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Variations in the Uptake of Routine Immunization in Nigeria: Examining Determinants of Inequitable Access

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Globally, immunization prevents an estimated 2–3 million deaths among under-5 children, yet in Nigeria, only 25% of children ages 12–23 months are fully immunized. There are also marked disparities in the uptake of immunizations, largely attributable to the context within which families live and seek health care. The authors assessed the individual and state determinants of child immunization in Nigeria and used multilevel logistic regression to estimate the odds of full immunization among 5,561 children aged 12–23 months, with their mothers clustered in the 36 states and the Federal Capital Territory (level 2). Findings indicate low immunization coverage rates overall: diphtheria, pertussis, and tetanus vaccine first dose (DPT1) = 49.8%, DPT3 = 38.2%, measles = 41.8%, and full immunization = 24.9%. There was also significant clustering of full immunization among states. The authors found that having a health card and receiving postnatal care within the first 2 months of life were positively associated with full immunization, as were maternal education, wealth, age, and ethnicity. At the state level, the proportion of employed mothers and those who received tetanus immunization before birth was positively associated with full immunization. The following barriers were negatively associated with full immunization: needing to obtain permission, poor financial situation, and far distance to clinic. These findings call for state-specific targeting to address inequitable access to routine immunization in Nigeria.

Globally, an estimated 3 million children under 5 years die annually from infectious diseases, and a large number of these deaths are preventable by vaccine (World Health Organization [WHO], 2015a). Immunization is one of the safest and most cost-effective ways of preventing childhood illnesses and deaths (Bbaale, 2015; Nyarko, Pence, & Debpuur, 2001), and forestalls an estimated 2–3 million deaths annually from vaccine-preventable diseases (WHO, 2014b). Globally, since the inception of the Expanded Program on Immunization, vaccination coverage has generally increased (WHO, 2014a), yet in Africa about 20% of children still do not receive immunizations (WHO, 2015a). Nigeria's poor child health indices are reportedly associated with low immunization coverage, which is among the lowest worldwide (Ophori, Tula, Azih, Okojie, & Ikpo, 2014).

Nigeria, located in West Africa, had an estimated midyear population of 177 million in 2014 (Population Reference Bureau, 2014). The country is composed of 36 states and the Federal Capital Territory (National Population

Commission [NPC] & ICF International, 2014). Recent data estimate the under-5 mortality rate to be 117 per 1,000 live births (UNICEF, 2015). Underlying the burden of morbidity and mortality is poor utilization of health services generally, and spatial variations in health care access and use across states and regions (Antai, 2011; Babalola, 2008; NPC & ICF International, 2014). Similarly, there are marked disparities in access to social and economic resources across the country. The female literacy rate, for example, ranges from a low of 10% in Sokoto state to a high of >90% in Imo State, and depending on where they live, women in Nigeria have unequal access to economic resources, employment opportunities, and social services including health care (Davis & Kalu-Nwiwu, 2001; Kritz & Makinwa-Adebusoye, 1999).

The socioeconomic status of women is known to affect their ability to access and use health care services, for both themselves and their children (Kritz & Makinwa-Adebusoye, 1999; Woldemicael, 2010). Therefore, identifying the determinants of spatial variations in immunization uptake in Nigeria would contribute to identifying underserved areas; developing appropriate targeted strategies for intervention and improving the utilization of immunization services; thereby providing evidence for the judicious allocation of public health funds for successful structural and individual behavior change interventions (Antai, 2009a; Cohen, Scribner, & Farley, 2000). Nigeria occupies a strategic position globally as one of the countries with the largest numbers of unvaccinated children (WHO, 2014a). Hence improving

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immunization access and use would have a global impact on efforts to reduce child mortality.

Immunization in Nigeria

Child immunization in Nigeria is provided through routine immunization and catch-up supplemental immunization campaigns (also known as National Immunization Days) organized across the country or subnationally in selected areas (Antai, 2012; National Primary Healthcare Development Agency, 2009). A fully immunized child in Nigeria is expected to have received one dose of Bacillus Calmette–Guérin (BCG) at birth or soon after, 3 doses each of diphtheria, pertussis, and tetanus (DPT) and oral polio vaccine (OPV) vaccines at 6, 10, and 14 weeks, and one dose of measles vaccine (at 9 months or soon after) (NPC & ICF International, 2014; Ophori et al., 2014). Yellow Fever vaccination is also provided at 9 months. Vaccines introduced more recently and administered during the first year of life include hepatitis B, pneumococcus, and rotavirus vaccines (National Primary Healthcare Development Agency, 2009). In addition, vitamin A is administered at 9 and 15 months (Ophori et al., 2014). As part of the Polio Eradication and Endgame Strategic Plan, inactivated polio vaccine was introduced in the routine immunization schedule in 2015, and Nigeria participated in the April 2016 switch from trivalent to bivalent polio vaccine (WHO, 2013a). Furthermore, as countries introduce a second dose of measles vaccine and other booster doses, improved coverage of routine immunization is expected in the second year of life and beyond as this provides opportunities to catch up on any missed immunizations from the first year (Ophori et al., 2014).

Nigeria has been part of the global efforts to eradicate polio since 1988 though things have obviously not always gone smoothly. In 2003, a polio vaccination boycott in three northern states caused a major setback in Nigeria and surrounding countries, contributing to the reintroduction of the wild polio virus (WPV) into 31 countries that were previously polio free (Ehrenfeld et al., 2008; WHO, 2014a; Yahya, 2007). This boycott was triggered by political tension between the north and south of the country, which ultimately led to allegations by political and religious leaders in the three affected northern states that the vaccines were contaminated with antifertility agents and HIV targeting the northern population (Pincock, 2003; Yahya, 2007). More recently, attacks on health workers and frequent attacks on communities by Boko Haram in some parts of northeastern Nigeria have created barriers to access to immunization in these affected parts of the country (WHO, 2013b, 2014a). Remarkably, and despite these and other setbacks, Nigeria was declared polio free in September 2015, and as of the publication of this article, has not had a single case of WPV since July 2014 (WHO, 2015b). Nonetheless concerted efforts are still required to ensure polio does not reemerge and to have the African region certified polio free in 2018.

There are marked disparities in immunization coverage between low- and high-income countries as well as within countries (Holte, Mæstad, & Jani, 2012). Individual, community and

systemic factors contribute to inequitable uptake of childhood immunization (Antai, 2009a; Babalola, 2008; Wiysonge, Uthman, Ndumbe, & Hussey, 2012). Antai (2011) posited that regional disparities in immunization coverage are linked to contextual factors distinguishing one region from another. The present study examined the role of socioeconomic status on state variations in child immunizations in Nigeria. We aimed to assess determinants of the spatial variations in child immunization in Nigeria by investigating the individual and contextual factors that may affect access to routine immunization services in Nigeria. The study hypothesizes that states with low socioeconomic status of women will equally have poor realized access to childhood immunizations evidenced by low rates of full immunization coverage as defined by the NPC.

Method

Data Source

Data for this study were drawn from the 2013 Nigeria Demographic and Health Survey (DHS). The data are nationally representative, cross-sectional samples of the noninstitutionalized population (NPC & ICF International, 2014). The design and method of the Nigeria DHS is detailed elsewhere (NPC & ICF International, 2014). Briefly, the survey has a hierarchical structure, with individuals nested in households, and households nested in primary sampling units and states. The survey uses a two-stage stratified sampling technique, which draws a random sample of households and individuals from primary sampling units, which are, in turn, drawn from the 36 states and the Federal Capital Territory. After the submission of a summary of research objectives, Measure DHS granted us access to the survey data for this study.

Sample

We used data from the women's questionnaire. Women were eligible for the survey if they were between 15 to 49 years old, and lived in the selected household, or were visitors who slept in the household the previous night. A total of 38,948 women were interviewed, of whom 16,426 reported recent live births within the 3 years preceding the survey. Of these recent live births, participants were excluded if the child was less than 12 months or greater than 23 months old ($n = 10,694$), and if they had missing information on child immunizations ($n = 164$). We also excluded data from strata with single primary sampling units ($n = 7$), yielding an analytical sample of 5,561 in the 36 states and the Federal Capital Territory (cluster $n = 37$).

Measures

Outcome Variables

The primary outcome variable is a binary measure of whether or not a child was fully immunized. Full immunization status, in this context, was defined as a child ages 12–23 months who had received one dose of BCG, three doses of DPT,

three doses of polio vaccine, and one dose of measles vaccine (National Primary Healthcare Development Agency, 2009; NPC & ICF International, 2014). Given the possibility that some children may receive some but not all recommended immunizations, we considered three secondary outcome measures: coverage with DPT1, DPT3, and Measles vaccines. DPT1, given at 6 weeks, is an indicator of access or entry into the immunization system for most children, while DPT3 and Measles vaccines, given at 14 weeks and 9 months respectively, are measures of continued use of immunization services, and core indicators of immunization systems performance (WHO, 2014c).

Individual-Level Independent Variables

We assessed two levels of independent variables—individual (child and maternal) and state (contextual) variables. At the individual level, we included the following child's characteristics: gender (male/female), born in a health facility (yes/no), has a health card (yes/no), and received postnatal care within 2 months of birth (yes/no). We also included maternal characteristics: age (15–24 years, 25–34 years, or 35–49 years), education (none, primary, secondary, or higher), household wealth (poorest, poorer, middle, richer, richest), and currently married/cohabiting (yes/no) as well as religion (Christian, Muslim, or traditional/others) and residence (urban or rural). On the basis of common cultures, beliefs, and practices, we grouped women's ethnicities as Hausa/Fulani/Kanuri, Yoruba, Igbo, or others (all minority ethnicities other than the major three already listed).

State-Level Independent Variables

To capture the context of the state socioeconomic environment we considered aggregates of the following variables: female literacy (proportion of women who can read), women currently working, and women living in wealthy (richer and richest) households. We also included the proportion of women who received at least one dose of tetanus vaccine before the most recent birth. To explain context-specific problems women faced, we included barriers to healthcare seeking, (obtaining permission, financial, distance to the nearest health facility, lack of someone to accompany them, and attitude of healthcare workers).

Statistical Analysis

Frequencies were calculated for the sample. We estimated two-level models to identify determinants of state variations in the use of child immunization services. We modeled the effects of child and maternal characteristics and state socioeconomic characteristics on the odds of child immunization. Given that the primary dependent variable is binary, we used multilevel logistic regression to estimate the likelihood of receiving all basic Expanded Program on Immunization scheduled vaccinations (National Primary Healthcare Development Agency, 2009).

First, we fitted a null model to estimate the extent of spatial variations in the likelihood of a child aged 12–23 months being fully immunized. We fitted a second model to include the child's characteristics to assess the independent contribution of each to the differences in a child's immunization status. In the third model, we added the selected maternal characteristics to those of the child in the preceding model. Last, the fourth model included the independent contributions of individual and state variables to the odds of full immunization.

We expressed measures of fixed effects as odds ratios and *p* values. To estimate the extent of spatial variations in the odds of full immunization, we used the state variance and intra-class correlation coefficient as the measures of random effects (Larsen & Merlo, 2005). The differences in the nested models were estimated using the likelihood-ratio test. We fitted random intercept models using Stata's *meologit* syntax (ver. 13, StataCorp LP, College Station, TX, 2013). To increase the precision of our estimates, we specified nine integration points. We assessed model fit by comparing the Akaike's information criterion, with lower values indicating better fit. To reduce same source bias, we aggregated the state level socioeconomic variables for all women who participated in the survey rather than for only women with a child aged 12–23 months. Furthermore, we assessed the data for multicollinearity and obtained a variance inflation factor of 1.2, indicating the absence of significant collinearity among the variables retained in the full model. All analyses were weighted for sampling and non-response, and to increase generalizability of the findings.

Results

Description of Child, Mother, and State Variables

One in four children were fully immunized (Table 1). About half the children received DPT1 (49.8%), while only 38.2% received DPT3, depicting a DPT1–DPT3 dropout rate of nearly 12%. Measles immunization coverage was equally low at 41.8%. Nearly 21% of the children were unimmunized. Nearly one half (48.4%) of the children included in this study had health cards seen by the interviewers. Most women included in this study had no formal education (48.5%), and were in the poorest (23.4%) or poorer (22.7%) wealth quintiles. In addition, the highest proportion of women were Muslim (61.4%), and employed in nonprofessional occupations (67.4%). Nearly two thirds of the women (64.6%) lived in rural areas. Approximately 60% of the women received at least one dose of tetanus vaccine before the index birth. Participants reported various barriers to seeking health care, notably financial situation (43.6%), distance to the nearest health facility (30.9%), attitude of health care workers (16.1%), lacking someone to accompany them (14.2%), and obtaining permission (12.1%).

There were marked variations among states in the percentage of fully immunized children, ranging from 1% in Sokoto

Table 1. Characteristics of the Sample, 2013 Nigeria Demographic and Health Survey

Variable	%
<i>Child's characteristics</i>	
Immunization status	
Fully immunized	25.0
DPT1	49.8
DPT3	38.2
Measles vaccine	41.8
Unimmunized	20.9
Gender	
Male	51.7
Female	48.3
Place of birth	
Home	62.9
Public facility	23.0
Private facility	14.1
Postnatal care within two months	28.8
Has health card	48.4
<i>Mother's characteristics</i>	
Age (years)	
15–24	29.2
25–34	48.2
35–49	22.6
Education	
None	48.5
Primary	18.0
Secondary	26.5
Higher	7.0
Wealth	
Poorest	23.4
Poor	22.7
Middle	18.6
Rich	17.8
Richest	17.5
Religion	
Christian	37.0
Muslim	61.4
Traditional/others	1.6
Ethnicity	
Hausa/Fulani/Kanuri	43.9
Igbo	11.4
Yoruba	11.4
Others	33.3
Marital status	
Not married/cohabiting	4.5
Married/cohabiting	95.5
Occupation	
Unemployed	28.9
Nonprofessional	67.4
Professional	3.7
Rural residence	64.6
<i>Contextual characteristics</i>	
Female literacy	35.5
Currently employed women	69.7
Women in wealthy households	35.3

Table 1. (Continued).

Variable	%
Received tetanus vaccination	59.3
Barriers to seeking health care ^a	
Permission	12.1
Financial	43.6
Distance to nearest facility	30.9
Going alone	14.2
Attitude of health worker(s)	16.1

^aRows are not mutually exclusive.

State to nearly 63% in Imo State (Figure 1). Similarly, coverage with DPT1, DPT3 and measles vaccines also varied widely among states (Table 2). DPT1 coverage ranged from 3% in Sokoto state to 96.1% in Ekiti state; whereas DPT3 coverage ranged from 2.3% in Sokoto state to 85% in Imo State. Measles vaccine coverage ranged from a low of 3.3% in Sokoto and Kebbi states to a high of 85.4% in Ekiti state. The percentage of unimmunized children ranged from 0 in Ekiti state to 73.2% in Borno state (Figure 2).

Results of Multilevel Logistic Regression

The null model yielded a significant state variance ($\tau = 1.49$, $SE = 0.37$) and an intrastate correlation coefficient of 0.31, suggesting that 31% of the variance in full immunization status is attributable to differences at the state level (Table 3). In the second model, which included covariates of the child, the variance attributable to state effects remained significant ($\tau = 0.31$, $SE = 0.09$). The third model, comprising maternal characteristics in addition to the child's characteristics indicated a significant variance across states ($\tau = 0.13$, $SE = 0.04$). Our final model, comprising aggregate measures of state socioeconomic characteristics (in addition to the child's and mother's characteristics) yielded a significant variance in full immunization across states ($\tau = 0.10$, $SE = 0.03$) and an intrastate correlation coefficient of 0.04. We assessed the goodness of fit of each higher-level model by examining the Akaike's information criterion, with lower values indicating better model fit. Compared with the preceding model, each higher model yielded a significant likelihood ratio test statistic ($p < .01$)

In the adjusted model, at the individual level, receiving postnatal care within the first 2 months of a child's life was associated with nearly two times the odds of full immunization ($OR = 1.93$, $p < .01$). Similarly, having a health card was associated with 21 times the odds of being fully immunized compared to children without a health card ($OR = 21.49$, $p < .001$). Among maternal socioeconomic characteristics, increasing levels of education (secondary education: $OR = 1.58$, $p < .01$; higher education: $OR = 2.06$, $p < .01$) and household wealth (middle quintile: $OR = 1.54$, $p < .05$; rich quintile: $OR = 2.01$, $p < .01$; richest quintile: $OR = 2.53$, $p < .001$) were positively correlated with the likelihood of a

(Continued)

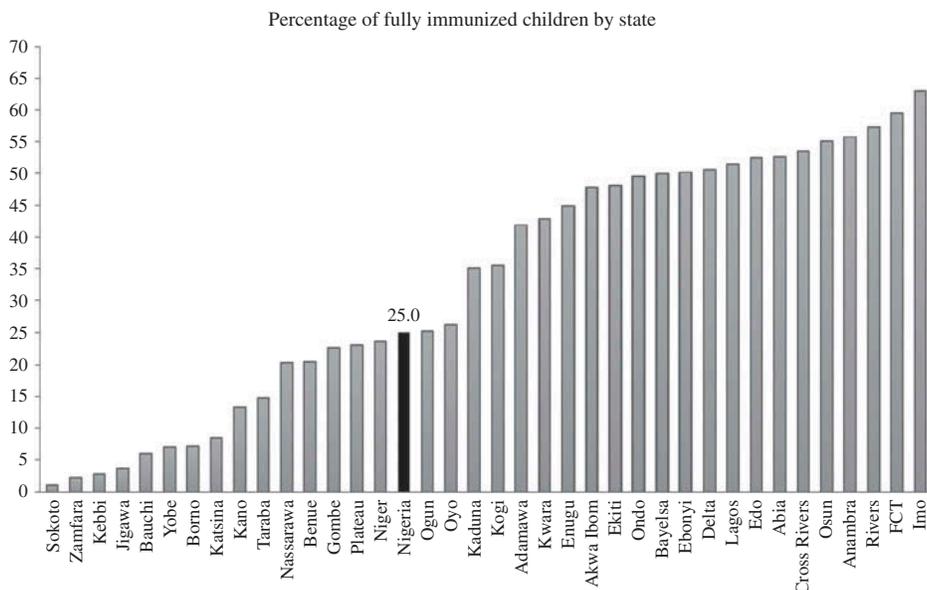


Figure 1. Percentage of fully immunized children by state, 2013 Nigeria Demographic and Health Survey.

child being fully immunized. Children with Muslim mothers were less likely to be fully immunized compared with children with Christian mothers ($OR = 0.68, p < .01$). Among state variables, receiving at least one dose of tetanus immunization prior to the index birth was associated with 36% higher odds of full immunization ($p < .05$). The following barriers to health care seeking were negatively associated with full immunization: obtaining permission ($OR = 0.73, p < .01$), financial ($OR = 0.77, p < .05$), and distance to the nearest health facility ($OR = 0.65, p < .05$).

Discussion

In this multilevel analysis of the socioeconomic determinants of spatial variations in child immunization among states in Nigeria, we found very low full immunization coverage overall (25%). We also found marked variations across states in the percentage of children 12–23 months who were fully immunized, ranging from a low of 1% in Sokoto State to a high of nearly 63% in Imo State. Additionally, approximately 1 in 5 children were unimmunized (20.9%). There was significant clustering of full immunization at the state level (31%, $p < .001$).

Our finding of a generally low proportion of fully immunized children ages 12–23 months is similar to the 2013 Nigeria DHS report of 25% (NPC & ICF International, 2014). Comparatively, the proportion of fully immunized children ages 12–23 months in Nigeria is lower than in other neighboring countries (Benin: 43%; Cameroun: 53%; Ghana: 77%; Niger: 52%; and Togo: 62%) (Ghana Statistical Service, Ghana Health Service, & ICF Macro, 2015; Institut National de la Statistique & ICF International, 2012, 2013; Institut National de la Statistique et de l'Analyse

Économique, & ICF International, 2013; Ministère de la Planification, du Développement et de l'Aménagement du Territoire, Ministère de la Santé, & ICF International, 2015). This comparison suggests that the Nigerian routine immunization program does not reach all vulnerable children with critical life-saving vaccines. Moreover, it is surprising that after several years of supplemental immunizations, nearly 21% of Nigerian children were unimmunized. Given the large population and ethnic and cultural diversity of the country, there is a need to intensify efforts to improve access to, and use of, child immunizations. Furthermore, the recent addition of rotavirus and pneumococcal vaccines to the Expanded Program on Immunization schedule demands strengthened immunization services. With the recent adoption of the Sustainable Development Goals, restructurizing is an important first step to the implementation of Sustainable Development Goal 3, one of whose targets is to end preventable deaths of newborns and under-5 children by 2030 (United Nations Department of Economic and Social Affairs, 2015). In addition, the 2013 Nigeria Routine Immunization Strategic Plan with an accountability framework (National Primary Healthcare Development Agency, 2013) offers a timely platform for reducing the inequities in access to, and use of, immunization services and strengthening immunization systems in the country.

Timely postnatal care offers an important opportunity for initiating the DPT or pentavalent vaccine series, as well as the administration of BCG vaccine to children who had not yet been immunized. It is important to promote early postnatal care, especially because many children are born outside health facilities and may not receive any birth doses of vaccines before the postnatal care visit. While having a health card could serve as a reminder to parents

Table 2. Ranking of States in Nigeria According to DPT3 Coverage and Distribution of Other Antigens and State Socioeconomic Characteristics, 2013 Nigeria Demographic and Health Survey

Rank	State	DPT1 (%)	DPT3 (%)	Measles (%)	Literacy rate (%)	Wealthy households (%)	Employment rate (%)
1	Sokoto	3.0	2.3	3.3	4.7	12.3	49.6
2	Kebbi	5.0	3.0	3.3	6.5	7.9	67.1
3	Zamfara	12.5	5.7	8.0	3.3	3.7	69.8
4	Jigawa	20.4	7.2	11.2	8.1	5.2	60.5
5	Borno	17.0	9.3	15.1	16.3	27.1	29.5
6	Yobe	17.8	11.3	10.3	11.6	15.5	38.1
7	Bauchi	24.2	13.2	20.1	11.3	13.7	59.1
8	Katsina	23.2	15.0	43.5	8.6	10.4	68.8
9	Kano	26.2	18.7	25.8	14.1	22.5	68.1
10	Taraba	42.9	22.9	28.1	21.1	11.9	68.5
11	Benue	55.9	29.1	44.0	46.5	15.5	91.9
12	Nasarawa	59.1	33.0	44.6	35.8	21.3	62.0
13	Gombe	43.8	36.9	36.2	19.9	15.6	53.2
14	Niger	52.7	37.4	40.0	16.6	32.9	82.9
15	Nigeria*	49.8	38.2	41.8	35.5	35.3	69.7
16	Kaduna	60.8	43.9	56.6	36.4	39.8	69.9
17	Oyo	71.9	48.6	46.0	52.5	64.8	95.5
18	Plateau	61.7	49.0	46.2	47.1	20.7	56.5
19	Adamawa	80.9	54.6	71.2	38.8	26.8	66.4
20	Ogun	77.3	59.1	52.4	61.1	69.3	88.1
21	Delta	73.6	61.6	60.6	65.2	67.2	81.2
22	Ondo	71.2	63.0	62.1	63.0	62.2	89.7
23	Kwara	73.5	65.1	56.9	50.8	72.4	86.0
24	Akwa-Ibom	90.5	65.4	74.2	72.4	59.2	73.6
25	Bayelsa	79.1	67.2	72.5	63.1	72.2	73.8
26	FCT	82.9	68.2	67.7	59.1	73.1	56.8
27	Rivers	86.2	72.5	81.4	87.9	75.5	82.0
28	Kogi	87.0	76.4	75.2	51.6	61.2	83.5
29	Lagos	89.2	77.8	73.9	82.6	97.8	77.7
30	Cross-River	87.0	77.9	76.9	63.5	31.9	80.0
31	Ebonyi	87.8	80.3	60.9	57.2	23.9	78.5
32	Ekiti	96.1	81.2	85.4	84.4	84.9	76.0
33	Enugu	87.5	81.4	77.2	72.7	46.2	76.8
34	Edo	88.3	81.5	76.6	70.0	73.3	77.1
35	Anambra	87.5	81.6	76.1	82.3	85.9	68.5
36	Osun	91.9	82.2	74.4	71.2	84.4	99.1
37	Abia	93.8	83.9	75.4	80.2	70.6	73.0
38	Imo	92.2	85.2	75.8	85.5	68.0	53.8

*National average.

that their children are due for immunizations, it is also possible that successful completion of all scheduled child immunizations may be a motivation for retaining the health card. However, the cross-sectional nature of our data did not allow for identifying the existence or directionality of causality. Contrary to the findings of prior studies (Antai, 2009b; Etana & Deressa, 2011), we found no association between facility birth and full immunization. This finding warrants further investigation because one would expect that mothers who give birth in a health facility may have better physical access to health services, in addition to the

higher likelihood that a child born in a health facility may be administered some vaccines at birth, thereby initiating early contact with routine immunization services.

Higher socioeconomic status (education and household wealth) are associated with the use of health services and better health outcomes. Wealthier mothers are more likely to be educated and to have the needed resources to seek child health services. Consistent with the findings of previous studies (Antai, 2009b; Etana & Deressa, 2012; Nath et al., 2007; Sullivan, Tegegn, Tessema, Galea, & Hadley, 2010), we found a positive association between maternal education and child

Table 3. Results of Multilevel Logistic Regression of Full Immunization Status on Selected Child, Maternal, and Contextual Characteristics ($n = 5,561$), 2013 Nigeria Demographic and Health Survey

Variable	Model 1 (null)	Model 2 (child)	Model 3 (child, mother)	Model 4 (child, mother, state)
Fixed effects				
<i>Child's characteristics</i>				
Gender (male)				
Female		1.02	1.02	1.03
Facility delivery (ref = no)	—			
Yes		1.55***	1.08	1.05
Postnatal care within 2 months (ref = no)	—			
Yes		2.20***	1.21*	1.93**
Child has health card (ref = no)	—			
Yes		32.33***	23.14***	21.50***
<i>Mother's characteristics</i>				
Mother's education (ref = none)	—	—		
Primary			1.31*	1.23
Secondary			1.69***	1.58**
Higher			2.21***	2.06***
Household wealth (ref = poorest)	—	—		
Poor			1.45*	1.39
Middle			1.64**	1.54*
Rich			2.16***	2.01**
Richest			3.72***	2.53***
Currently married/cohabiting (ref = no)	—	—		
Yes			0.77	0.77
Maternal age (ref = 15–24)	—	—		
25–34			1.24*	1.25*
35–49			1.29*	1.29*
Religion (ref = Christian)	—	—		
Muslim			0.58 **	0.68**
Traditional/others			0.55	0.54
Ethnicity (ref = Hausa)	—	—		
Igbo			1.23	1.25
Yoruba			1.18	1.51*
Others			1.34*	1.36*
Residence (urban)				
Rural			0.93	0.94
<i>Contextual characteristics</i>				
Literate (%)	—	—	—	1.02
Currently employed (%)	—	—	—	1.16*
Living in wealthy households (%)	—	—	—	1.07
Received tetanus vaccine (%)	—	—	—	1.36*
Barriers to health care (ref = none)	—	—	—	
Permission				0.73**
Financial				0.77*
Distance				0.65*
Going alone				0.73
Attitude of health workers				1.57
Random effects				
State variance (SE ^a)	1.49 (0.37)	0.31 (0.09)	0.13 (0.04)	0.10 (0.03)
Log likelihood	-2710.16	-2131.62	-2068.47	-2038.97
ICC ^b	0.31	0.18	0.07	0.04
PCV ^c (%)	Reference	79.2	58.1	23.1
AIC ^d	5424.32	4275.24	4180.93	4149.94

Ref: Reference category (in parenthesis).

*** $p < .001$, ** $p < .01$, * $p < .05$.

^aStandard error; ^bIntra-class (state) correlation; ^cProportional change in variance; ^dAkaike's information criterion.

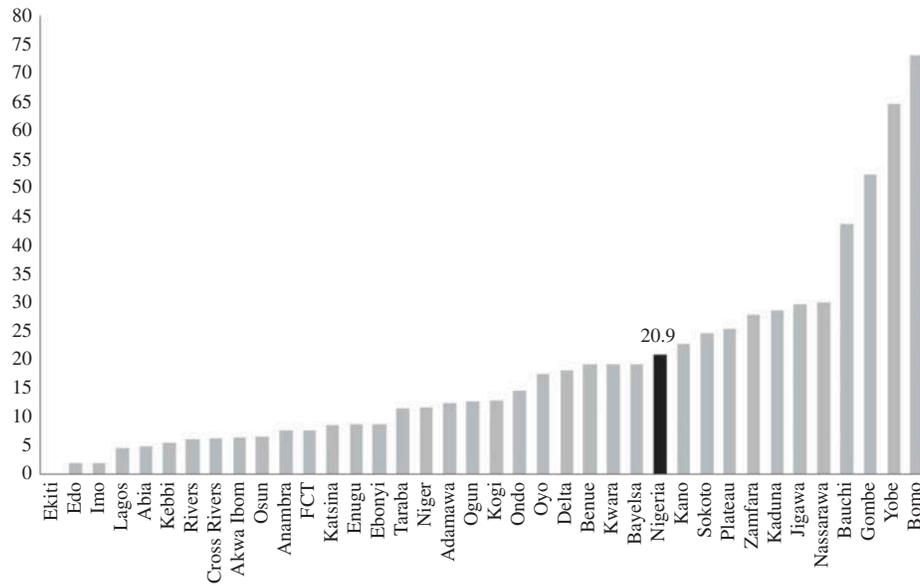


Figure 2. Percentage of unimmunized children by state, 2013 Nigeria Demographic and Health Survey.

immunization. Educated mothers are more likely to comprehend health information and to be aware of the availability and benefits of child immunization.

Muslim religious affiliation was associated with reduced odds of full immunization. On the one hand, a recent study in three northern Nigeria states found little effect of religious affiliation on the decision of parents to immunize their children (Taylor, 2015). The political and socioeconomic climate seemed to better explain household immunization decision making. On the other hand, scholars have found positive associations between Muslim religious affiliation and reduced odds of full immunization in Nigeria (Antai, 2009a; Ophori et al., 2014; Singh, Haney, & Olorunsaiye, 2013). Furthermore, Ophori and colleagues (2014) suggested that poor utilization of immunization services in Muslim communities may have cultural underpinnings, in addition to the mistrust of vaccinations. The devastating effect of the mistrust of vaccinations is an issue that needs to be addressed on an ongoing basis. This is especially important now that Nigeria has been polio-free for nearly 2 years. This will go a long way towards consolidating and sustaining the success so far recorded in polio eradication efforts and ensuring equitable access to routine immunization services. There was no association between child immunization and residence which may suggest that the effect of residence is indirect and may have been explained by other variables in the adjusted model (e.g., education, household wealth).

Contrary to our expectation, there was no association between female literacy at the state level and child immunization. Besides the fact that individual levels of women's education may be a stronger predictor of immunization uptake (Babalola, 2008; Singh et al., 2013) than the aggregate measure, we used female literacy rather than education. The

DHS assesses literacy as the ability to read selected text in either English or the predominant local language of the area, and thus may not adequately measure formal education. Furthermore, Wiysonge et al. (2012) and Antai (2009b) found a positive association between contextual levels of education and child immunization. However, the researchers clustered their observations at the community level, whereas we clustered ours at the state level. Thus, it is possible that the community may be more homogeneous in terms of the socioeconomic status of the compositional households than the state. These differences may be responsible for the lack of associations we observed, and warrants further investigation.

Nonetheless, the above average clusters of unimmunized children in the northeast are not surprising. For several years, many states in the northeast of the country have experienced series of armed conflicts and attacks on communities and health care workers by the fundamentalist group, Boko Haram, which may possibly explain the extremely high proportions of unimmunized children in these states (Borno: 73.2%, Yobe: 64.8%, Gombe: 52.3%, and Bauchi: 43.7%) (Figure 2). It is worth noting that these high numbers of unimmunized children are very concerning. Given the improved quality of polio supplementary immunization activities and surveillance in the country, it is unlikely that there are such large pockets of unimmunized children in these northern states. It is possible that as a result of DHS focus on routine immunizations, the survey may not have captured children who received polio vaccinations during supplemental campaigns.

Consistent with reports from previous studies (Etana & Deressa, 2012; Sullivan et al., 2010), there was a positive association between maternal tetanus vaccination and child immunization. Maternal tetanus immunization is not only a

proxy for the use of maternal health services during the index pregnancy (Etana & Deressa, 2012; Sullivan et al., 2010), but may also provide insights into a woman's approval of immunization. Thus, improving access and utilization of maternal health services generally, and tetanus immunizations during pregnancy may improve the acceptance and uptake of child immunizations, especially in states with low routine immunization coverage.

Our results also suggest that the barriers women face in accessing healthcare for themselves also affected access to child immunization services. In particular, needing to obtain permission to use health services, lack of financial resources either for transportation or to pay for services, and distance to the nearest health facility posed barriers to child immunization in this study. The free immunization policy in the country may not be enough to ensure equitable access and use of these services. There are other salient factors that may limit the use of the seemingly free services (Eisenberg & Power, 2000). Even where services are offered free, there are other important barriers and indirect costs, such as travel times and transportation when the nearest public health facility providing these services is not within a short distance (Adeyinka, Oladimeji, Adeyinka, & Aimakhu, 2009; Diaz et al., 2013; Hjortsberg, 2003). In addition, private facilities, where available, typically charge a fee for services, thus posing a financial barrier to women who may, otherwise, find them more conveniently located (Adeyinka et al., 2009). Completing the scheduled routine immunizations requires that a parent/caretaker is committed to making multiple visits to a health facility or outreach site during the first year of a child's life and beyond. This commitment may be hampered by problems of distance, finances, and permission. We found no association between attitudes of health workers and full immunization. Although health worker attitude has been shown to negatively affect the use of immunization uptake in some settings, (Babirye, Engebretsen, Rutebemberwa, Kiguli, & Nuwaha, 2014; Ehiri, Oyo-Ita, Anyanwu, Meremikwu, & Ikpeme, 2005), the research is limited, and will need further investigation. As a result of the sociocultural underpinnings of some of these factors, they may be better assessed qualitatively (e.g., through in-depth interviews and focus group discussions of parents or caretakers and health care workers).

After accounting for child, maternal sociodemographic and state socioeconomic characteristics, the state variance in child immunization status decreased but remained statistically significant, suggesting substantial variations in access to, and use of, immunization services among states. The residual variance suggests that the variables included in the model did not fully explain all the variation among states in child immunization. This further suggests that regardless of individual child and maternal characteristics, children living in the same state are vulnerable to common contextual impacts of state factors on the likelihood of being fully immunized. For example, states have different levels of health care infrastructure and human resources to provide immunization services. These factors are beyond the control of individuals and

families, and will need evidence-based policy making to mitigate the systemic factors that foster social inequities within and between states in the country. These findings call for state-specific policy making to address the prevailing barriers to immunization services (Campbell, 2006).

Our findings should be considered in the light of certain limitations. This analysis was limited to the variables available in the data. We intended to include supply side variables in this study, but attempts to obtain permission to use those data were unsuccessful as of the time of this report. Thus, endogeneity resulting from omitted variables may be an issue. However, we attempted to account for multiple dimensions of individual and contextual factors that may affect the demand for child immunization services. It is very important to note that because of data access issues, we could not account for immunization system factors (e.g., geographic access to services, and availability of vaccines and other immunization infrastructure and supplies in states). These factors may limit the ability of families to access or use immunization services beyond the contribution of individual characteristics, and will warrant further research. Also, the reliance on verbal reporting of immunization in approximately half the sample may cause some recall bias; however, limiting our sample to the youngest cohort of children who would have completed the infant series of vaccinations (12–23 months) should significantly reduce this bias. Although we considered how urban or rural residence may affect immunization coverage, we could not take account of peri-urban residence as this category was not included in the dataset. It is worth mentioning that peri-urban settings could differ in significant ways from rural or urban areas in terms of socioeconomic, political, and infrastructural characteristics, which could inevitably affect the supply and demand for immunization services.

Despite these limitations, our findings are relevant to the discourse on improving immunization coverage in Nigeria. This study identified significant variations in immunization access and utilization among states. As the second tier of government in Nigeria, states occupy a strategic position in policy making, and we hope that these findings will inform planning and implementing programs aimed at improving immunization uptake, and closing the equity gap in access to routine immunizations. Going forward, further research into vaccine supply and availability of immunization services will be very helpful in identifying supply side barriers to full immunization among states. Furthermore, qualitative or mixed methods study design would provide an understanding of contextual barriers and social norms affecting immunization that are not measured in the prevalent quantitative surveys, and provide evidence for education and behavior change communication for childhood immunizations.

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