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Original Article

Vaccination compliance of selected childhood immunization programs and the socio-determinant factors in Nigeria

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Abstract

Introduction: Adherence to full vaccination is important in preventing childhood diseases. The aim of this study was to evaluate the level of compliance to full vaccination and identify the socio-cultural factors associated with full vaccination compliance in children.
Methodology: The socioeconomic variables associated with each of the four binary dependent variables of whether or not a child is fully vaccinated against tetanus, BCG, measles, and pentavalent were determined using logistic regression.
Results: While compliance to full tetanus and BCG vaccinations was > 60% at the national level, less than 50% and 10% full vaccination compliance were recorded for pentavalent and measles vaccinations, respectively. The South East region of Nigeria recorded the overall highest full vaccination compliance while the least performing region was the North West zone. The mother or guardian literacy level, employment status, antenatal care attendance, and internet usage were strong predictors of full vaccination compliance ($p < 0.05$).
Conclusions: The socio-cultural factors associated with achieving full vaccination coverage in Nigeria in this study should drive the implementation of policies that will be best suited to each geopolitical zone of Nigeria.

Key words: Vaccination; children; coverage; socioeconomic factors; Nigeria.

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Introduction

Vaccines and immunization are established public health prevention approaches that have effectively combated the menace of high mortality and morbidity from infectious diseases in both children and women at reproductive age [1]. Over 2 million people die each year because of vaccine-preventable diseases (VPDs), and Nigeria continues to be a major contributor to these VPD-related childhood deaths [2]. The World Health Organization (WHO) launched the expanded programme on immunization (EPI) in 1974, where diphtheria, measles, pertussis, polio, tetanus, tuberculosis, and yellow fever vaccines were recommended. This programme was first implemented in Nigeria in 1979, and it provided routine immunization to children under the age of two [3]. Childhood immunization coverage had risen to 81.5% in the 1990s, but there has since been in decline, with 12.9% recorded in 2003 [3].

Globally, approximately 22.7 million children do not receive a single dose of vaccine or they are only partially vaccinated. According to the Nigerian Federal Ministry of Health, a child is considered fully vaccinated if he or she receives a Bacillus Calmette-Guerin (BCG) vaccine, three doses of Diphtheria-Pertussis-Tetanus (DPT), a minimum of three doses of polio vaccine, and a dose of measles vaccine [3]. According to reports from the global estimate of the percentage of children with zero vaccination dose, approximately 14% of this vulnerable group reside in Nigeria [4]. In a study which was conducted in Zamfara state in the North West zone, a 7.6% prevalence of full vaccination in children was observed [5]. In 2017, a pooled estimate of 34.4% of Nigerian children was fully vaccinated, with the South-South zone having the highest (51.5%) and the North-West zone having the lowest (9.5%) [6]. In a study conducted by Uwaibi and Omozuwa [7], they found 85.2% full compliance in children under the age of two years in primary healthcare facilities in Benin, Edo state.

On the other hand, the investigation of Adeloye *et al.* [6], showed that low maternal education, poor

information, mother's social engagements, and vaccine unavailability were the main reasons for the low vaccine coverage. Another study in North-Central Nigeria identified distance, vaccine side effects, and a negative attitude of health workers as reasons for partial immunization. Short messaging service (SMS) was suggested as a tool for increasing vaccination uptake [8]. In addition, some of the identified barriers to childhood vaccination in Northwest Nigeria were campaign preference, misinformation, and opposition to vaccination by male heads of households [9].

Previous studies have reported vaccination compliance rates in various locations throughout Nigeria, and others have looked into the factors that contribute to incomplete immunization. The present study's goal is to identify the socio-cultural factors that influence full vaccination of the four major routine vaccines (tetanus, BCG, measles, and pentavalent vaccines) in children across the six geopolitical zones of Nigeria.

Methodology

This study relied on the nationally representative 2018 Nigeria demographic and health survey (DHS) sponsored by the United States Agency for International Development (USAID). The National Population Commission (NPC) and the Ministry of Health collaborated to coordinate this survey. The survey used a two-stage stratified sample design with 74 sampling strata, which was identified by dividing the 36 states and federal capital territory into urban and rural areas. The first stage of the sampling design selected 1400 households with a probability proportional to the size of the enumeration area (EA), while the second stage used an equal probability systematic sampling scheme to select a fixed number of 30 households, yielding a total sample of approximately 42,000 households [10].

The study's target population was parents at childbearing age with children under the age of five in their households; households that did not meet this condition were excluded. SPSS version 26.0 statistical software was used for data sorting and cleaning, resulting in only 15,454 cases after deleting all inconsistent entries. A child was considered fully vaccinated if he or she had received neonatal tetanus, a dose of BCG, two doses of measles, and three doses of pentavalent [DPT, Hepatitis B (Hep B), *Haemophilus influenzae* type B (Hib) vaccines]. Each of these was classified as yes or no, yielding four outcome/dependent variables. The following socioeconomic-related independent variables were selected: maternal age, literacy level, respondent currently working, respondent currently residing with husband/partner, getting the money needed for medical treatment is a big problem, antenatal care attendance, use of internet in the last twelve months, gender of household head, type of place of residence, distance to a health facility is a problem in getting medical treatment, place of delivery, child is twin, and gender of child.

The socioeconomic variables that associated with each of the four binary dependent variables of whether or not a child was fully vaccinated against tetanus, BCG, measles, and pentavalent were determined using logistic regression.

Mathematics of logistic regression model

A logistic regression model is a statistical model that models the likelihood of an event occurring by making the event's log-odds a linear combination of one or more independent variables. The multiple binary logistic regression was specified as:

$$\pi(x) = \frac{Exp(B_0+B_1X_1+B_2X_2+\ldots B_kX_K}{1+\exp\,(B_0+B_1+\ldots B_kX_k)} \quad (1)$$

In matrix form, (1) can be expressed as:

$$\pi(x) = \frac{\exp(X\beta)}{1+\exp(X\beta)} \quad (2)$$

$$Log\pi(x) = \log\,(\frac{1}{1+\exp(-X\beta)}) \quad (3)$$

$$Log1 - \log\,(1+\exp\,(-X\beta) \quad (4)$$

$$Log1 - log1 - \log\,(\exp(-X\beta)) \quad (5)$$

$$Log\pi(x) = -(-X\beta) \quad (6)$$

$$Log\pi(x) = X\beta = \pi(x) = exp(X\beta) \quad (7)$$

Then if y was a binary response variable is defined as:

$$y = \begin{cases} 1\ if\ the\ child\ received\ full\ immunization \\ 0\ if\ the\ child\ did\ not\ receive\ full\ immunisatiion \end{cases}$$

Then the probability of a child being fully immunized was π and the probability of its contrast was $1-\pi$. Following this representation, (7) was re-expressed as

$$Log\pi(x) = log\,\frac{\pi}{1-\pi} = \text{Xβ or } \frac{\pi}{1-\pi} = \exp\,(\text{Xβ}) \quad (8)$$

The statistical implication of the above was that y had a Bernoulli distribution with mass function

$$f(x) = \pi^y(1-\pi)^{1-y} \quad (9)$$

For a sample size n, the likelihood for a binary logistic regression was given by:

$$L(\beta; y, X) = \prod_i^n \pi^y(1-\pi_i)^{1-y_i} \quad (10)$$

$$\prod_{i=1}^n (\frac{\exp(X_{i\beta})}{1+\exp(X_{i\beta})})^k (\frac{1}{1+\exp\,(X_{i\beta})})^{1-y_i} \quad (11)$$

This yielded the log likelihood:

$$l(\beta) = \sum_{i=1}^n (y_i \log(\pi_i) + (1-y_i)\log\,(1-\pi_i) \quad (12)$$

$$= \sum_{i=1}^n \lfloor y_iX_i - \log\,(1+\exp\,(X_i\beta)) \rfloor \quad (13)$$

Because maximization or log likelihood had no closed-form solution, iteratively re-weighted least square was used to estimate the regression coefficients.

Model performance measure

One of the commonly used metrics for evaluating the quality of prediction for classification model is receiver operating characteristic curve (ROC). Given a 2×2 classification table in which true positive (TP) was the number of correctly predicted positive classes (fully vaccinated), true negative (TN) was the number of correctly predicted negative classes (not fully vaccinated), false positive (FP) was the number of incorrectly predicted positive classes (fully vaccinated), and false negative (FN) was the number of incorrectly predicted negative classes (not fully vaccinated), the sensitivity and specificity of the model were defined as;

$$TPR\ or\ Sensitivity = \frac{True\ positive}{True\ positive + False\ negative} \times 100 \quad (14)$$

$$TNR\ or\ Specificity = \frac{True\ negative}{True\ negative + False\ positive} \times 100 \quad (15)$$

Table 1. Geographical Distribution of samples and status of completeness of immunization.

		Tetanus (%)		BCG (%)		Measles (%)		Pentavalent (%)	
Region	**State**	**Full**	**Partial**	**Full**	**Partial**	**Full**	**Partial**	**Full**	**Partial**
North Central	Niger	303 (16.1)	297 (33.4)	320 (15.8)	280 (37.8)	14 (5.9)	586 (23.2)	172 (13.0)	428 (29.6)
	FCT Abuja	298 (15.9)	94 (10.6)	343 (16.9)	49 (6.6)	34 (14.3)	358 (14.2)	263 (20.0)	129 (8.9)
	Nasarawa	286 (15.2)	87 (9.8)	306 (15.1)	67 (9.1)	45 (19.0)	328 (13.0)	166 (12.6)	207 (14.3)
	Plateau	232 (12.4)	145 (16.3)	300 (14.8)	77 (10.4)	29 (12.2)	348 (13.8)	220 (16.7)	157 (10.8)
	Benue	325 (17.3)	105 (11.8)	337 (16.6)	93 (12.6)	60 (25.3)	370 (14.6)	214 (16.2)	216 (14.9)
	Kogi	211 (11.2)	54 (6.1)	206 (10.1)	59 (8.0)	20 (8.4)	245 (9.7)	126 (9.6)	139 (9.6)
	Kwara	223 (11.9)	107 (12.0)	215 (10.6)	115 (15.5)	35 (14.8)	295 (11.7)	158 (12.0)	172 (11.9)
	Total	**1878 (67.9)**	**889 (32.1)**	**2027 (73.3)**	**740 (26.7)**	**237 (8.6)**	**2530 (91.4)**	**1319 (47.7)**	**1448 (52.3)**
North East	Yobe	382 (18.1)	200 (16.9)	233 (13.2)	349 (22.8)	46 (21.5)	536 (17.4)	140 (14.0)	442 (19.2)
	Borno	246 (11.7)	255 (21.5)	282 (16.0)	219 (14.3)	54 (25.2)	447 (14.5)	144 (14.4)	357 (15.5)
	Adamawa	371 (17.6)	80 (6.7)	315 (17.9)	136 (8.9)	26 (12.1)	425 (13.8)	214 (21.4)	237 (10.3)
	Gombe	371 (17.6)	217 (18.3)	285 (16.2)	303 (19.8)	26 (12.1)	562 (18.2)	160 (16.0)	428 (18.6)
	Bauchi	422 (20.0)	281 (23.7)	341 (19.3)	362 (23.6)	31 (14.5)	672 (21.8)	186 (18.6)	517 (22.5)
	Taraba	319 (15.1)	153 (12.9)	307 (17.4)	165 (10.8)	31 (14.5)	441 (14.3)	156 (15.6)	316 (13.8)
	Total	**2111 (64.0)**	**1186 (36.0)**	**1763 (53.5)**	**1534 (46.5)**	**214 (6.5)**	**3083 (93.5)**	**1000 (30.3)**	**2297 (69.7)**
North West	Sokoto	226 (8.5)	297 (14.4)	173 (8.5)	350 (13.1)	17 (6.9)	506 (11.3)	42 (3.8)	481 (13.3)
	Zamfara	183 (6.9)	422 (20.5)	92 (4.5)	513 (19.1)	4 (1.6)	601 (13.4)	51 (4.6)	554 (15.3)
	Katsina	359 (13.5)	369 (17.9)	325 (15.9)	403 (15.0)	27 (11.0)	701 (15.7)	206 (18.6)	522 (14.5)
	Jigawa	496 (18.6)	187 (9.1)	367 (18.0)	316 (11.7)	49 (20.0)	634 (14.2)	205 (18.5)	478 (13.2)
	Kano	692 (26.0)	238 (11.6)	547 (26.8)	383 (14.3)	98 (39.8)	832 (18.6)	352 (31.7)	578 (16.0)
	Kaduna	424 (15.9)	229 (11.1)	386 (18.9)	267 (10.0)	43 (17.5)	610 (13.6)	204 (18.4)	449 (12.4)
	Kebbi	281 (10.6)	317 (15.4)	149 (7.3)	449 (16.7)	8 (3.3)	590 (13.2)	49 (4.4)	549 (15.2)
	Total	**2661 (56.4)**	**2059 (43.6)**	**2039 (43.2)**	**2681 (56.8)**	**246 (5.2)**	**4474 (94.8)**	**1109 (23.5)**	**3611 (76.5)**
South East	Anambra	374 (24.4)	14 (15.9)	364 (24.3)	24 (19.5)	19 (8.9)	369 (26.2)	298 (26.2)	90 (18.6)
	Enugu	240 (15.7)	13 (14.8)	231 (15.4)	22 (17.9)	34 (16.0)	219 (15.6)	175 (15.4)	78 (16.1)
	Ebonyi	389 (25.4)	37 (42.0)	398 (26.6)	28 (22.8)	66 (31.0)	360 (25.6)	308 (27.1)	118 (24.4)
	Abia	246 (16.1)	17 (19.3)	250 (16.7)	13 (10.6)	74 (34.7)	189 (13.4)	175 (15.4)	88 (18.2)
	Imo	282 (18.4)	7 (8.0)	253 (16.9)	36 (29.3)	20 (9.4)	269 (19.1)	180 (15.8)	109 (22.6)
	Total	**1531 (94.6)**	**88 (5.4)**	**1496 (92.4)**	**123 (7.6)**	**213 (13.2)**	**1406 (86.8)**	**1136 (70.2)**	**483 (29.8)**
South South	Edo	181 (16.9)	29 (9.5)	195 (17.4)	15 (5.9)	24 (15.5)	186 (15.2)	144 (17.4)	66 (12.0)
	Cross River	138 (12.9)	26 (8.5)	135 (12.0)	29 (11.3)	19 (12.3)	145 (11.9)	94 (11.4)	70 (12.7)
	Akwa Ibom	181 (16.9)	52 (17.0)	200 (17.8)	33 (12.9)	23 (14.8)	210 (17.2)	134 (16.2)	99 (18.0)
	Rivers	250 (23.3)	39 (12.8)	251 (22.4)	38 (14.8)	22 (14.2)	267 (21.8)	184 (22.2)	105 (19.1)
	Bayelsa	146 (13.6)	108 (35.4)	166 (14.8)	88 (34.4)	49 (31.6)	205 (16.8)	126 (15.2)	128 (23.2)
	Delta	177 (16.5)	51 (16.7)	175 (15.6)	53 (20.7)	18 (11.6)	210 (17.2)	145 (17.5)	83 (15.1)
	Total	**1073 (77.9)**	**305 (22.1)**	**1122 (81.4)**	**256 (18.6)**	**155 (11.2)**	**1223 (88.8)**	**827 (60.0)**	**551 (40.0)**
South West	Oyo	267 (18.4)	53 (23.7)	245 (17.4)	75 (28.3)	74 (29.7)	246 (17.3)	121 (11.7)	199 (31.1)
	Osun	228 (15.7)	15 (6.7)	220 (15.6)	23 (8.7)	48 (19.3)	195 (13.7)	171 (16.5)	72 (11.3)
	Ekiti	203 (14.0)	31 (13.8)	211 (15.0)	23 (8.7)	27 (10.4)	207 (14.5)	178 (17.2)	56 (8.8)
	Ondo	214 (14.8)	38 (16.9)	212 (15.1)	40 (15.1)	28 (11.2)	224 (15.7)	173 (16.7)	79 (12.4)
	Lagos	323 (22.3)	51 (22.8)	343 (24.4)	31 (11.7)	58 (23.3)	316 (22.2)	278 (26.9)	96 (15.0)
	Ogun	214 (14.8)	36 (16.1)	177 (12.6)	73 (27.4)	14 (5.6)	236 (16.6)	113 (10.9)	137 (21.4)
	Total	**1449 (86.6)**	**224 (13.4)**	**1408 (84.2)**	**265 (15.8)**	**249 (14.9)**	**1424 (85.1)**	**1034 (61.8)**	**639 (38.2)**
National (n = 15, 454)		**10703 (69.3)**	**4751 (30.7)**	**9855 (63.8)**	**5599 (36.2)**	**1314 (8.5)**	**14140 (91.5)**	**6425 (41.6)**	**9029 (58.4)**

Figure 1. Compliance status of full vaccination for tetanus according to state of residence (Map generated by QGIS 3.26.0 software).

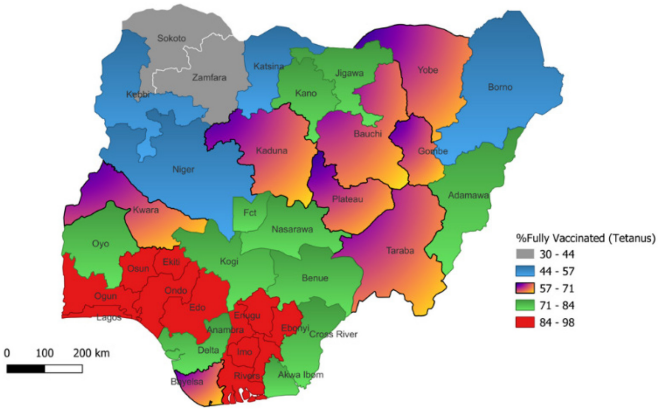
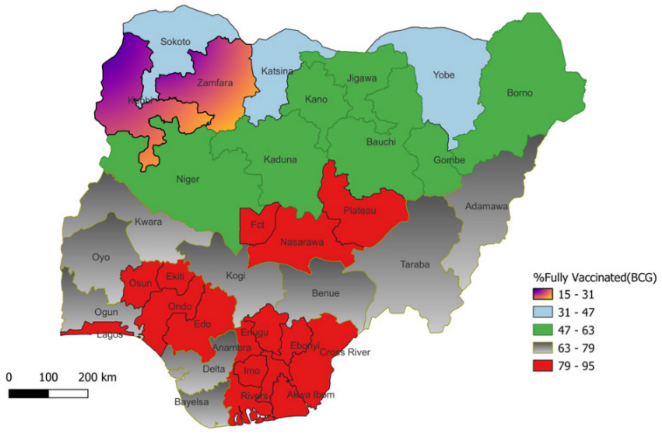


Figure 2. Compliance status of full vaccination for BCG according to state of residence (Map generated by QGIS 3.26.0 software).



The true positive rate (TPR) and the false positive rate (FPR) were plotted on this curve. The true positive rate, also known as sensitivity, was the percentage of positive class predictions that were correct while the false positive rate gave the percentage of incorrect predictions in positive class and it was defined as:

$$FPR = 1 - Specificity = \frac{False\ positive}{False\ positive + true\ negative} \times 100 \qquad (16)$$

The ROC curve was constructed for each of the tabulated values across all classification thresholds by plotting sensitivity (true positive rate) on the y-axis against 1-specificity (false positive rate) on the x-axis and the area under the curve of ROC was called area under curve (AUC). A high AUC value indicated good classification performance. It was interpreted as how well our model predicted either the positive or negative class.

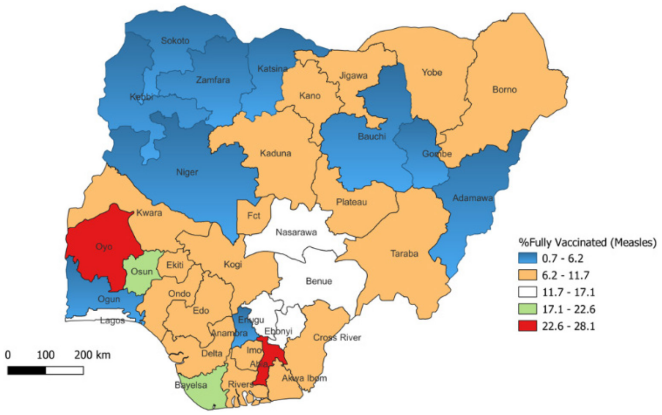
Results

Data on immunization status for tetanus, BCG, measles, and pentavalent vaccines were obtained for 15,454 children. At the national level, those who had received full tetanus, BCG, measles, and pentavalent vaccinations were 69.3%, 63.8%, 8.5%, and 41.6%, respectively (Table 1). Of the immunizations studied, 45.8% were fully vaccinated on average. Full vaccination compliance was highest in the South East for tetanus (94.6%), pentavalent (70.2%), and BCG (92.4%), while South West was highest for full vaccination of measles (14.9%). For all vaccines, the North West zone had the lowest compliance with full vaccination (Table 1).

Evaluation of compliance for vaccination according to state of residence showed that ten states had the highest percentage of those who were fully vaccinated for tetanus (84-98%). These states were Ogun, Lagos, Osun, Ekiti, Ondo, Edo, Enugu, Anambra, Abia, Ebonyi, Imo and Rivers states. Sokoto and Zamfara states were the least compliant (Figure 1). As shown in Figure 2, the number of states with full BCG vaccination (79-95%) compliance had risen to fifteen. These are Lagos, Osun, Ondo, Ekiti, Edo, Enugu, Anambra, Imo, Rivers, Akwa-Ibom, Cross-River, Ebonyi, FCT, Nasarawa and Plateau states. The least compliance (15-31%) were in Kebbi and Zamfara states.

The completeness of measles vaccine was very poor generally and only Oyo and Rivers states attained 22.6-28.1% full vaccination status. Majority of the states in the North were within 0.7–6.2% full vaccination status (Figure 3). The percentage of those who were fully vaccinated for pentavalent vaccine was highest (63-77%) in Lagos, Osun, Ekiti, Ondo, Edo, Delta,

Figure 3. Compliance status of full vaccination for measles according to state of residence (Map generated by QGIS 3.26.0 software).



Anambra, Enugu, Rivers, Ebonyi states and FCT (Figure 4).

The logistic regression analysis in Table 2 identified some social factors influencing full vaccination compliance in Nigeria.

Tetanus

The adjusted odds ratio showed that literacy level, working status of respondents, antenatal care attendance, access to internet, gender of the household head and place of delivery were strong influencers of completeness of tetanus vaccine. The literate mothers or guardians were 1.82 times more likely to complete the vaccination schedule for tetanus relative to the illiterates (Table 2). Furthermore, antenatal attendance was a very strong determinant of tetanus vaccine compliance. Those who attended antenatal clinic were

Figure 4. Compliance status of full vaccination for pentavalent according to state of residence (Map generated by QGIS 3.26.0 software).

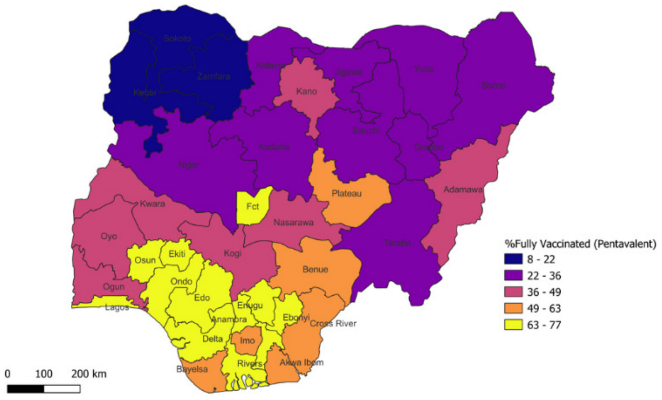


Table 2. Socio-determinant factors for full vaccination compliance in Nigeria.

	Adjusted odd ratio at 95% confidence interval			
	Tetanus	**BCG**	**Measles**	**Pentavalent**
Maternal age				
< 30 years	1.07	0.75***	0.73***	0.73***
≥ 30 years	1.00	1.00	1.00	1.00
Literacy Level				
Literate	1.82***	3.84***	1.5***	1.94***
Illiterate	1.00	1.00	1.00	1.00
Respondent currently working				
Yes	2.39***		8.15***	37.77***
No	1.00		1.00	1.00
Currently residing with husband/partner				
Staying with husband/partner	1.04	0.93	1.3**	1.03
Staying elsewhere	1.00	1.00	1.00	1.00
Getting money needed for medical treatment is a big problem				
Yes	1.07	0.93	1.17**	1.06
No	1.00	1.00	1.00	1.00
Antenatal care attendance				
Attended	56.41***	4.36***	1.04	1.44***
Not attended	1.00	1.00	1.00	1.00
Use of internet in the last twelve month				
Yes	2.14***	4.15***	1.26***	1.47***
No	1.00	1.00	1.00	1.00
Sex household head				
Female	1.44**	1.28**	1.25	1.14
Male	1.00	1.00	1.00	1.00
Type of place of residence				
Urban	1.12	1.31***	1.07	1.15**
Rural	1.00	1.00	1.00	1.00
Distance to health facility is a problem to getting medical treatment				
Yes	0.98	0.91	0.88	0.82***
No	1.00	1.00	1.00	1.00
Place of delivery				
Government hospital	1.77***	2.46***	1.18***	1.25***
Elsewhere	1.00	1.00	1.00	1.00
Child is twin				
Yes	0.86	0.99	0.80	0.97
No	1.00	1.00	1.00	1.00
Gender of child				
Male	0.95	0.92	1.08	0.97
Female	1.00	1.00	1.00	1.00
Constant	0.05***	0.33***	0.01***	0.02***
Model Evaluation Metric				
Area under curve	**0.910**	**0.830**	**0.721**	**0.845**

** and *** indicate Significant effect at 5% and 1% level of significance, respectively.

56.41 times more likely to complete the vaccination schedule compared to those who do not. The working class were also more likely to comply relative to the others (AOR = 2.39, $p < 0.01$). The model's performance is quite good, with the model able to predict whether a child will be fully vaccinated or not approximately 91 times out of 100 (Figure 5).

BCG

As shown in Table 2, maternal age, literacy level, antenatal clinic attendance, internet access, gender of the household head, place of residence and place of delivery were the major determinants for completion of BCG vaccine. Mothers that were less than 30 years old were less likely to fully vaccinate their children/wards than those that were 30 years old and above (AOR = 0.75, $p < 0.01$). Urban dwellers were 1.31 times more likely to get full vaccination compared with the rural dwellers. Likewise, the literates were 3.84 times more likely to be vaccinated fully relative to the illiterates. According to the model performance, 83.0% of the classes are correctly classified (Figure 5).

Measles

Maternal age, literacy level, working status of respondents, residing with husband or spouse, finance, internet access and place of delivery were the significant socio-determinants for full compliance to measles vaccination (Table 2). Those working were 8.15 times more likely to ensure full vaccination relative to others. Similarly, those residing with spouse were more likely to comply relative to those staying elsewhere (AOR = 1.3, $p < 0.05$). Our model's AUC of 0.721 indicated that it can discriminate between positive and negative classes by approximately 72.1% (Figure 5).

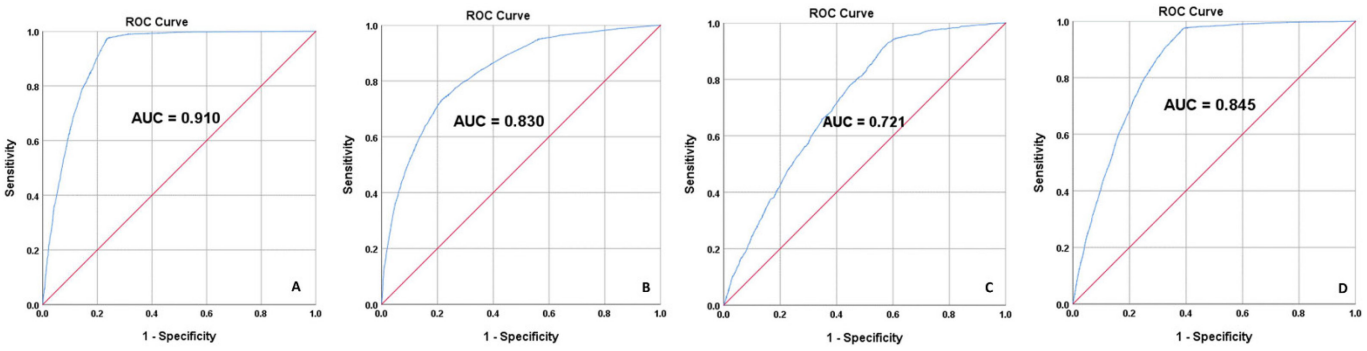
Pentavalent

In Table 2, the identified determinants for full compliance to pentavalent vaccination were maternal age, literacy level, working status of respondents, antenatal care attendance, internet access, place of residence, distance to health facility and place of delivery. Respondents who were working were 37.77 times more likely to complete vaccination compared with others. Likewise, those who resided in urban settings and gave birth in government hospitals were 1.15 times and 1.25 times more likely to comply fully with the vaccination schedule respectively. Being literate was also a strong determinant of compliance to full vaccination (AOR = 1.94, $p < 0.01$). The model's performance evaluation is impressive, with an ability to correctly identify a positive or negative class approximately 84.5% of the time (Figure 5).

Discussion

This study evaluated the level of compliance to full vaccination and the associated socio-determinant factors. Data on immunization status for tetanus, BCG, measles, and pentavalent vaccines were obtained for 15,454 children. On average, 45.8% were fully vaccinated. This is considerably lower than 60.59% reported in children under one year in 2020 [11]. This decline in overall number of fully vaccinated children over the years have been reported earlier [3,12]. This implies that more strategic interventions may be required to encourage full vaccination compliance. Furthermore, from the data of full vaccination for the immunizations reported here, none of the states in North Central and North West geopolitical zones of Nigeria attained the 80% full immunization coverage expected by WHO. This finding supports an earlier report by Abdulkarim *et al.* [13] who stated that low rates of immunization were common in the northern part of Nigeria [13]. The low vaccination coverage in

Figure 5. Receiver operating characteristic curve (ROC) and Area under curve (AUC) for the four models.



A: Tetanus; B: BCG; C: Measles; D: Pentavalent vaccine.

the northern zone was also highlighted in a review by McGavin *et al.* [14] who affirmed the low rate of complete immunization in Nigeria. In this present study, Zamfara state had the lowest percentage of children (0.7%) that were fully vaccinated. This corroborates a similar report of 0.2% from the same location in 2009 [15]. The urgent review of the logistics on full immunization coverage and the probable lack of synergy with the way of life of the residents may aid in improving the compliance rate.

In the current work, the percentage of those who were fully vaccinated for pentavalent vaccine was highest in Anambra state (76.8%) while the South East zone seems to have a persistent record of high coverage of pentavalent vaccine (formerly DPT). In 2010, the South East zone reported the highest figure with Enugu state having a coverage rate of 98.21% [3]. Despite this encouraging full vaccination coverage index, Nigeria is yet to actualize the vision of the EPI policy which is to have no reported cases of diphtheria.

In this present study, full BCG vaccination was highest in Abia state (95.1%) and lowest in Zamfara state (15.2%). In 2010, the findings of Ophori *et al*. [3] showed highest number of fully vaccinated children in Enugu state (99.55%) and lowest in Kano State (35.23%). The implications of this finding shows that the national outlook may not be the best in attaining complete vaccination in all states. Policies should be better suited for each territory or state to improve outcome. The high compliance of full vaccination witnessed in the South East agrees with a study that found that the likelihood of full immunisation was highest in children from Igbo mothers [16]. The reason alluded to this was the Igbos high economic power, which is a characteristic that increases their propensity to migrate from areas with poor economic opportunities into areas with higher economic opportunities, more than most other ethnic groups in Nigeria [17]. Increased socio-economic status of the Igbo mothers could be a positive predictor of children being fully immunized.

Measles vaccine compliance rate in Nigeria was extremely low in this study compared to previous studies [3,12]. According to Orjingene *et al.* [11], lack of political will to ensure fulfillment of the EPI policy in Nigeria is one of the factors associated with the poor coverage rate of measles vaccine.

Level of literacy, access to internet and place of delivery were positively correlated with full vaccination in this study. This agrees with the findings of Olorunsaye and Degge [12] who reported the increasing levels of education as a strong predictor of full vaccination. In a study carried out by Adedokun *et al*. [18], mothers who didn't have access to the internet were more unlikely to complete the routine immunization schedule. This corroborates the finding of this study. Likewise, Antai [16] reported hospital delivery as a major determinant of full vaccination. Furthermore, children of low working-class mothers were also not likely to be fully vaccinated as reported in the study. This supports the finding of this study that being a working-class mother strongly correlated with full vaccination of tetanus before birth, measles and pentavalent vaccines.

Maternal age, literacy level, antenatal clinic attendance, internet access, gender of the household head, place of residence and place of delivery were the major determinants for completion of BCG vaccine. The gender of the household head negatively correlated with full vaccination of BCG and tetanus. This is an expected situation as the culture of the Nigerian nation places the responsibility of making decision on men irrespective of the tribe.

Antenatal care attendance was a strong predictor of full vaccination of BCG, tetanus before birth and pentavalent vaccination in this study. A similar finding was reported by Adedokun *et al*. [18], however, the predictions were not considered separately for each vaccine. Similar finding was reported by Adedire *et al.* [19] in a study carried out in Osun State, Nigeria. The enlightening health education talks which are usually given at every antenatal clinic visit provides vital information for mothers. This may be responsible for the increased vaccination compliance in mothers.

Conclusions

The limiting factors for achieving full vaccination coverage in Nigeria as discussed in this study and previous works should drive the implementation of policies that will be best suited to each geopolitical region based on the challenges identified. Emphasis should be placed on interventions geared towards the expanded programme on immunization's goal of ensuring wide coverage of full immunization.

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Author contributions

OAO: Conception and design of the study; OAO and IDF: data analysis; OAO, ORO, and OTO: interpretation of data, drafting the article and revising it critically for important

intellectual content. All authors approved the final version of the article.

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