical proximity to health facilities.

List of abbreviations

ANC	Antenatal care
BCG	Bacille Calmette Guerin
DPT	Diphtheria-Pertussis-Tetanus
EPI	Expanded program on immunization
FIC	Full immunization coverage
IPV	Inactivated Polio vaccine
MHC	Maternal Healthcare
OPV	Oral polio vaccine
PNC	Postnatal care
SBA	Skilled birth attendant
TT	Tetanus toxoid
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval for the study was obtained from the Ethical Committee of the Enugu State University Teaching Hospital – Reference number: ESUTHP/C-MAC/RA/034/Vol1/264. Permission was also obtained from the State Ministry of Health, Enugu.

Informed verbal consent was obtained from each mother before participating in the study. Verbal consent was deemed appropriate and approved by the ethics committee. Informed verbal consent consisted of a description of the objectives of the study, assurance of confidentiality of personal information, and a specific request for permission to conduct the interview. Consent was obtained in Igbo (the local language) except for a few non-Igbo speaker whose consent was obtained in English. Where the mother was less than 18 years, consent to participate in the study was obtained from the husband (if mother was married) or from the mother's mother/father (if the mother was single).

Children with zero or incomplete immunization were referred to the nearest health center for vaccination. All patient identifiers were removed prior to statistical analysis.

Consent for publication

Not applicable

Availability of data and materials

The dataset generated and analyzed in this study is freely available from the corresponding author on reasonable request or directly from the data repository, Zenodo; http://doi.org/10.5281/zenodo.4294847

Competing interests

None declared.

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Author contributions

PE and YA conceptualized the study, oversaw its conduct, analyzed the data, interpreted the results, drafted the original article, and reviewed the final draft. UJA, CLA, SAA, and LOL contributed to the collection and analysis of the data, interpretation of the results, and review of the final draft. All authors read and approved the final manuscript.

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Authors' information (optional)

Not applicable

Caption for Figure 1

Figure 1: Map of Nigeria above showing Enugu State and Map of Enugu state showing the study area (four LGAs).

Adapted from image culled from Ugoyibo OV, Amaechi IF, Obinna AC. Evaluation of Groundwater Pollution Sources in Enugu North LGA of Enugu State , Nigeria. IJSAR J Environ Earth Phys Sci. 2015;2(3):54–69.

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Table 1: Socio-demographic characteristics of mother and children in Enugu State, Nigeria, July 2020

Socio-demographic characteristics	Frequency (N = 1,254)	Proportion (%)
Mothers' age		
– < 20 years	54	4.3%
– 20 – 29 years	602	48.0%
– ≥ 30 years	598	47.7%
Marital status		
– Single	50	4.0%
– Currently Married	1127	89.9%
– Divorced/Widowed	77	7.1%
Mothers' education		
– Primary or lower	77	6.1%
– Secondary or higher	1177	93.9%
Mothers' working status		
– Stay-at-home/Housewife	307	24.5%
– Working mom	947	75.5%
Religion		
– Christian	1,214	96.8%
– Islam/Muslim	20	1.6%
– African Traditional Religion	20	1.6%
Family monthly income **		
– < N40,000 (Approx. US $100)	544	43.4%
– N40,000 – N79,999	416	33.2%
– N80,000 – N119,999	256	20.4%
– ≥ N120,000	38	3.0%
Ethnic group		
– Igbo	1201	95.8%
– Others	53	4.2%
Sex/gender of child		
– Female	640	51.0%
– Male	614	49.0%
Birth order of child		
– First born	347	27.7%
– Second or third	625	49.8%
– Others	282	22.5%
Residence/Community		
– Rural	503	40.1%
– Urban	751	59.9%
Walking distance to nearest health facility		
– < 30-minutes' walk	546	43.5%
– ≥ 30-minutes' walk	708	56.5%
Source of information on Immunization (more than source applies)		
– Hospital/Health facility	913	72.8%

– Family/friends	789	62.9%
– Church/Mosque	328	26.2%
– TV, Radio, and social media	193	15.4%

** 1 USD = N400.00 on the Currency exchange market in July 2020; www.oanda.com

Table 2: Immunization coverage for routine immunization (RI) antigens in Enugu State, Nigeria, July 2020

RI Antigen	State-wide Coverage N = 1,254 n, (%, [95% CI])	Coverage in Urban communities N = 751 n, (%, [95% CI])	Coverage in Rural communities N = 503 n, (%, [95% CI])
Antigens administered at birth			
– BCG ##	1,136 (90.6%, [88.8% – 92.1%])	741 (98.7%, [97.6% – 99.4%])	395 (78.5%, [74.7% – 82.0%])
Antigens administered at 6 weeks			
– OPV 1	1,137 (90.7%, [88.9% – 92.2%])	742 (98.8%, [97.7% – 99.5%])	395 (78.5%, [74.7% – 82.0%])
– Penta 1	1,136 (90.6%, [88.8% – 92.1%])	738 (98.3%, [97.1% – 99.1%])	398 (79.1%, [75.2% – 82.7%])
Antigens administered at 10 weeks			
– OPV 2	1,083 (86.4%, [84.3% – 88.2%])	741 (98.7%, [97.6% – 99.4%])	342 (68.0%, [63.7% – 72.1%])
– Penta 2	1,090 (86.9%, [84.9% – 88.7%])	736 (98.0%, [96.7% – 98.9%])	354 (70.4%, [66.2% – 74.3%])
Antigens administered at 14 weeks			
– OPV 3 ##	1,042 (83.1%, [80.9% – 85.1%])	740 (98.5%, [97.4% – 99.3%])	302 (60.0%, [55.6% – 64.3%])
– Penta 3 ##	1.052 (83.9%, [81.7% – 85.9%])	735 (97.9%, [96.6% – 98.8%])	317 (63.0%, [58.6% – 67.3%])
Antigens administered at 9 months			
– Measles ##	1,101 (87.8%, [85.9% – 89.6%])	716 (95.3%, [93.6% – 96.7%])	385 (76.5%, [72.6% – 80.2%])
– Yellow fever	1,081 (86.2%, [84.2% – 88.1%])	720 (95.9%, [94.2% – 97.2%])	361 (71.8%, [67.6% – 75.7%])
Supplements			
– Vitamin A	1,059 (84.4%, [82.3% – 86.4%])	721 (96.0%, [94.3% – 97.3%])	338 (67.2%, [62.9% – 71.3%])
Immunization status ##			
– Fully immunized	989 (78.9%, [76.5% – 81.1%])	710 (94.5%, [92.7% – 96.1%])	279 (55.5%, [51.0% – 59.9%])
– Partially immunized	197 (15.7%, [13.7% – 17.8%])	34 (4.5%, [3.2% – 6.3%])	163 (32.4%, [28.3% – 36.7%])
– Unimmunized (Zero-dose)	68 (5.4%, [4.2% – 6.8%])	7 (0.9%, [0.4% – 1.9%])	61 (12.1%, [9.4% – 15.3%])

Vaccines included in the definition of immunization status (Fully immunized child vs Partially immunized vs Unimmunized)

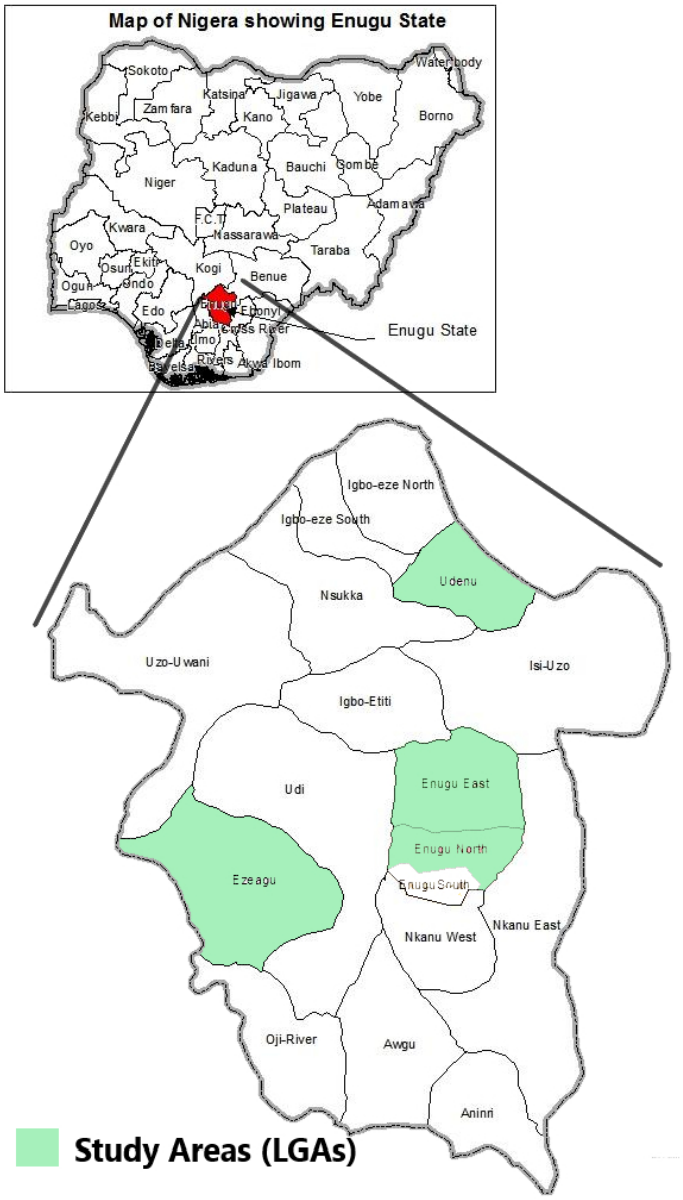
Table 3: Maternal health care utilization history and knowledge of routine immunization in Enugu State, Nigeria 2020

Characteristics	Fully immunized (n = 989)	Not fully immunized (n = 265)	Crude Odds ratio (95% CI)	p-value
MOTHERS' HEALTH CARE UTILIZATION HISTORY				
Use of Skilled birth attendants (SBA)				
– Yes (Hospital)	309 (84.7%)	56 (15.3%)	1.70 (1.23 – 2.35)	0.001
– No (TBA, Home delivery)	680 (76.5%)	209 (23.5%)		
Attended ante-natal care (ANC)				
– ≥ Four ante-natal visits	762 (77.8%)	217 (22.2%)	0.74 (0.53 – 1.05)	0.091
– < Four ante-natal visits	227 (82.5%)	48 (17.5%)		
Tetanus toxoid (TT) injection during pregnancy				
– ≥ 2 TT injections	784 (79.0%)	209 (21.0%)	1.03 (0.74 – 1.43)	0.888
– < 2 TT injection	205 (78.5%)	56 (21.5%)		
Attended post-natal care (PNC)				
– Yes	866 (89.2%)	105 (10.8%)	10.73 (7.87 – 14.63)	< 0.001
– No	123 (43.5%)	160 (56.5%)		
MOTHERS' AWARENESS OF ROUTINE IMMUNIZATION				
What do vaccines do to your child's body?				
– Vaccines help prevent illness	937 (78.5%)	256 (21.5%)	0.63 (0.31 – 1.30)	0.210
– Other responses **	44 (88.0%)	6 (12.0%)		
– I do not know **	8 (72.7%)	3 (27.3%)		
Mention any disease(s) children's vaccines can prevent				
– Mentioned Four (4) or more diseases	481 (90.6%)	50 (9.4%)	4.07 (2.92 – 5.68)	< 0.001
– Less than four (4) diseases **	502 (70.1%)	214 (29.9%)		
– I do not know **	6 (85.7%)	1 (14.3%)		
At what age does child immunization start?				
– Just after birth	858 (84.6%)	156 (15.4%)	4.58 (3.37 – 6.22)	< 0.001
– Stated other dates (1 week, 1 month, etc.) **	95 (50.3%)	94 (49.7%)		
– I do not know **	36 (70.6%)	15 (29.4%)		
When does a child complete his/her immunization?				
– 9 to 15 months	930 (79.6%)	238 (20.4%)	1.79 (1.11 – 2.88)	0.016
– < 6 months OR > 15 months **	51 (67.1%)	25 (32.9%)		
– I do not know **	8 (80.0%)	2 (20.0%)		
What is the age/schedule for each vaccine?				
– Correct schedule for three or more vaccines	952 (83.3%)	191 (16.7%)	9.97 (6.52 – 15.24)	< 0.001
– Other responses **	26 (26.3%)	73 (73.7%)		
– I do not know **	11 (91.7%)	1 (8.3%)		
How many HF visits are required for full immunization?				
– At least 5 or 6 visits	686 (80.4%)	167 (19.6%)	1.33 (1.00 – 1.76)	0.049
– < 5 visits **	183 (88.0%)	25 (12.0%)		
– I do not know **	120 (62.2%)	73 (37.8%)		
Scores for Knowledge of routine immunization				
– Mean Score (± Std Dev)	10.71 (1.61)	9.63 (1.82)	1.07 (0.83 – 1.32) ##	< 0.001

** These responses were combined for estimation of Crude OR. | ## Mean difference (95% CI) | Abbreviations: HF, Health Facility

Table 4: Factors associated with immunization status of children aged 12-23 months in Enugu State, Nigeria, July 2020

Socio-demographic Characteristics	Reference	Adjusted OR	95% CI	p-value
INDIVIDUAL LEVEL FACTORS				
Mothers' age				
– < 20 years	20 – 29 years	0.17	0.03 – 1.06	0.058
– ≥ 30 years	20 – 29 years	0.87	0.57 – 1.34	0.534
Marital status				
– Single	Married	5.74	1.45 – 22.76	0.013
– Divorced/Widowed	Married	1.35	0.60 – 3.07	0.468
Mothers' educational status				
– Primary education or lower	Secondary education or higher	0.64	0.26 – 1.56	0.383
Mother's working status				
– Working mom	Stay-at-home/Housewife	1.08	0.63 – 1.85	0.327
Religion of family				
– Islam/Muslim	Christian	1.53	0.27 – 8.62	0.627
– African traditional	Christian	2.21	0.44 – 11.13	0.335
Sex of the child				
– Male	Female	0.98	0.66 – 1.45	0.914
Child's birth order				
– Second/third child	First child	1.52	0.78 – 2.98	0.220
– Fourth and later children	First child	1.34	0.48 – 3.74	0.577
MATERNAL HEALTHCARE UTILIZATION				
Antenatal care (ANC)				
– < 4 ANC visits	≥ 4 ANC visits	1.52	0.71 – 3.22	0.472
Maternal tetanus toxoid (TT)				
– < 2 doses	≥ 2 doses	0.93	0.41 – 2.10	0.864
Use of Skilled birth attendants (SBA)				
– No	Yes	1.93	1.24 – 2.99	0.003
Postnatal care (PNC)				
– No	Yes	6.53	4.17 – 10.22	< 0.001
KNOWLEDGE OF ROUTINE IMMUNIZATION				
Mothers' knowledge of RI				
– Poor	Satisfactory	1.76	1.09 – 2.87	0.022
COMMUNITY LEVEL FACTORS				
Area of residence				
– Rural	Urban	7.49	4.84 – 11.59	< 0.001
Household monthly income				
– < N80,000 (Approx. USD 200)	≥ N80,000 (Approx. USD 200)	1.56	1.17 – 2.81	< 0.001
Distance to nearest vaccination point				
– ≥ 30 minutes' walk	< 30 minutes' walk	2.15	1.31 – 3.52	0.003



Map of Nigeria above showing Enugu State and Map of Enugu state showing the study area (four LGAs). Adapted from image culled from Ugoyibo OV, Amaechi IF, Obinna AC. Evaluation of Groundwater Pollution Sources in Enugu North LGA of Enugu State , Nigeria. IJSAR J Environ Earth Phys Sci. 2015;2(3):54–69.

56x85mm (300 x 300 DPI)

Supplement 1: Reasons mothers of zero-dose (unvaccinated) children gave for not vaccinating their children

Reasons	Frequency N = 68	Proportion (%)
◦ I was busy with other things	1	1.5%
◦ Child was too sick to receive vaccines	3	4.4%
◦ I did not know the schedule for vaccination	8	11.8%
◦ There were no vaccines in our health facility	26	38.2%
◦ My religion forbids vaccination	1	1.5%
◦ Vaccination site is too far	29	42.6%

Supplement 2: Comparing vaccine-specific coverage rate and FIC rate on the Enugu sub-set of 2018 Nigeria DHS dataset using DHS's and current study's definitions

Vaccine-specific coverage rate	Current study	Authors' calculations from 2018 Nigeria DHS using DHS definition	Authors' calculations from 2018 Nigeria DHS using current study's definition
◦ BCG	90.6%	92.8%	92.8%
◦ Measles	87.8%	80.4%	80.4%
◦ DPT	--	74.3%	--
◦ Pentavalent 3	83.9%	--	80.4%
◦ OPV	--	44.3%	--
◦ Polio (tOPV; or bOPV + IPV)	83.1%	--	89.6%
FIC rate	**78.9%**	**32.3%**	**68.1%**

tOPV = Triple OPV doses; bOPV = two OPV doses

Supplement 3: Comparing socio-demographic characteristics of mothers in the current study with mothers in the Enugu sample of the 2018 Nigeria DHS

Socio-demographic characteristics	Current study sample (N = 1,254)	2018 DHS Enugu sub-set (n = 105)	p-value
Mothers' age			0.089
° < 20 years	54 (4.3%)	2 (1.9%)	
° 20 – 29 years	602 (48.0%)	42 (40.0%)	
° ≥ 30 years	598 (47.7%)	61 (58.1%)	
Marital status			0.097
° Single	50 (4.0%)	7 (6.7%)	
° Currently married	1127 (89.9%)	96 (91.4%)	
° Divorced/Separated	77 (6.1%)	2 (1.9%)	
Educational status			0.001
° Primary or lower	77 (6.1%)	15 (14.3%)	
° Secondary or higher	1177 (93.9%)	90 (85.7%)	
Mothers' occupation			< 0.001
° Stay-at-home/Housewife	307 (24.5%)	47 (44.8%)	
° Working mom	947 (75.5%)	58 (55.2%)	
Religion			0.198
° Christian	1214 (96.8%)	104 (99.0%)	
° Others	40 (3.2%)	1 (1.0%)	
Ethnicity			0.498
° Igbos	1201 (95.8%)	102 (97.1%)	
° Others	53 (4.2%)	3 (2.9%)	
Birth order of child			< 0.001
° First born	347 (27.7%)	23 (21.9%)	
° Second/Third born	625 (49.8%)	37 (35.2%)	
° Others	282 (22.5%)	45 (42.9%)	
Residence			< 0.001
° Urban	751 (59.9%)	84 (80.0%)	
° Rural	503 (40.1%)	21 (20.0%)	

Study Interview guide

Factors associated with incomplete immunization in children aged 12 to 23 months at sub-national level, Nigeria – a cross-sectional study

INSTRUCTIONS

1. Seek permission from the mother to participate before you commence. If mother is < 18 years old, seek permission of the husband (if mother is < 18 years old and married) or mother's mother/father (if mother is < 18years old and single)
2. If more than two children in the age bracket, only interview for the youngest child more than 12 months of age
3. Always be polite and courteous throughout the interview. NEVER Shout. NEVER Criticize.
4. Please complete ONE questionnaire for one/each child

Section A: Sociodemographic Data

1. **Local Government Area: _____**

2. **Cluster or Ward: _____**

3. **Mother's age**
   a. < 20 yrs
   b. 20 – 24 yrs
   c. 25 – 29 yrs
   d. 30 – 34 yrs
   e. ≥ 35 yrs

4. **Marital status**
   a. Single
   b. Married
   c. Divorced
   d. Widow

5. **Mother's education**
   a. None
   b. Primary
   c. Secondary
   d. Tertiary

6. **Mother's Occupation**
   a. Stay-at-home/Housewife
   b. Farmer
   c. Civil Servant
   d. Trader
   e. Artisan

7. **Tribe/Ethnicity**
   a. Igbo
   b. Hausa/Fulani

c. Yoruba
d. Igala
e. Others

8. Family religion

a. Christian
b. Islam/Muslim
c. African Traditional Religion

9. Family monthly income

a. < N 40,000
b. N40,000 to N79,999
c. N80,000 to N119,999
d. ≥ N120,000

10. Sex of child

a. Female/Girl
b. Male/Boy

11. Birth order in the family

a. First born
b. Second or third born
c. Others

Section B: Prevalence & Determinants

1. **Has your child been vaccinated?**

A. YES
B. NO

>> If YES to Q1 above, when was your child vaccinated?

A. At the appropriate age
B. Later than appropriate date

2. **Please where is the Immunization card? Is the mother able to provide the card?**

A. YES
B. NO

>> If mother is NOT able to provide the card, Why?

A. Mother cannot find it during interview
B. Mother lost card before interview, i.e. could not find the card before the day of interview
C. Mother was not given any immunization card at health centre

3. **How many antenatal care visits did you attend while pregnant for this child?**

A. None, I did not attend any antenatal clinic
B. Only one visit
C. Two visits
D. Three visits
E. Four visits or more

4. **How many TT injections did you receive during pregnancy?**
   A. None, I did not receive any TT injection
   B. One injection
   C. Two or more injections

12. Where did you deliver this child?
   A. In a hospital
   B. With Traditional birth attendants (TBA)
   C. At home

5. **Did you attend any post-natal care consultation after delivering this child?**
   A. YES
   B. NO

6. **Where did you hear of vaccination**? (Please tick all that apply)
   A. Hospital/Health facility
   B. Family/friends
   C. Church/Mosque
   D. TV
   E. Radio
   F. Social media (Facebook, Twitter, WhatsApp, Instagram)

7. **What does vaccination do to your child's body?**
   A. Vaccination prevent illnesses in children
   B. Vaccines treat illnesses in children like drugs
   C. Vaccines provide nutrients to children like food
   D. I do not know

8. **Please mention any disease vaccination can prevent:**
   (Use this list to assess mothers' response: Tuberculosis, Diphtheria, Whooping cough, Tetanus, Poliomyelitis, Hepatitis B virus infection, Measles, Pneumococcal pneumonia)
   A. Mother mentions four (4) or more diseases
   B. Mother mentions three (3) or fewer diseases
   C. I do not know any diseases vaccination can prevent

9. **When do you start to vaccinate a child?**
   A. Just after birth
   B. 1 week after birth
   C. 2 weeks after birth
   D. 1 month after birth
   E. Anytime
   F. I do not know

10. **When does a child complete his routine vaccination?**
   A. 6 months
   B. 9 months
   C. 12 months (1 year)

D. 15 months
E. 2 years
F. 5 years
G. I do not know

11. **Do you know the right age or schedule for routine vaccination of infants?**
(Use vaccination schedule on the paper titled, 'NPHCDA routine immunization schedule' to assess mothers' response)
A. Mother mentions correct schedule for three (3) or more vaccines
B. Mother mentions correct schedule for one or two vaccines
C. I do not know

12. **How many visits are needed to complete the immunization for a child**
A. One (1) visit
B. 2 or 3 visits
C. 5 or 6 visits
D. I do not know

13. **Using the Google Map app on your phone, how far is the nearest vaccination centre to this house?**
A. Less than 30 mins walk
B. About or more 30 mins' walk

Section C: Immunization status

If you answered YES to Question 1 above, which of these vaccines has he/she received?

Step 1: FIRST, ask the mothers to know how many vaccinations she can recall, and tick accordingly

Step 2: Then, cross check with the Vaccination/Immunization Card, if available, and tick accordingly

S/n	Vaccine	Age	1). Mothers recall		2). Immunization Card	
			YES	NO	YES	NO
1	BCG	At birth				
2	OPV-1	6 weeks				
3	OPV-2	10 weeks				
4	OPV-3 or Polio vaccine	14 weeks				
5	Pentavalent – 1	6 weeks				
6	Pentavalent – 2	10 weeks				
7	Pentavalent – 3	14 weeks				
8	Vitamin A	6 months				
9	Measles vaccine	9 months				
10	Yellow fever	9 months				

** The END **

Thank the mother profusely …. Daalu nnukwu / Thank you very much!!

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	1
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	2,3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	3
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	3
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4
Bias	9	Describe any efforts to address potential sources of bias	4
Study size	10	Explain how the study size was arrived at	3,4
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	5
		(*c*) Explain how missing data were addressed	5
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	5
		(*e*) Describe any sensitivity analyses	5
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	Not applicable
		(c) Consider use of a flow diagram	Not applicable
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	5
		(b) Indicate number of participants with missing data for each variable of interest	Not applicable
Outcome data	15*	Report numbers of outcome events or summary measures	5
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	5
		(*b*) Report category boundaries when continuous variables were categorized	5
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	5
Discussion			
Key results	18	Summarise key results with reference to study objectives	6
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	6,7
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	6
Generalisability	21	Discuss the generalisability (external validity) of the study results	7
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	9

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.