8-11-2020

Risk Factors of Incomplete Immunization Among Children Under Five in Nigeria: An Analysis of theDemographic Health Survey

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July 24th, 2020

A Thesis Submitted to the Graduate Faculty

of Georgia State University in Partial Fulfillment

of the

Requirements for the Degree

MASTER OF PUBLIC HEALTH

ATLANTA, GEORGIA

30303

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By

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Defense date: July 24th, 2020

ABSTRACT

BACKGROUND: Nigeria is among the countries with the lowest immunization coverage in the AFRO region according to the WHO estimates. In 2018, 70% of the population is not vaccinated, representing an approximated 3 million people. Incomplete or inexistent vaccination is due to multiple factors pertaining to the health system, family factors, available information, and communication strategies. This multilevel aspect of the risk factors was identified in a systematic review that focused on low and middle-income countries suggesting that social determinants of health have an impact on the immunization coverage. The present thesis focused on the individual, family, and community socio-economic factors that influence incomplete immunization in Nigeria.

METHODS: Data from the Demographic and Health Survey (DHS) datasets made publicly available by USAID (DHS program, available datasets, 2009 -2018) were used to conduct a cross-sectional analysis. Factors were categorized into individual-, family-, and community-levels. We focused on the following vaccines' coverage status: BCG, Pentavalent, Polio 3, and Measles. The data analysis was performed using SAS software to run a multilevel model. We also used ArcMap to perform a spatial analysis of the immunization coverage rates in the country.

RESULTS: We identified risk factors such as lack of access to prenatal care, home delivery, lack of access to media outlets, the lack of mothers education, and the low economic status that influence incomplete immunization in Nigeria in children aged between 12 – 23 months old. This study also showed the increased influence of family and community factors on immunization coverage, in accordance with the Social Determinants of Health concept.

CONCLUSION: Interventions that aim to increase the uptake of child immunization should focus on these factors and act on three axes: a policy, research, and health systems strengthening components.

KEY WORDS: Child Immunization, Incomplete immunization, Risk factors, Nigeria

ACKNOWLEDGEMENTS

I would like to extend gratitude and appreciation to my committee chair Dr. Xiangming Fang and my committee member Dr. Qian An for their guidance, assistance, and encouragement throughout the thesis process.

I would like to also thank my family and friends for their continuous support, Georgia State University faculty and staff, and my internship preceptors at the US Center for Disease Control and Prevention and Emory School of Medicine.

AUTHOR'S STATEMENT

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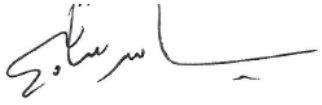

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ACRONYMS

AFR/WHO:	Who African Region
AIC:	Akaike Information Criterion
ALGON:	Association of Local Governments of Nigeria
AOR:	Adjusted Odds Ratio
BCG:	Bacillus Calmette–Guérin
BCR :	Benefit–Cost Ratio
BIC:	Bayesian Information Criterion
CDC:	Center for Disease Control and Prevention
CFR:	Council on Foreign Relations
CHAI:	Clinton Health Access International
CHEW:	Community Health Extension Workers
CI:	Confidence Interval
DFID:	UK Department for International Development
DTP:	Diphtheria, Tetanus and Pertussis Vaccine (3 Doses)
EA:	Enumeration Area
EPI:	The Expanded Programme On Immunization
EUR/WHO:	Who European Region
GAVI:	The Vaccine Alliance
GHO:	Global Health Observatory
GVAP:	Global Vaccine Action Plan
HDI:	Human Development Index
HERFON:	Health Reform Foundation of Nigeria
HH:	Household
HIV:	Human Immunodeficiency Viruses
ICC:	International Coordination Committee
ICERs:	Incremental Cost-Effectiveness Ratio
IDP:	Internally Displaced Persons
IDSR:	Integrated Diseases Surveillance and Response
IVAC:	International Vaccine Access Center
KAP:	Knowledge Attitudes and Principles
LGA:	Local Government Association
LICs:	Low Income Countries
LMICs:	Low- And Middle-Income Countries
MDG:	Millennium Development Goals
MMR:	Measles, Mumps, And Rubella
MSS:	Midwives Service Scheme
NDHS:	Nigeria Demographic Health Survey
NPHCDA:	National Primary Health Care Development Agency
OPV:	Oral Polio Vaccine

PHC:	Primary Healthcare Center
PSU:	Primary Sampling Unit
QALY:	Quality-Adjusted Life Year
RI:	Routine Immunization
SDH:	Social Determinants of Health
TB:	Tuberculosis
TRIPS:	Agreement on Trade-Related Aspects of Intellectual Property Rights
UNHCR:	United Nations High Commissioner for Refugees
UNICEF:	United Nations Children's Fund
USAID:	United States Agency for International Development
USD:	United States Dollar
WHO:	World Health Organization

1 INTRODUCTION

1.1 BACKGROUND

Often used interchangeably, “Immunization,” “vaccination,” or “Inoculation is the “process by which a person becomes protected against a disease through vaccination”(US CDC, 2020). The world health organization adds to this definition by specifying protection against infectious diseases (WHO, 2020c). In fact, it has been agreed that immunization is an effective tool for “controlling and eliminating life-threatening infectious diseases”(WHO, 2020c). The WHO also estimates that two to three million deaths are averted each year thanks to immunization (WHO, 2020c) and contributes to increasing life expectancy and quality of life worldwide (Rappuoli et al., 2019). Besides the recent “outbreak” in antivaccine movements and vaccine skeptics (Rappuoli et al., 2019), the WHO continues to work on “closing the immunization gap” (WHO, 2015). Through accountability and tailored resources mobilization, the goal is to prevent the 1.5 million deaths per year that are accounted for the lack of immunization (WHO, 2015).

Added to that, global efforts to increase the immunization rate coverage are anchored in the “United Nations: Sustainable Development Goals” to “ensure healthy lives and promote wellbeing for all at all ages” (UN, 2020). Widely recognized as the “most cost-effective” health intervention, vaccines and vaccinations are cited four times in the “targets and goals section” as follows:

Table 1: Sustainable development goals focusing on vaccine coverage (UN, 2020)

Targets	Indicators
3B Support the research and development of vaccines and medicines for the communicable and non-communicable diseases that primarily affect developing countries, provide access to affordable essential medicines and vaccines, in accordance with the Doha Declaration on the TRIPS Agreement and Public Health	**3.B.1** The proportion of the population with access to affordable medicines and vaccines on a sustainable basis
3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all	**3.8.1** Coverage of essential health services (defined as the average coverage of essential services based on tracer interventions that include reproductive, maternal, newborn and child health, infectious diseases, non-communicable diseases and service capacity and access, among the general and the most disadvantaged population)

In the Report of the Secretary-General published on May 8th, 2019 (UN, 2020), coverage of the second vaccine of measles, although increased from 59% to 67%, is still insufficient to prevent the contagious disease. On the other hand, the three doses of vaccine that prevent diphtheria, tetanus, and pertussis (DTP vaccine) remained unchanged after an increase of 72% in 2000 to 85% in 2015.

1.2 COST-EFFECTIVENESS OF VACCINATION

The cost-effectiveness of vaccination campaigns has been widely agreed upon and is a motivator for the World Health organization to promote and recommend mass vaccination campaigns. Multiple studies have studied and asserted the cost-effectiveness of vaccination worldwide. A systematic review reviewed the published literature on the cost-effectiveness of vaccination against flu-like illnesses (Ting et al., 2017). The study found that, when focused on children, vaccinating all versus only high-risk children was cost-effective. From a societal perspective, ICERs ranged from dominant to $47,000 per QALY. From the healthcare perspective, it ranged from dominant to $18,000 per QALY (Ting et al., 2017). The author came to a favorable conclusion when it came to mass immunization programs. Taking into account the indirect or herd protection effect of vaccination, rotavirus vaccines are also considered a cost-effective

intervention among LICs and LMICs. Added to that, they offer a "good value-for-money" in the same setting (Kotirum et al., 2017).

Rubella and measles vaccines, since highly effective and inexpensive, are also proven to be cost-effective with significant health and economic benefits (Thompson & Odahowski, 2016). The first dose of MMR vaccine compared to baseline (no vaccination) yields the most net benefits expected (BCR > 9:1). Adding a second dose to a 95% coverage is also cost and lifesaving, depending on the first dose coverage (Beutels & Gay, 2003). BCG vaccination against TB as a universal strategy has also shown cost-effectiveness, versus no vaccination, in high incidence countries. The strategies where infants are targeted (selective strategies) are deemed the most cost-effective (Machlaurin et al., 2019). BCG vaccination is estimated to save USD 1,105 per TB case averted and USD 284,017 per TB death averted (Channing & Sinanovic, 2014). A separate analysis of the "Vaccines for Children Program Era" program in the United States 1994–2013 demonstrated that in 2009 alone, each dollar invested in vaccines and administration returned $3 indirect benefits ($10 when considering the societal costs) (G. Whitney et al., 2014).

1.3 GLOBAL VACCINE INITIATIVES

Multiple efforts led by the World Health Organization aimed at ensuring a more equitable vaccination coverage worldwide. The first 10-year strategic plan was launched in 2005 under the "Global Immunization Vision and Strategy 2006-2015" name. The followed by the "The Global Vaccine Action Plan (GVAP)" (Berkley et al., 2012), a framework developed by the World Health Organization to guide the global immunization activities and set six guiding principles necessary to guarantee that "all individuals and communities enjoy lives free from vaccine-preventable diseases." Although the GVAP needs to be adapted for the specific national context of the country of interest, the six guiding principles are considered universal: "Country ownership, Shared responsibility and partnership, equity, integration, sustainability, and innovation." The goals of the GVAP are to: "Achieve a world free of poliomyelitis, Meet

global and regional elimination targets, Meet vaccination coverage targets in every region, country, and community, Develop and introduce new and improved vaccines and technologies, and to exceed the Millennium Development Goal 4 target for reducing child mortality." The framework also contains a set of strategic objectives:

1. All countries commit to immunization as a priority
2. Individuals and communities understand the value of vaccines and demand immunization as both their right and responsibility
3. The benefits of immunization are equitably extended to all people
4. Strong immunization systems are an integral part of a well-functioning health system
5. Immunization programs have sustainable access to predictable funding, quality supply, and innovative technologies
6. Country, regional and global research and development innovations maximize the benefits of immunization

GVAP was the product of the collaboration between the Bill & Melinda Gates Foundation, GAVI Alliance, UNICEF, United States National Institute of Allergies and Infectious Diseases, and WHO. These efforts are implemented by various stakeholders, with GAVI – the Vaccine Alliance – being the most prominent one. "As part of its mission to save lives, reduce poverty and protect the world against the threat of epidemics, GAVI has helped vaccinate more than 760 million children in the world's poorest countries, preventing more than 13 million deaths" (GAVI, 2020). With the recent COVID19 pandemic, these efforts were put to a halt or impeded by the increased focus on the pandemic and lockdowns. Tedros, WHO's director, affirmed that "in 2020 because of a failure to invest in preparedness we now risk backsliding on child immunization, malaria, neglected tropical diseases and HIV" (WHO, 2020e). Drawing from the lessons learned from new and current infectious diseases challenges (Ebola, COVID-19, etc.), the WHO is starting the "Immunization Agenda 2030" (IA 2030) that will become operational during 2020-21 "through

regional and national strategies, a mechanism under development to ensure ownership and accountability and a monitoring and evaluation framework to guide country implementation" (WHO, 2020a).

1.4 THE STATE OF IMMUNIZATION WORLDWIDE

The world health organization recognized that global vaccination coverage has remained stagnant in the past few years. Nevertheless, 1 billion children received vaccination in the past ten years, with an increase in the uptake of new and underused vaccines. In 2019, 85% of infants worldwide (116 million infants) received three doses of DTP3 vaccine reaching 125 countries, ensuring a 90% vaccination coverage for the DTP3 vaccine. Added to that, poor maternal and child health indicators worldwide have affected the attainment of the United Nations Millennium Development Goals 4 and 5 (under-five child and maternal mortality) (WHO, 2020b). Figure 1 shows the change in immunization coverage by WHO regional office and globally.

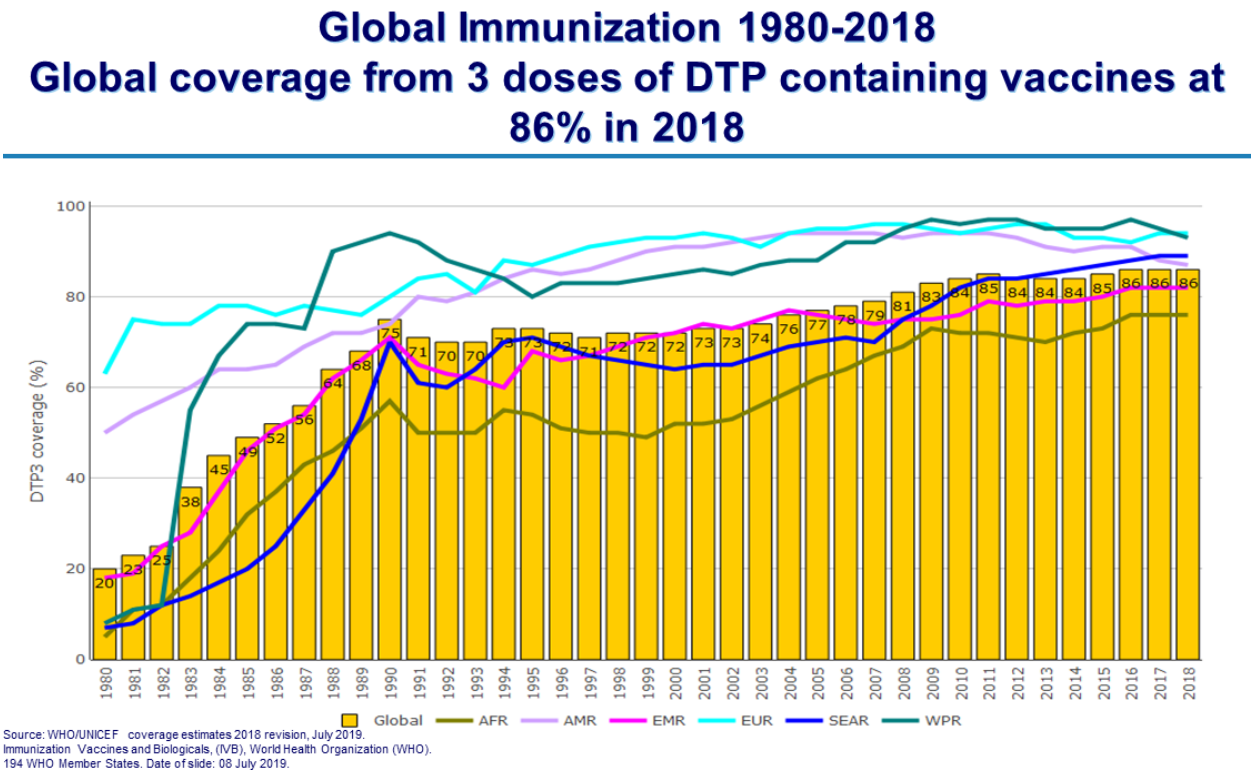

Figure 1: Global immunization coverage from 3 doses of DTP vaccines, by regional office and globally (Global Health Observatory (GHO), 2019)

The figure shows that the African region suffers from the lowest immunization rates when compared to other regional offices when considering the intake of 3 does od DTP vaccine. A closer look at the national levels of the continent, Nigeria is among the lowest in immunization coverage for the three doses of the vaccine with discrepancies between official national averages and WHO/UNICEF estimate. Figure 2 displays these proportions and the discrepancies between national and WHO estimates in Nigeria, with 60% of the 774 LGAs reporting a coverage greater or equal to 80% and 40% reporting a coverage lower than 79%. The Global vaccine Action Plan's goal for immunization coverage was set at 90% national coverage and 80% in every district or equivalent administrative unit for all vaccines in national programs by 2020.

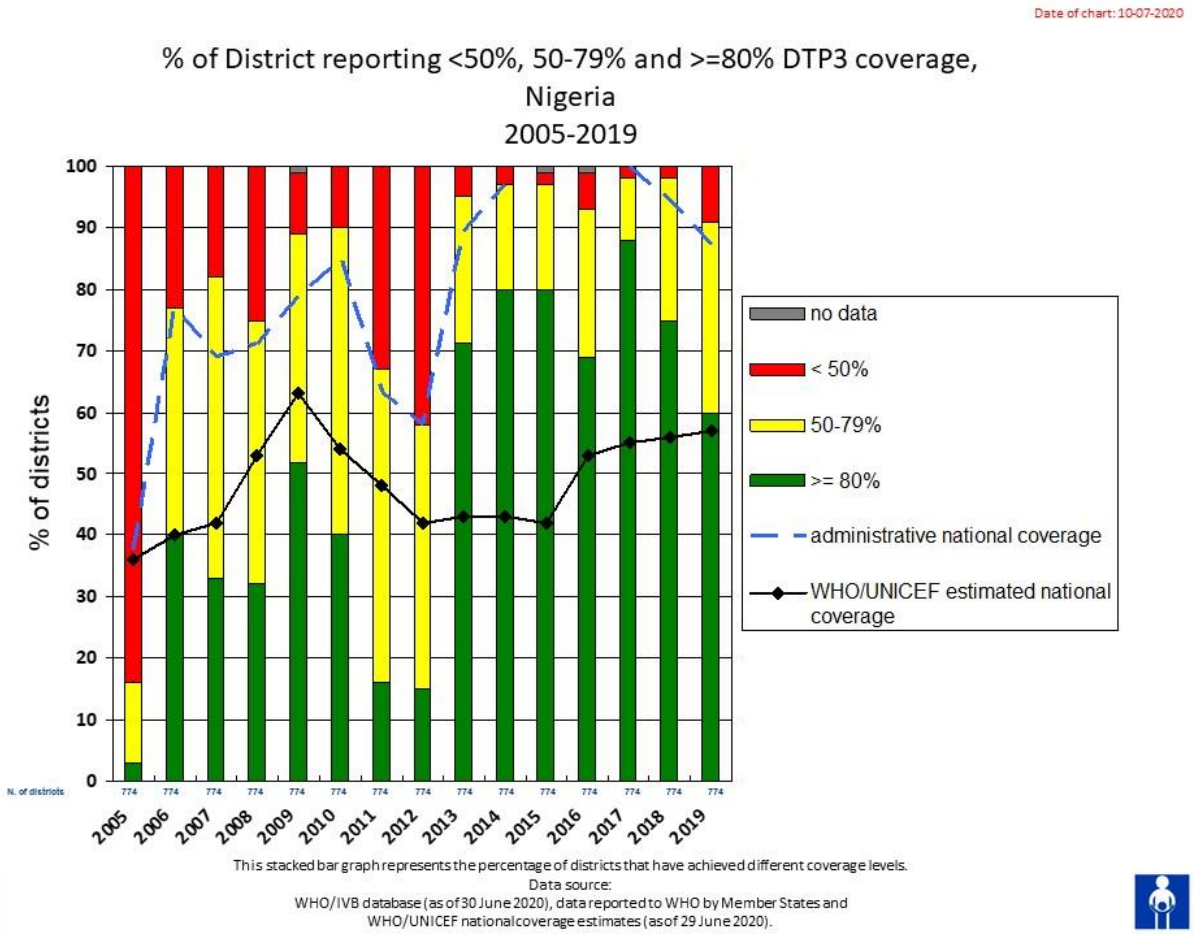

Figure 2: Proportion of districts reporting below 50%, 50 - 79%, and above 80% DTP3 coverage (WHO, 2020d)

1.5 Research Questions

The above observations regarding the immunization status in Nigeria encouraged this thesis in an attempt to uncover the risk factors that lie behind the low immunization rates (less than 60% coverage for the 3 DTP doses). The global health observatory data shows the death rate under five is the highest in the WHO African region, with 74 per 1000 live births (GHO, 2019). In fact, under-five children have a 15 times higher chance of dying when compared to their peers in high-income countries (WHO, 2019). Preventable diseases are a significant factor that influences the high rate of these mortalities observed in the region, particularly those preventable by proper and complete vaccination (Wiysonge et al., 2012). Nigeria is among the countries with the lowest immunization coverage in the region, according to the WHO

estimates. In 2018, 70% of the population was not vaccinated, representing approximately 3 million people (WHO, 2020f). The purpose of this study is to identify and update the current knowledge about the risk factors that influence the vaccination rate in Nigeria among under-five children, and help increase the efficiency of the "Expanded Program of Immunization in Nigeria" (Sorungbe, 1989). Incomplete or inexistent vaccination is due to multiple factors pertaining to the health system, family factors, available information, and communication strategies. This multilevel aspect of the risk factors was identified in a systematic review that focused on low- and middle-income countries (Rainey et al., 2011), suggesting that social determinants of health have an impact on the immunization coverage. Figure 3Figure 4 show the vaccination coverage estimates in a comparison between the AFR and the EUR regions for the DTP1, DTP3, and the BCG vaccines from 2013 to 2018. The present thesis focused on the individual, family, and community-level factors that might influence the immunization coverage rate in Nigeria. Based on the belief that "public health is a data-intensive field which needs high-quality data and authoritative information to support public health assessment, decision-making and to assure the health of communities" (Nagbe et al., 2019), we aim to:

- **Aim1:** determine the determinants of the lack of vaccination coverage in Nigeria among children under-five considering individual, community, and state-level factors.
    - **Hypothesis 1:** The current lack of vaccination coverage will be explained by a mix of individual factors related to the child, family-related factors (especially the mother's education level), and community-level factors.
- **Aim 2:** To determine the most influencing factors that affect the incomplete childhood immunization rates in Nigeria.
    - **Hypothesis 2:** Family and community-level factors have the highest odds ratios of influencing high levels of incomplete vaccination rates in Nigeria among the under-five population.

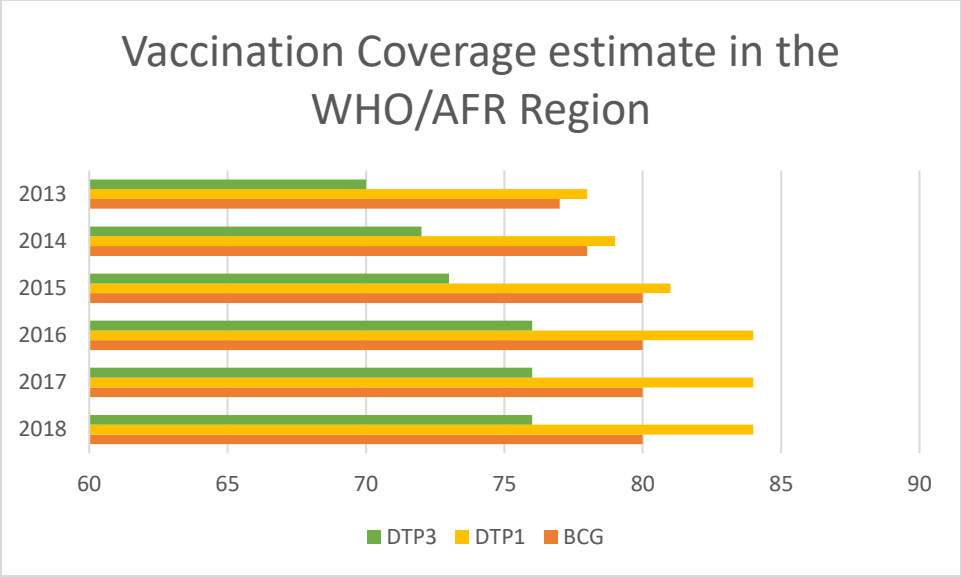

Figure 3: Vaccination Coverage estimate in the WHO/AFR Region from 2013 to 2018

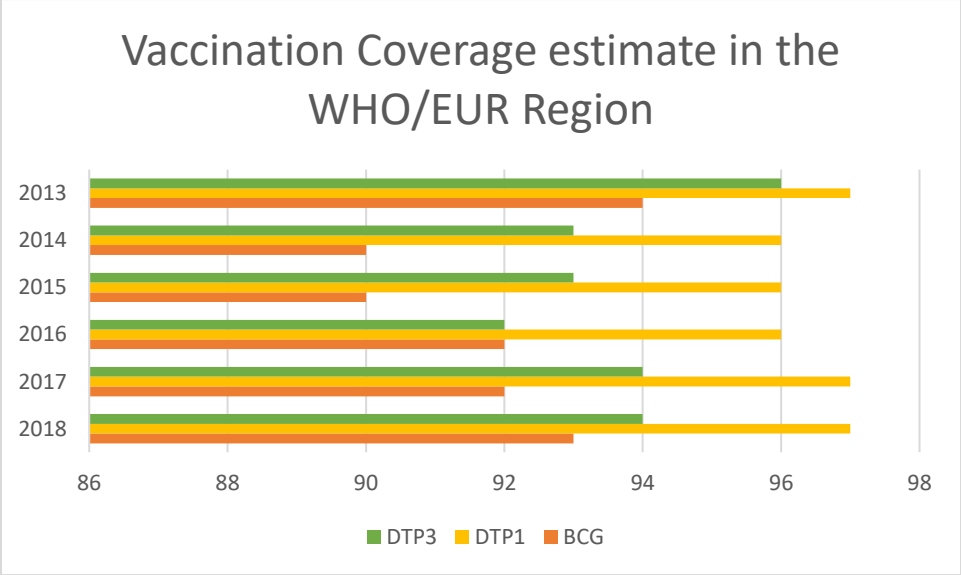

Figure 4: Vaccination Coverage estimate in the WHO/EUR Region from 2013 to 2018

2 REVIEW OF THE LITERATURE

2.1 COUNTRY PROFILE

In 2019, the WHO identified ten countries that 60% of the 19.7 million children that did not receive full DTP vaccines (either did not receive an initial dose or partially vaccinated). Of these ten countries, Nigeria had an alarming rate of incomplete immunization. The country is one of the largest in the African continent, covering an area of 923,678 square kilometers and located on the west coast bordered by Benin, the Republic of Cameroon, the Republic of Niger, and chad (Federal Ministry of Health, 2016). The climate is categorized by two main types: a dry and rainy season dividing the country into a desertic area in the North, savannah in the middle belt, and swamps and rain forests in the south. The country is divided into 36 states and one federal capital territory, with a total of 774 local government areas (LGAs). The states are grouped into six geopolitical zones: South-South (SSZ), South East (SEZ), South West (SWZ), North East (SEZ), North West (NWZ) and North Central (NCZ) (Federal Ministry of Health, 2016). Security-wise, the country is facing “insurgents” in the North and “militants” in the south, as the Comprehensive EPI Multi-Year Plan describes it (Federal Ministry of Health, 2016). The document also raises the concern that health workers engaged in vaccination efforts were targeted. Besides the security challenge, poverty is another hurdle that impacts the vaccination efforts. Sixty-four percent of the 175,074,668 people living in Nigeria (in 2013) were estimated to be living under the poverty line. With a Human Development Index (HDI) of 0.5, Nigeria is ranked 152 among 187 countries of the world (Federal Ministry of Health, 2016). This means that the population is vulnerable to health-related financial issues due to poor socio-economic factors. Literacy is the third challenge that was pointed out by the multi-year vaccination plan, with 53% of women aged 15-49 are literate. The data also shows discrepancies between rural and urban areas (4 in 10 vs. 7 in 10 literate women) (Federal Ministry of Health, 2016). From 2000 to 2013, the country showed

little to no change in select health indicators related to the mother's and child's health. Table 2 shows indicators of child mortality and maternal health (Federal Ministry of Health, 2016).

Table 2: Indicators for reduced child mortality and improved maternal health (Federal Ministry of Health, 2016).

Indicator	2000	2013
Reduce child mortality (MDG 4)		
Under 5 mortality rates (per 1000 live births)	213	117
Infant mortality rate (per 1000 live births)	100	69
Improve Maternal Health Indicators Baseline (MDG 5)		
Maternal Mortality Ratio (in 100,000)	545	576
Births attended by skilled health personnel (%)	35	36
Prenatal Coverage (at least four visit) (%)	45	51

The healthcare system in Nigeria includes both a public and a private sector, with LGA level facilities responsible for primary care. Overall, the healthcare systems' delivery of health services is disparate between regions. The Nigeria government initialized three interventions that aim to respond to the demand and supply imbalance in child and maternal health services:

- Midwives Service Scheme (MSS):
    - Training and deployment of 4,000 midwives and 1,000 community health extension workers (CHEWs) in 1,000 PHC facilities with a focus on immunization.
- the Subsidy reinvestment and Empowerment Program, Maternal and Child Health (SURE-P-MCH):
- systematic PHC infrastructure upgrades through the Ward Health System:
    - Building 1,156 PHC facilities across the country, 228 maternal health care centers, and ten health training institutions built by the MDG office

2.2 Expanded Program on Immunization

Efforts to increase the number of children being immunized against vaccine-preventable diseases started in Nigeria in 1979 with the Expanded Program on Immunization (EPI) with the aim to improve primary healthcare delivery (Adedokun et al., 2017). Between 1988 and 1990, the EPI program reached a milestone when the coverage rate of the DTP 3 vaccine reached 81.5%. The following years a decline in those results was observed, and the country embarked on renewing efforts to improve vaccine coverage (Federal Ministry of Health, 2011). The current strategy is to (Federal Ministry of Health, 2016):

- Streamline EPI management structures
- Improve immunization delivery through:
    - increasing skilled immunization staff
    - ensuring micro-planning in health facilities
    - Use of polio staff in improving immunization
- Upgrade of physical infrastructure and logistics
- Increase the sustainability of immunization through improved planning and budgeting
- Increase political and public awareness of the importance of immunization through evidence-based advocacy, communication, and social mobilization activities

The aim of the 2016-2020 strategy is to increase Penta-3 vaccination coverage to reach 95%, BCG vaccine coverage to reach 94%, and measles vaccine coverage to reach 95%. The Federal Ministry of health is, however, aware of the limited resources needed to attain their goals. In fact, for the 2016 – 2020 period, the government is estimating a need of $3,420.5 million but managed to secure only 59% of that amount ($1,398.9 million). In 2012, Nigeria joined the global efforts led by the world health organization to ensure universal access to immunization by 2020, by endorsing the Global Vaccine Action Plan (Berkley et al., 2012).

2.3 IMMUNIZATION SERVICE DELIVERY AND ROUTINE IMMUNIZATION SCHEDULE

In Nigeria, immunization services are provided through the primary healthcare system, with 25,132 Primary Health Facilities (Federal Ministry of Health, 2016). Following a "1 – 2 – 3" strategy, the immunization services are being provided through the fixed, outreach and mobile sites. The federal ministry of health recognizes that the implementation strategy of the immunization services is not adequate to the demand, by state and by LGA. Added to that, data collected suffers from inaccuracies that make adapting the service delivery process cumbersome and inadequate. Routine immunization is provided through primary healthcare centers for those who live in a 5 km area radius. Outreach services provide the same services twice a month for those living 5 to 10 km away from the PHC. For those living more than 10 km away from the PHC, mobile services performed by the Community Extension Health Workers (CHEW) provide the same services once a month. Table 3 shows the national routine immunization schedule that these services are providing.

Table 3: National Immunization Schedule for Routine Immunization Among Children and Women (Federal Ministry of Health, 2016)

VACCINE NAME	TARGET POPULATION	VACCINE CLASSIFICATION	1ST DOSE	2ND DOSE	3RD DOSE	4TH DOSE
BCG	Births	Traditional				
ORAL POLIO VACCINE	Births	Traditional	Birth	6 weeks	10 weeks	14 weeks
HEP-B (BIRTH DOSE)	Births	Underused	Birth			
PENTAVALENT (DPT-HEPB-HIB)	Surviving Infants	Underused	6 weeks	10 weeks	14 weeks	
MEASLES	Surviving Infants	Traditional	9 months			
	Surviving Infants	Traditional	9 months			
VITAMIN A	Surviving Infants	Underused	6 months	12 months		

2.4 THE POLITICAL AND SECURITY SITUATION IN THE COUNTRY

Under British rule, Nigeria was created following the fusion of the northern and southern regions in 1914 (The Historical Background of Boko Haram, 2016). Until Boko haram formed in 2002, Nigeria was evenly distributed between Muslims and Christians. The Boko Haram conflict started later in 2009, following the summary execution of its previous leader. In 2011 the terrorist group targeted police buildings and the United Nations offices in Abuja, inducing the announcement of a state of emergency fostering an increased report of military abuses in the country and militant attacks (The Rise of Boko Haram in Nigeria, 2011). Boko haram is considered one of the four deadliest terrorist groups in 2018 by the Global Terrorism Index (Peace, 2019), killing more than 38 thousand people and displacing 2.4 million people in the Lake Chad Basin (UNHCR, 2020). The United Nations High Commissioner for Refugees states that although the Nigerian military is controlling most of the country's North East, violence incidents, as shown in the figure below, continue to be perpetrated against women and children. Violent acts are sexual, and gender-based and include forced recruitment (UNHCR, 2020). Neighboring Nigeria, Cameroon, Chad, and Niger are also affected [Figure 5].

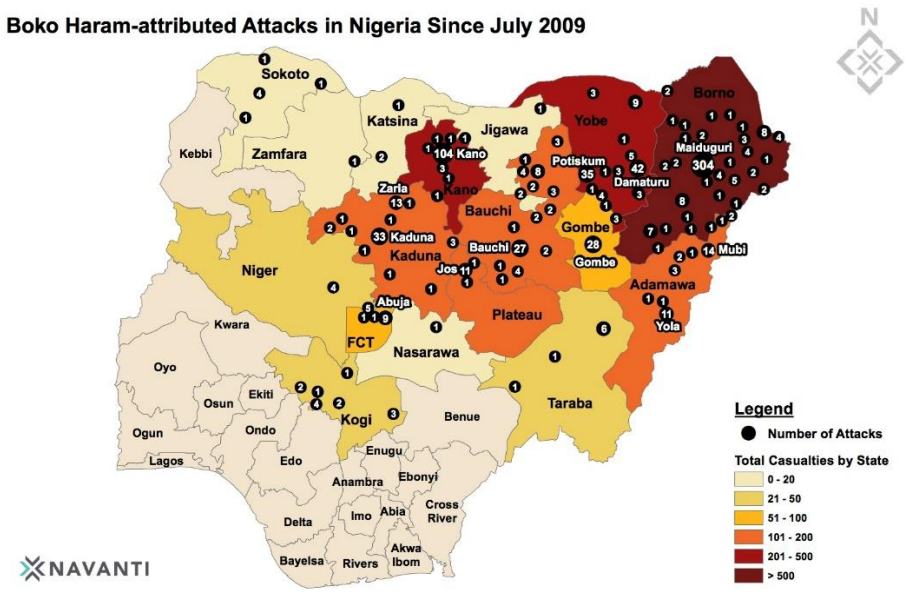

Figure 5: A map showing the number of attacks perpetrated by Boko Haram since July 2009 in Nigeria (Navanti, 2014)

An incident is defined as a "geographically isolated act of violence that takes place over a continuous period of time (Tracking Boko Haram With the Nigeria Security Tracker, 2020). The CFR provides a graphical representation of the monthly incidents that are perpetrated by Boko Haram, with more than 39 thousand deaths since 2011 [Figure 6].

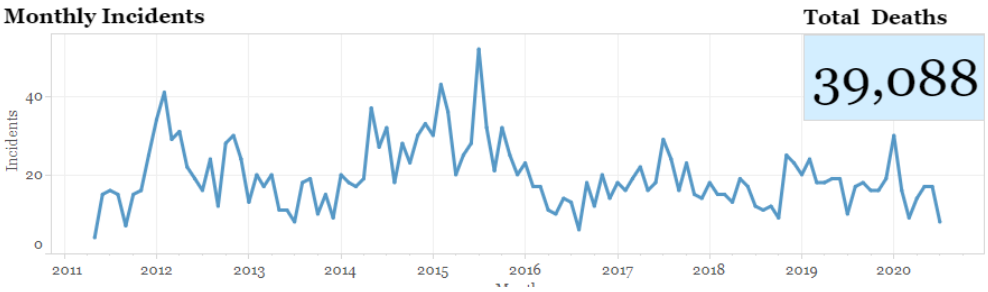

*Figure 6: Tracking the impact of the Boko Haram conflict (*Tracking Boko Haram With the Nigeria Security Tracker, *2020)*

2.5 IMPACT OF BOKO HARAM ON HEATH

Nigeria is the third most terrorized country (Zenn, 2017). This unstable situation causes adverse health effects in children by causing trauma or worsening malnutrition in affected areas (Kah, 2017). A study that

explored the Demographic Health Survey data from 2008 and 2013 estimated the health impact of the Boko Haram conflict on children. It reveals that the violence incidents pose early-life health shocks in children living in “high active areas.” The extensive margin effect of exposure to the conflict causes is correlated with increased infant death and a reduced probability of vaccination. These effects limit the potential to develop human capital in those populations (Ekhator-Mobayode & Asfaw, 2019).

3 METHODS AND PROCEDURES

3.1 DATA SOURCE

Secondary data was used for the purposes of this study. Data sets form the Demographic Health Survey (DHS) were requested through the DHS request form, and a written agreement was received from the Demographic Health Survey and ICF international. A request for the geographical data was submitted separately. The data examined were the 2018 Nigeria Demographic and Health Survey (NDHS 2018), which used a two-stage stratified sample of households. Stratification was achieved by categorizing the 36 states and the Federal Capital Territory into rural and urban areas (Npc & ICF, 2019). In total, 74 sampling strata, 1400 clusters, and 42000 households were sampled with a fixed number of 30 households in each cluster through equal probability systematic sampling (Npc & ICF, 2019). Due to security concerns, 11 clusters were dropped in the Zamfara, Lagos, Katsina, Sokoto, and Borno region. Sampling weights were applied to the data since the sample was not allocated proportionally across the states, and response rates were different. Weights were calculated for each sampling stage and for each cluster. We used the 2 of the 4 questionnaires that were used for the NDHS 2018, i.e.: the household and women questionnaires. Questionnaires were conducted face-to-face and finalized in English, then translated into Hausa, Yoruba, and Igbo. The household questionnaire listed all the residents and visitors of the selected household. The women's questionnaire asked women aged 15 to 49 years old demographic questions, birth history, prenatal delivery, and postnatal care, among other categories. The response rate in every questionnaire was 99% on average (Npc & ICF, 2019). Additionally, NDHS datasets from the years 1990, 2003, 2008, and 2013 were used to analyze the trend in immunization coverage during these years.

3.2 SAMPLE SIZE

Our sample of interest included 5821 children aged 12 to 23 months. Cases with missing age data, and children who were not alive at the time of the survey were excluded. We followed the Guide to DHS Statistics DHS-7 (Cutts et al., 2013) to determine the denominator for the present analysis. The DHS recommends using cohorts of children aged 12 to 23 months and children aged 24 to 35 months to assess their immunization status and immunization coverage. The choice to only includes living children aged 12 to 23 was to assess the immunization status regarding all basic vaccines in the past year, as these children are expected to have received all the basic doses of immunization. Including children aged below the age of 12 months would bias the results since they did not complete their immunization schedule given their age.

3.3 DEFINITION OF THE VARIABLES

The analysis of the data considered more than one level. In fact, to assess the risk factors associated with the low rate of immunization in children, a multilevel model was built to account for individual, household and family, and community-level factors. These levels follow the concept of the Social Determinants of Health (SDH). The choice of variables was based on previous evidence and studies that found that incomplete immunization in children were related to those factors (Adedokun et al., 2017; Antai, 2009a; Rainey et al., 2011).

3.3.1 Dependent variable

As expressed above, the sample was set to only include children aged 12 to 23 months to assess their immunization status in the past year. The dependent variable or outcome variable was constructed using the immunization information provided by the mothers during the interview. Information was collected through to vaccination cards and the mother's verbal report. When vaccination card data was unavailable,

the mothers were asked on the immunization status of their child based on what they recalled during the interview. We considered a specific vaccine as received either when vaccination date was mentioned on the card, simply marked on the card, or when only reported by the mother. Further information on how the data were collected are published elsewhere (Demographic Health Survey 2018, 2019). To calculate the outcome variable, we considered the immunization status of a respondent as complete when they have received nine doses of 4 vaccines. The vaccines of interest were Bacillus Calmette–Guérin (BCG) (1 dose), Polio (4 doses), DTP (3 doses), and Measles (1 dose) and were chosen according to the National Immunization Schedule For Routine Immunization Among Children and Women (Table 3) shared by the Federal Ministry of Health in Nigeria published in the "Comprehensive Multi-Year Plan 2016-2020 on immunization" (Federal Ministry of Health, 2016). Where mothers were not able to recall if their child was vaccinated or not, we considered the child as non-immunized to that specific vaccine. Our calculations of the complete immunization status variable are in accordance with the WHO recommendations and the guidance provided by NDHS to calculate the variable (Cutts et al., 2013; World Health Organization, 2009). In fact, "complete or full immunization" is defined as a child who received BCG against Tuberculosis, three doses of vaccine against DTP, at least three doses of vaccine against polio, and one dose of vaccine against measles (World Health Organization, 2009). Each of the vaccine doses had variables with five response categories: no vaccination, vaccination date on the card, reported by mothers, vaccination marked on the card, and DK (don't know). Using SAS, we recorded each of these variables into 1 (labeled as "received the vaccine") and 0 (labeled as "did not receive vaccine") to denote vaccination status for that specific dose. We then combined the recoded variables into a single one denoting complete immunization "1" and incomplete immunization "0".

3.3.2 Independent variables

We categorized exposure variables into three levels: individual, family, and community risk factors. Table 4 lists all the variables used as independent variables in our analysis.

Table 4: Independent variables considered for the analysis

Level (Factor)		Independent variables
Individual factors	1.	Child Sex
	2.	Child age in months
	3.	Birth order
	4.	Size of the child at birth
Family factors	1.	Age of mother
	2.	Media exposure
	3.	Access to prenatal care
	4.	Place of delivery
	5.	Education level
	6.	Wealth index
	7.	Marital status
	8.	Religion
	9.	Ethnicity
	10.	Number of under 5 children in the household
	11.	Health insurance coverage
	12.	Number of household members
	13.	Getting medical help for self: getting permission to go the doctor
	14.	Getting medical help for self: getting money needed for treatment
	15.	Getting medical help for self: distance to health facility
	16.	Getting medical help for self: not wanting to go alone
Community factors	1.	Region
	2.	Low-income family's percentage in the community
	3.	Lack of access to ante-natal care percentage in the community
	4.	Home delivery percentage in the community
	5.	Low education percentage in the community

3.3.2.1 Individual-level risk factors

Were considered individual factors: child Sex, child age in months, birth order, and the size of child at birth. The child's sex assessed as female and male. Birth order was grouped as birth order 1-3, birth order 4-6, and birth order 7+. The size of the child at birth was grouped as very large, larger than average, average, smaller than average, and very small. The Age of the child was calculated from the NDHS dataset in months to limit the analysis to those aged 12 to 23 months.

3.3.2.2 Family -level risk factors

The next level of risk factors included: mother's age, media exposure, access to prenatal care, place of delivery, education level, wealth index, marital status, religion, ethnicity, number of under 5 children in

the household, health insurance coverage, number of household members, getting medical help for self: getting permission to go the doctor, getting medical help for self: getting money needed for treatment, getting medical help for self: distance to health facility, getting medical help for self: not wanting to go alone.

Mother's age was categorized as follows: 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, and 45-49 years old. The media exposure variable was constructed by combining the frequency of reading newspapers, listening to the radio, and watching television available in the NDHS dataset. The mother was considered not exposed to media when the response to these three questions was "not at all," or the response was missing (coded as 0). Otherwise, the mother was considered having access to at least one media outlet (coded as 1). Access to prenatal care was considered inexistent when the mother responded "no prenatal visits" when asked about the number of prenatal visits during pregnancy (recoded as "No prenatal care"); otherwise, those who had at least one visit were considered as having access to prenatal care. The place of delivery was grouped into two categories: "at home" and "in a healthcare facility," either public or private. The mother's education level factor was recoded into four categories: higher, primary, secondary, and no education accounting for missing values. We used the wealth index constructed by NDHS to account for the family income. We grouped the variable into three categories instead of five: Richest, middle, and poorest. Marital status was recorded and grouped as: currently married and currently not married (involving those divorced and never married). Religion was also recoded and grouped into "Muslims," "Catholics," and "other." More than 374 identifiable ethnic groups cohabit in Nigeria; the NDHS only categorized "Ekoi, Fulani, Hausa, Ibibio, Igala, Igbo, Ijaw/Izon, Kanuri/Beriberi, Tiv, Yoruba, and Other (that included the remaining ethnic groups.) The number of children in the household was categorized as follows: "1 child, two children, and three or more children under five in the household. "Health insurance coverage was grouped as "covered" or "not covered" by health insurance. The number of household members was grouped as "1-4 members", "5-9 members", "10 and more members" in the

household. We additionally considered four other variables that probed the mothers on their difficulty to getting medical help for themselves by asking if they needed permission to go the doctor if they had difficulty accessing money needed for treatment, if the distance to health facility was a problem, and if going alone is problematic. These four variables were all grouped as "problematic" and "not problematic."

3.3.2.3 Community-level risk factors

We used five variables to control for the community level factors in the constructed models. These variables are region, low family income, lack of access to ante-natal care, home delivery, and low education. Besides the region variable that was not recoded for the analysis, we constructed the other four community-level factors using Primary Sampling Units (PSU). These clusters were developed according to the census enumeration areas (EAs) of the 2006 Population and Housing Census of the Federal Republic of Nigeria (NPHC) that divided each locality into these areas. Added to that, PSUs are used as proxies for communities in multiple other studies that used DHS datasets (Antai, 2009a; Diez-Roux, 2001; Pearl et al., 2001; USAID, 2019). The number of households per PSU was not communicated by USAID since the NPHC did not provide that estimate for each EA, but the population estimates were published for 774 local government areas (LGAs) that represent a higher level than the PSUs.

Each of the four community-level factors that were considered for the purposes of this analysis was constructed following the same procedure that was previously described in a similar analysis that used the 2003 data (Antai, 2009a).

Community family's low income defined as the percentage of low-income families within the PSU. The community level of lack of access to ante-natal care was defined as the percentage of lack of access to prenatal care. Similarly, community home delivery was constructed by calculating the percentage of women who delivered in their homes within each PSU. Community low education was defined as the percentage of women who had no or only primary education. These variables were kept into percentages

during the analysis. Adding and constructing these variables stems from the unequivocal evidence that: access to prenatal care directly increases the subsequent access to healthcare by the mother and the child after birth, thus increasing access to immunization (Case et al., 2002; Currie & Stabile, 2003). Similarly, hospital delivery increases the probability of full immunization (Lee, 2005; Sugathan et al., 2001). Additionally, a higher mother education is correlated with positive health outcomes for the children (Case et al., 2002; Currie & Stabile, 2003).

3.4 Statistical Analysis

As expressed above, a multilevel statistical analysis was performed using child-related variables as the first level, nested within households (level 2) who were, in turn, nested within communities representing the third level. The data analysis was generated using SAS software (*SAS Institute Inc.*, 2013), Version 9.4 of the SAS System for Windows 10. The SAS software procedure "Proc Glimmix" was used to construct the three multilevel logistic regression models taking into account the hierarchical data structure of the NDHS datasets (SAS Institute, 2020). In total, three models were fitted. A model containing child-level variables, a second model containing family and household factors added to the those included in the first model. The third model included all the factors listed above to which community-level variables were added. Geographical data were also obtained from the DHS website to construct maps of some of the dependent and independent variables.

3.5 Geographical analysis

For geographical representation, ArcMap version 10.0 (Redlands, CA) was used. The referencing map for Nigeria was the current TIGER/Line® data available through the USAID DHS website.

3.6 ETHICAL CONSIDERATIONS

This Analysis was based on secondary data that were deidentified prior to its release. Informed consent was obtained from the participants, and the survey received approval from the National Ethics committee in the Federal Ministry of Health, Nigeria, and the Ethics Committee of the Opinion Research Corporation Macro International, Incorporated (ORC Macro Inc.), Calverton, USA. Access to the dataset was granted by DHS after providing information about the purpose and the desired outcomes of this analysis.

4 RESULTS

4.1 DESCRIPTIVE STATISTICS

Table 5 shows the uptake of full immunization among children and the percentage of complete immunization by the vaccine for the following vaccines: BCG, Polio, Pentavalent, Measles. Immunization was considered complete for a specific vaccine when the child received the total number of doses recommended. Overall, vaccination levels were low (25% complete) when considering the four vaccines. BCG vaccination completion was the highest among the recommended vaccines (67%) followed by Measles (54%), Pentavalent vaccine (50%), and Polio vaccine (33%).

Table 5: Child Immunization status

Vaccine	Immunization status	N	Percent
BCG	Incomplete	1970	33%
	Complete	3947	67%
Polio	Incomplete	3993	67%
	Complete	1924	33%
Pentavalent	Incomplete	2954	50%
	Complete	2964	50%
Measles	Incomplete	2744	46%
	Complete	3173	54%
Full immunization	Incomplete	4368	75%
	Complete	1453	25%

We provide a graphical representation of the immunization status in Figure 7.

Figure 7: Child Immunization status, graphical representation

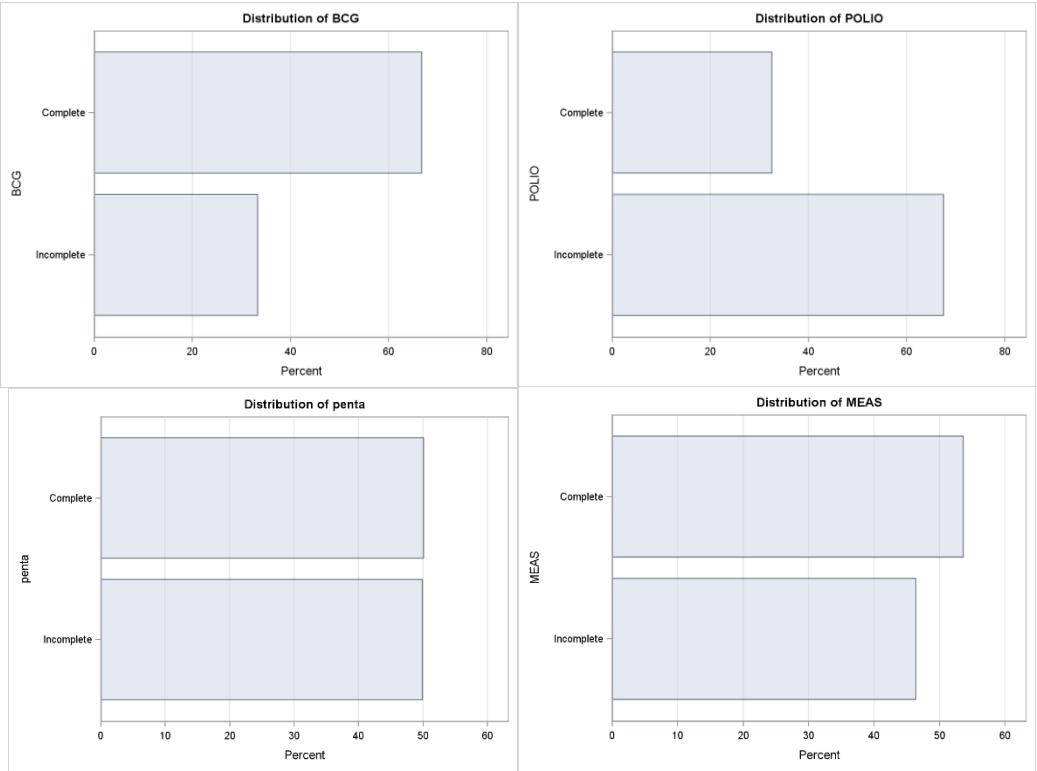

Table 6 describes the study sample by independent variables. The analysis involved 5821 children in 5641 households, and 1326 communities. The children were aged 12 to 23 months, with 51% males and 34% considered larger than average or very large. 45% of the children were either 4th, 5th, or 6th inline in the households. Around 51% of the mothers in the sample were aged between 20 and 29 years old in Muslim households, from which 70% have five or more members. Fifty-one percent of the children included in our study lived in the Northeast and Northwest of the country.

Table 6: Descriptive statistics of the study sample

	Total	
	N	**Percentage**
Sex of child		
Male	2990	51%
Female	2831	49%
Child's line number in household		
1 to 3	1252	22%
4 to 6	2643	45%
7+	1926	33%

Size of child at birth		
Very large	515	9%
Larger than average	1469	25%
Average	3019	52%
Smaller than average	611	11%
Very small	207	4%
Mother's age in 5-year groups		
15-19	361	6%
20-24	1320	23%
25-29	1616	28%
30-34	1240	21%
35-39	861	15%
40-44	325	6%
45-49	98	2%
Age of household head		
15-19	23	0%
20-24	157	3%
25-29	668	11%
30-34	1017	17%
35-39	1206	21%
40-44	908	16%
45-49	1842	32%
Media exposure		
not exposed to media	3736	64%
Exposed to media	2085	36%
Access to prenatal care		
NO Ante-natal care	1423	24%
Ante-natal care	4398	76%
Place of delivery (home or healthcare facility)		
Home	3346	57%
Healthcare facility	2475	43%
Highest educational level		
No education	2546	44%
Primary	844	15%
Secondary	1945	33%
Higher	486	8%
Wealth index		
Poorest	2689	46%
Middle	1200	21%
Richest	1932	33%
Current marital status		
Currently married	5333	92%
Currently not married	488	8%
Religion		
Catholic	2304	40%
Muslim	3464	60%
Other	53	1%
Ethnicity		
Ekoi	23	0%
Fulani	561	10%
Hausa	1781	31%
Ibibio	93	2%
Igala	49	1%

Igbo	800	14%
Ijaw/Izon	162	3%
Kanuri/Beriberi	145	2%
Tiv	139	2%
Yoruba	565	10%
Other	1503	26%
Number of children 5 and under in household (de jure)		
1 child 5 and under	1855	32%
2 children 5 and under	2327	40%
3+ child 5 and under	1639	28%
Covered by health insurance		
No	5689	98%
Yes	132	2%
Number of household members (listed)		
1 to 4 members in HH	1763	30%
5 to 9 members in HH	2932	50%
10 + members in HH	1126	19%
Getting medical help for self: getting permission to go the doctor		
Big problem	720	12%
Not a big problem	5101	88%
Getting medical help for self: getting money needed for treatment		
Big problem	2924	50%
Not a big problem	2897	50%
Getting medical help for self: distance to health facility		
Big problem	1733	30%
Not a big problem	4088	70%
Getting medical help for self: not wanting to go alone		
Big problem	955	16%
Not a big problem	4866	84%
Region		
North Central	998	17%
North East	1295	22%
North West	1675	29%
South East	657	11%
South South	592	10%
South West	604	10%

The distribution of the immunization status, expressed in numbers and percentages, by independent factors is shown for categorical and continuous variables in Table 7 and Table 8. Children that are 4th or higher in line in the household, having mothers in the 15-20 and 45-49 age brackets, had higher rates of incomplete immunization. Added to that, mothers that lived in households with no media exposure had children with high rates of incomplete immunization (81.5%). Similarly, children whose mothers had no access to prenatal care, delivered at home, or with lower education levels had higher incomplete

immunization rates 95.1%, 85.9%, and 90%, respectively. The same high rates can be observed when mothers live in poor households, have more than five children, or live in the northern region of the country (Northcentral, east, and west). When it comes to community factors, the lower the rates of low-income families, low education, or mothers who deliver at home, the higher the complete immunization rates are.

Table 7: Child immunization status at different levels of independent categorical variables

Demographic Characteristic	Category	Incomplete Immunization % (n)	Complete Immunization % (n)	Total	p-value (2 sided)
Sex of child					
	Male	73.4 (2251)	26.6 (817)	3068	0.2676
	Female	74.6 (2126)	25.4 (723)	2849	
Child's line number in household					
	1 to 3	69.8 (902)	30.2 (389)	1291	<0.0001*
	4 to 6	70.8 (1907)	29.2 (786)	2693	
	7+	81.1 (1568)	18.9 (365)	1932	
Size of child at birth					
	Very large	72.4 (364)	27.6 (139)	504	0.4834
	Larger than average	75 (1124)	25 (375)	1499	
	Average	73.3 (2255)	26.7 (820)	3075	
	Smaller than average	75.9 (501)	24.1 (159)	660	
	Very small	73.7 (132)	26.3 (47)	179	
Mother's age in 5-year groups					
	15-19	87.7 (311)	12.3 (44)	355	<0.0001*
	20-24	80.3 (1059)	19.7 (260)	1320	
	25-29	71.1 (1162)	28.9 (473)	1635	
	30-34	69.9 (890)	30.1 (383)	1273	
	35-39	68.7 (622)	31.3 (283)	905	
	40-44	74.1 (246)	25.9 (86)	332	
	45-49	87.9 (87)	12.1 (12)	99	
Age of household head					
	15-19	82.7 (18)	17.3 (4)	21	<0.0001*
	20-24	82.5 (125)	17.5 (26)	151	
	25-29	80.4 (537)	19.6 (131)	668	
	30-34	71.8 (744)	28.2 (293)	1037	
	35-39	70.6 (890)	29.4 (370)	1260	
	40-44	71.9 (685)	28.1 (268)	954	
	45-49	75.4 (1377)	24.6 (448)	1826	
Media exposure					
	not exposed to media	81.5 (3062)	18.5 (695)	3757	<0.0001*
	Exposed to media	60.8 (1314)	39.2 (846)	2160	
Access to prenatal care					
	NO Ante-natal care	95.1 (1355)	4.9 (69)	1424	<0.0001*
	Ante-natal care	67.3 (3022)	32.7 (1471)	4493	
Place of delivery (home or healthcare facility)					

	Home	85.9 (2900)	14.1 (476)	3376	<0.0001*
	Healthcare facility	58.1 (1477)	41.9 (1064)	2541	
Highest educational level					
	No education	90 (2323)	10 (259)	2583	<0.0001*
	Primary	73.8 (619)	26.2 (220)	839	
	Secondary	62.3 (1204)	37.7 (729)	1934	
	Higher	40.9 (230)	59.1 (332)	562	
Wealth index					
	Poorest	88.6 (2298)	11.4 (296)	2594	<0.0001*
	Middle	77 (906)	23 (270)	1177	
	Richest	54.6 (1172)	45.4 (974)	2147	
Current marital status					
	Currently married	74.1 (4031)	25.9 (1410)	5441	0.4903
	Currently not married	72.6 (346)	27.4 (130)	476	
Religion					
	Catholic	60.1 (1327)	39.9 (882)	2209	<0.0001*
	Muslim	82.3 (3024)	17.7 (652)	3676	
	Other	79.7 (26)	20.3 (7)	32	
Ethnicity					
	Ekoi	74.9 (16)	25.1 (5)	21	<0.0001*
	Fulani	89.9 (443)	10.1 (50)	493	
	Hausa	84.8 (1753)	15.2 (315)	2067	
	Ibibio	68 (56)	32 (26)	82	
	Igala	71 (30)	29 (12)	42	
	Igbo	47 (385)	53 (434)	818	
	Ijaw/Izon	74.9 (76)	25.1 (26)	102	
	Kanuri/Beriberi	91.4 (140)	8.6 (13)	153	
	Tiv	81.1 (123)	18.9 (29)	152	
	Yoruba	61.7 (419)	38.3 (261)	680	
	Other	71.7 (937)	28.3 (371)	1307	
Number of children 5 and under in household (de jure)					
	1 child 5 and under	68.7 (1314)	31.3 (600)	1914	<0.0001*
	2 children 5 and under	73.7 (1738)	26.3 (620)	2358	
	3+ child 5 and under	80.5 (1325)	19.5 (321)	1646	
Covered by health insurance					
	No	74.4 (4306)	25.6 (1480)	5786	<0.0001*
	Yes	54.1 (71)	45.9 (60)	131	
Number of household members (listed)					
	1 to 4 members in HH	67.8 (1243)	32.2 (590)	1833	<0.0001*
	5 to 9 members in HH	74.4 (2211)	25.6 (759)	2970	
	10 + members in HH	82.8 (922)	17.2 (192)	1114	
Getting medical help for self: getting permission to go the doctor					
	Big problem	85.9 (604)	14.1 (100)	704	<0.0001*
	Not a big problem	72.4 (3772)	27.6 (1441)	5213	
Getting medical help for self: getting money needed for treatment					
	Big problem	79.8 (2307)	20.2 (585)	2892	<0.0001*
	Not a big problem	68.4 (2070)	31.6 (955)	3025	
Getting medical help for self: distance to health facility					
	Big problem	83.1 (1385)	16.9 (281)	1666	<0.0001*
	Not a big problem	70.4 (2991)	29.6 (1260)	4251	
Getting medical help for self: not wanting to go alone					
	Big problem	84 (770)	16 (147)	917	<0.0001*
	Not a big problem	72.1 (3606)	27.9 (1394)	5000	

Region					
	North Central	75.5 (619)	24.5 (201)	820	<0.0001*
	North East	83.2 (931)	16.8 (188)	1120	
	North West	84.5 (1704)	15.5 (314)	2018	
	South East	46.7 (287)	53.3 (328)	615	
	South South	66.6 (375)	33.4 (187)	562	
	South West	58.9 (461)	41.1 (322)	783	

* Statistically significant difference

Table 8:Child immunization status at different levels of independent variables (continuous variables)

	Incomplete			**Complete**		
Variables	**N**	**Mean**	**StdDev**	**N**	**Mean**	**StdDev**
Age in months	4368	16.95	3.31	1453	17.09	3.51
Low income family's percentage in the community	4368	51.91	41.81	1453	21.39	35.07
Lack of access to ante-natal care percentage in the community	4368	29.44	31.75	1453	8.84	17.91
Home delivery percentage in the community	4368	66	36.46	1453	34.77	37.02
Low education percentage in the community	4368	64.78	35.79	1453	35.33	36.45

StdDev: Standard deviation

Figure 8 shows the rates of complete immunization in Nigeria by the administrative region. The northern part of the country had lower rates of complete immunization when compared to the southern region. It is notable that the "Rivers" state had low complete immunization rates (part of the South-South region. To better understand immunization inequities, we drew maps that illustrate the geographical distribution of risk factors of interest in Figure 9

Figure 10.

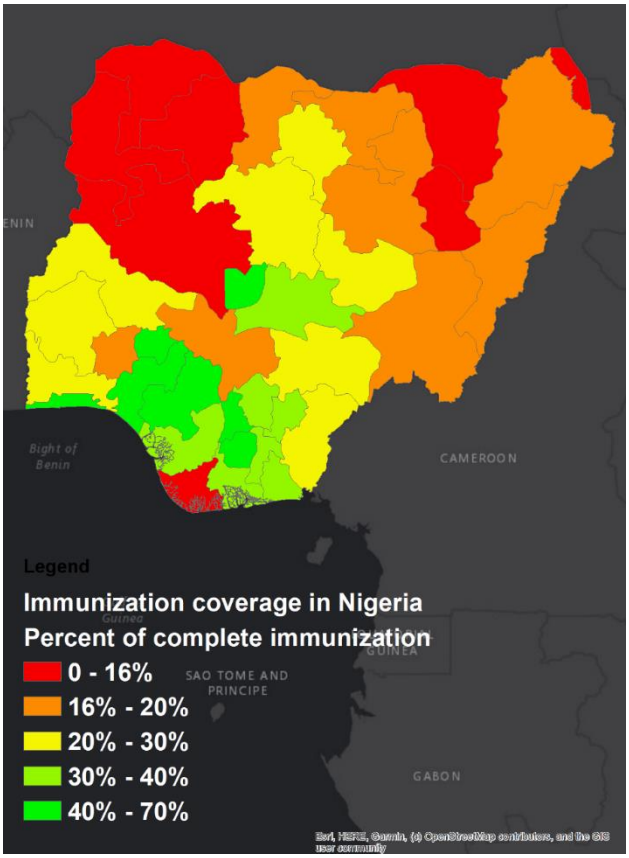

Figure 8: Map showing the complete immunization rates in the Nigeria (NDHS 2018)

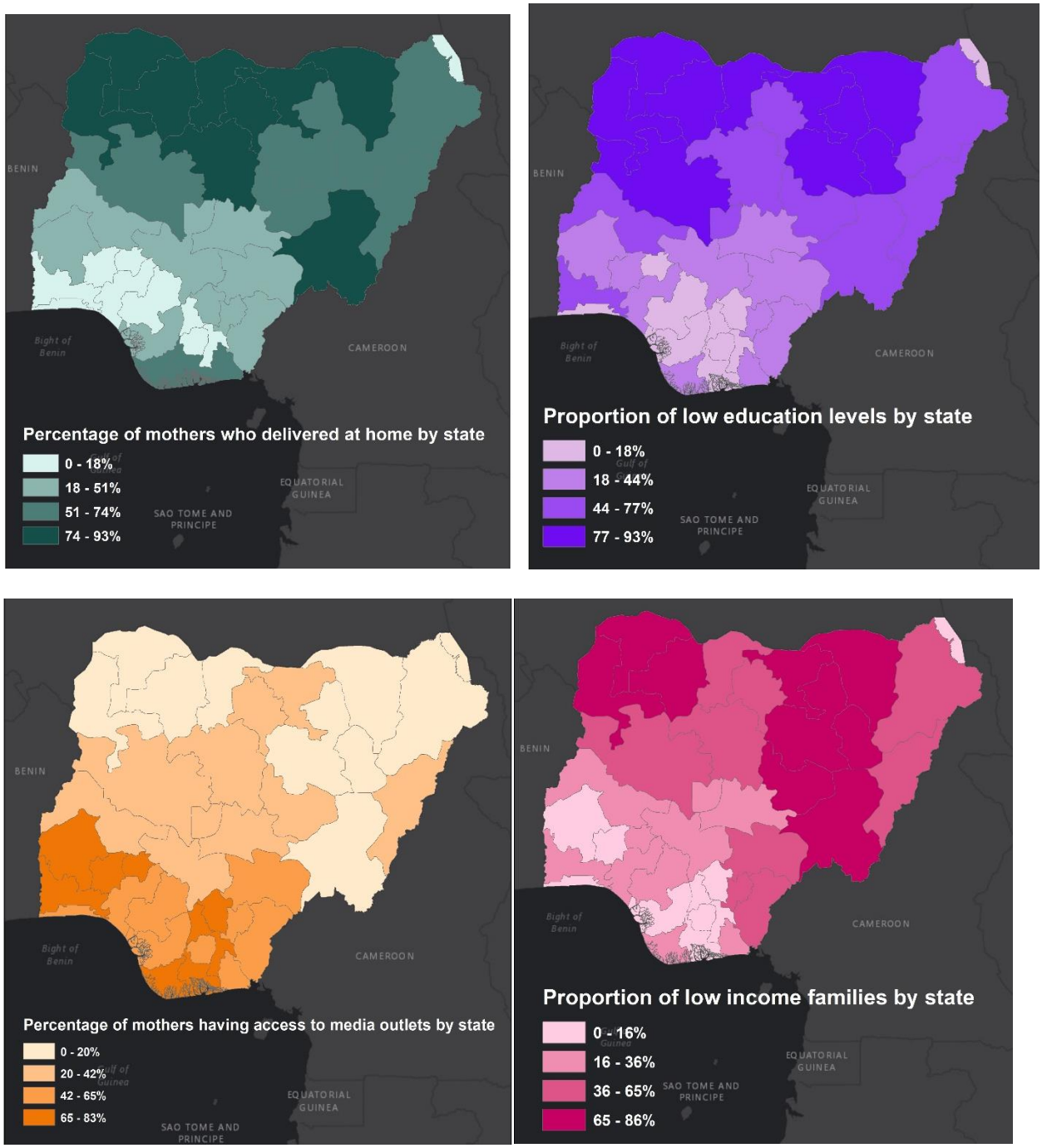

Figure 9: Maps showing home delivery, low education, media access, and low-income families by state

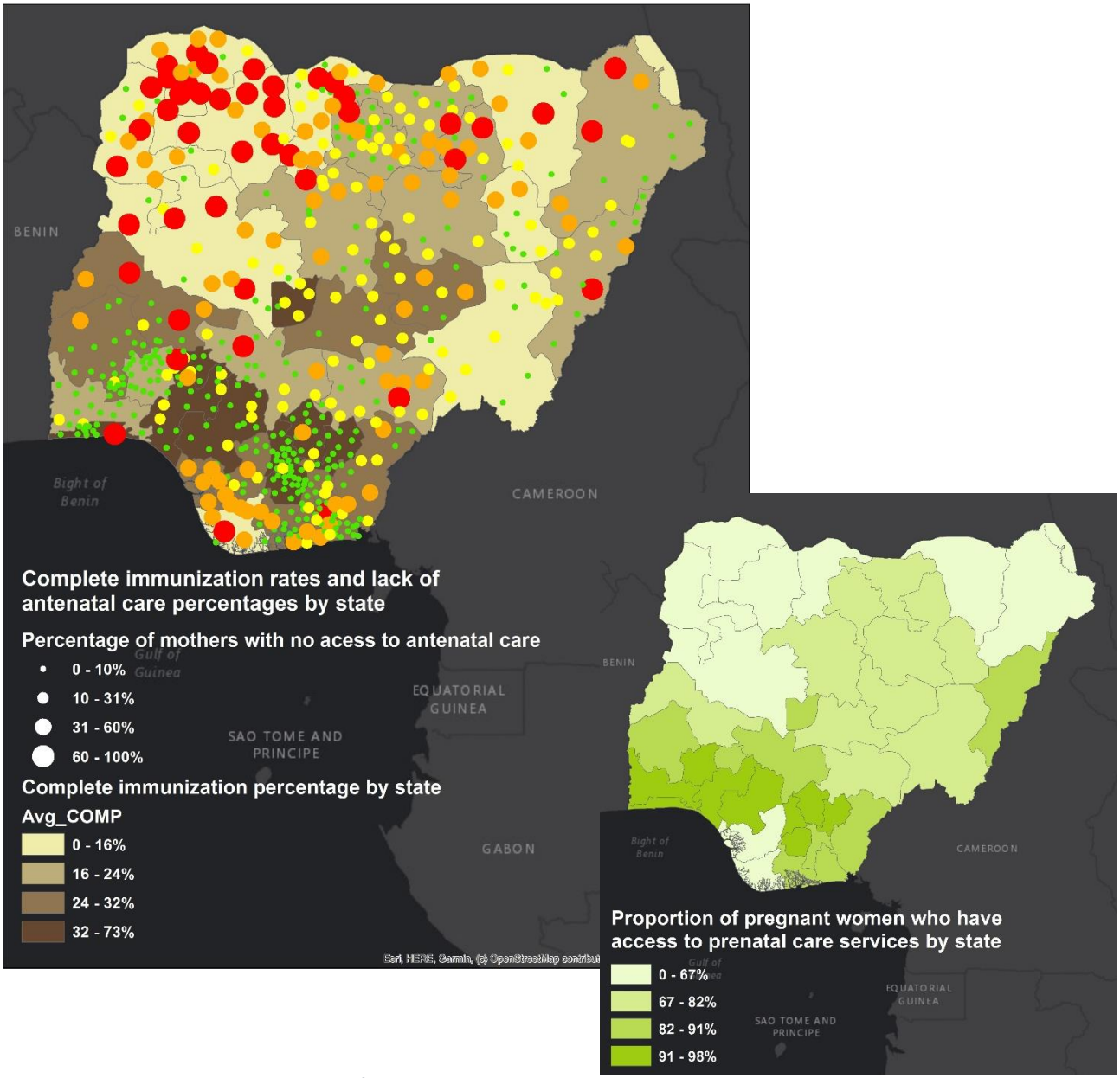

Figure 10: Map illustrating the rates of prenatal care and complete immunization in Nigeria

4.2 MEASURES OF ASSOCIATION

Table 9 shows the results of the models that were considered for this analysis. After controlling for individual, household (family), and community factors, children with mothers aged 25-39 (AOR = 0.465; 95% CI = 0.244 - 0.887) and 40-44 (AOR = 0.449; 95% CI = 0.211 - 0.957) had significantly lower odds of having incomplete immunization when compared to children with mothers aged 15 -19. Similarly,

children who lived in wealthier families had significantly lower odds of having incomplete immunization when compared to those living in poorer families (AOR = 0.336; 95% CI = 0.178 - 0.634). On the other hand, children with mothers that had no access to prenatal care (AOR = 5.175; 95% CI = 2.456 - 10.904), who delivered at home(AOR = 1.714; 95% CI = 1.178 - 2.493), with primary education level(AOR = 4.715; 95% CI = 2.201 - 10.101), and who have problems with the distance to the healthcare facility (AOR = 1.471; 95% CI = 1.000 - 2.163)were at higher odds of having incomplete vaccination compared to those with mothers that had access to prenatal care, who delivered at a health care facility, with higher education level, and who did not have any problems with the distance to the healthcare facility. Children living in communities with a higher lack of access to prenatal care had significantly higher odds of having incomplete vaccination. In other terms, an increase of 1.01% (95% CI = 1.002 - 1.018) in the rate of mothers not having access to prenatal care increased the odds of incomplete children vaccination in that community by around 5%. This increase is statistically significant. Table 10 shows the models fit statistics and information criteria for model selection. Values of AIC and BIC are successively smaller with each additional model, meaning that model presentation is improved when compared to the previous model, with a goodness of fit of the model used in the analysis.

Table 9: Factors associated with incomplete child immunization identified by multilevel multivariate logistics regression models (modeling incomplete immunization)

Variable		Model 1			
		AOR	**CI -**	**CI +**	**Type III fixed effects**
Individual Factors					
Child Sex	Female	1.074	0.853	1.353	0.5419
	Male	1 (reference)			
Child age in months	mean = 17.034	0.982	0.949	1.017	0.3081
Birth order	4 to 6	1.076	0.803	1.441	**<.0001*** **
	7+	3.162	2.103	4.756	
	1 to 3	1 (reference)			
Size of child at birth	Very large	0.956	0.628	1.455	0.7862
	Larger than average	1.163	0.877	1.541	
	Smaller than average	1.173	0.799	1.721	
	Very small	1.036	0.527	2.036	
	Average	1 (reference)			

	Variable		Model 2				Model 3			
			AOR	**CI -**	**CI +**	**Type III fixed effects**	**AOR**	**CI -**	**CI +**	**Type III fixed effects**
	Individual Factors									
1.	**Child Sex**	Female	1.069	0.856	1.334	0.5545	1.092	0.876	1.362	0.4320
		Male	1 (reference)				1 (reference)			
2.	**Child age in months**	mean = 17.034	1.018	0.984	1.052	0.3033	1.023	0.989	1.059	0.1844
3.	**Birth order**	4 to 6	0.831	0.574	1.203	0.4968	0.826	0.570	1.197	0.4459
		7+	0.948	0.597	1.506		0.962	0.608	1.523	
		1 to 3	1 (reference)				1 (reference)			
4.	**Size of child at birth**	Very large	1.022	0.685	1.525	0.5969	0.995	0.668	1.481	0.5697
		Larger than average	1.052	0.801	1.383		1.077	0.820	1.414	
		Smaller than average	0.761	0.519	1.118		0.764	0.521	1.120	

		Very small	0.802	0.408	1.576		0.801	0.410	1.565	
		Average	1 (reference)				1 (reference)			
	Family factors									
5.	**Age of mother**	20-24	0.827	0.456	1.499	**0.0062*** **	1.062	0.586	1.926	**0.019** **
		25-29	0.431	0.228	0.812		0.580	0.323	1.043	
		30-34	0.433	0.225	0.833		0.597	0.325	1.095	
		35-39	0.339	0.167	0.685		0.465	0.244	0.887	
		40-44	0.344	0.155	0.765		0.449	0.211	0.957	
		45-49	1.326	0.401	4.382		1.404	0.435	4.525	
		15-19	1 (reference)				1 (reference)			
6.	**Media exposure**	Exposed to media	1 (reference)			**0.0437** **	1 (reference)			**0.0674***
		not exposed to media	0.745	0.560	0.992		0.770	0.582	1.019	
7.	**Access to prenatal care**	Ante-natal care	1 (reference)			**<.0001*** **	1 (reference)			**<.0001*** **
		NO Ante-natal care	7.073	3.528	14.180		5.175	2.456	10.904	
8.	**Place of delivery**	Healthcare facility	1 (reference)			**0.0004*** **	1 (reference)			**0.0052*** **
		Home	1.836	1.319	2.555		1.714	1.178	2.493	
9.	**Education level**	Higher	1 (reference)			**<.0001*** **	1 (reference)			**0.0015*** **
		Primary	6.698	3.069	14.617		4.715	2.201	10.101	
		Secondary	3.406	1.850	6.272		2.686	1.465	4.922	
		No education	2.330	1.448	3.751		2.197	1.359	3.553	
10.	**Wealth index**	Middle	0.701	0.488	1.006	**<.0001*** **	0.787	0.498	1.245	**0.0006*** **
		Richest	0.278	0.162	0.478		0.336	0.178	0.634	
		Poorest	1 (reference)				1 (reference)			
11.	**Marital status**	Currently not married	1.379	0.900	2.113	0.1393	1.430	0.920	2.223	0.1108
		Currently married	1 (reference)				1 (reference)			
12.	**Religion**	Catholic	1.056	0.738	1.511	0.8293	1.046	0.714	1.533	0.7152
		Other	1.637	0.306	8.748		2.045	0.362	11.545	

		Muslim	1 (reference)				1 (reference)			
13.	**Ethnicity**	Ekoi	0.938	0.160	5.517	**0.0128****	0.662	0.107	4.081	0.1488
		Fulani	1.266	0.667	2.403		1.271	0.584	2.764	
		Hausa	0.853	0.545	1.336		1.002	0.516	1.945	
		Ibibio	0.653	0.254	1.677		0.656	0.233	1.850	
		Igala	0.632	0.170	2.347		1.039	0.263	4.101	
		Igbo	0.259	0.140	0.481		0.385	0.188	0.787	
		Ijaw/Izon	0.752	0.298	1.898		0.641	0.224	1.835	
		Kanuri/Beriberi	3.159	1.123	8.886		2.402	0.812	7.103	
		Other	0.572	0.372	0.879		0.587	0.333	1.034	
		Tiv	1.087	0.473	2.499		1.317	0.506	3.427	
		Yoruba	1 (reference)				1 (reference)			
14.	**Number of under 5 children in the household**	2 under five children	1.408	1.018	1.949	**0.0643***	1.391	1.001	1.932	**0.081***
		3+ under five children	1.575	1.043	2.376		1.562	1.029	2.373	
		One under-five child	1 (reference)				1 (reference)			
15.	**Health insurance coverage**	No	0.752	0.372	1.522	0.4258	0.965	0.478	1.947	0.9208
		Yes	1 (reference)				1 (reference)			
16.	**Number of household members**	10 + members in HH	0.961	0.577	1.602	0.2145	1.024	0.617	1.700	0.1975
		5 to 9 members in HH	1.242	0.900	1.714		1.285	0.927	1.780	
		1:4 members in HH	1 (reference)				1 (reference)			
17.	**Getting medical help for self: getting permission to go the doctor**	Not a big problem	1 (reference)			**0.0833***	1 (reference)			0.1198
		Big problem	1.515	0.946	2.426		1.455	0.906	2.338	
18.	**Getting medical help for self: getting money needed for treatment**	Not a big problem	1 (reference)			0.1430	1 (reference)			0.1069
		Big problem	1.219	0.935	1.589		1.245	0.953	1.626	

19.	**Getting medical help for self: distance to health facility**	Not a big problem	1 (reference)			**0.0171****	1 (reference)			**0.0498****
		Big problem	1.606	1.089	2.367		1.471	1.000	2.163	
20.	**Getting medical help for self: not wanting to go alone**	Not a big problem	1 (reference)			0.1215				0.1274
		Big problem	0.700	0.444	1.101		0.701	0.444	1.108	
	Community factors									
21.	**Region**	North Central					0.846	0.485	1.473	0.2925
		North East					0.894	0.476	1.677	
		North West					0.724	0.368	1.421	
		South East					0.640	0.326	1.255	
		South					1.309	0.721	2.376	
		South West					1 (reference)			
22.	**Low-income family's percentage in the community**	mean = 46.324					1.001	0.994	1.007	0.8227
23.	**Lack of access to ante-natal care percentage in the community**	mean = 24.502					1.010	1.002	1.018	**0.0104****
24.	**Home delivery percentage in the community**	mean = 57.524					0.999	0.993	1.005	0.7617
25.	**Low education percentage in the community**	mean = 58.31					1.006	0.999	1.012	**0.0941***

Model 1 is adjusted for age, education, wealth status of the family, marital status, occupation, sex of the child, birth order, size of child at birth, exposure to media, prenatal care and place of delivery

Model 2 is additionally adjusted for residency, getting to health facility, ethnicity diversity index and community socio-economic factors

Model 3 is additionally adjusted for state-level socio-economic factors.

Effects of continuous variables are assessed as one-unit offsets from the mean/ Marginal Significance: *: 90%, ****:** 95%, *****:** 99%

Table 10: Fit statistics and information criteria for the three considered models

		Model 1		*Model 2*		*Model 3*	
CAIC (smaller is better)							
-2 Log Likelihood		6675.05		5468.19		5448.17	
AIC (smaller is better)		6695.05		5560.19		5558.17	
AICC (smaller is better)		6695.09		5560.94		5559.24	
BIC (smaller is better)		6761.43		5865.53		5923.25	
CAIC (smaller is better)		6771.43		5911.53		5978.25	
HQIC (smaller is better)		6718.17		5666.56		5685.34	
-2 log L (COMP | r. effects)		1876.77		2051.91		2083.77	
Pearson Chi-Square		1125.04		1367.59		1393.76	
Pearson Chi-Square / DF		0.19		0.23		0.24	
Intercept	SE	Estimate	SE	Estimate	SE	Estimate	SE
HH(PSU_c)	2.0152	7.7973	2.2882	5.1144	2.5561	4.9307	2.8624

5 DISCUSSION

5.1 DISCUSSION OF RESEARCH QUESTIONS

Several studies analyzed DHS datasets in Nigeria to investigate the risk factors behind the lack of immunization coverage in the country (Adedokun et al., 2017; Antai, 2009b). These two studies concluded that the focus on community-level factors is primordial to tackling the lingering issue of low levels of immunization coverage in Nigeria without any specific information on which community-level factors are incriminated or need attention. There were also no recommendations on which type of interventions to be prescribed. This analysis identified family and community level factors that shed light on the most pressing issue regarding incomplete immunizations. We also aim, throughout our discussion, to address the issue and propose concrete recommendations for interventions that have the potential to answer the issue systematically. The current analysis was performed to determine the immunization coverage in Nigeria for DPT, Polio, Measles, and BCG vaccines in children aged 12 to 18 months old and to explore the risk factors associated with incomplete immunization in these children.

5.2 DISCUSSION OF THE RESULTS

The results show that community-level factors added to factors associated with the mothers' education and access to prenatal care are incriminated in the lack of immunization of their children. However, we did not find any significance when exploring the influence of the individual child factors (age, size, sex, and birth order). In fact, the age of the mother was found to be an influencing factor with mothers aged 35 to 44 years old have lower odds of having children with incomplete immunization when compared to younger mothers aged 15 to 19 years old. The older the mother, the higher the chance of complete immunization for their children, although the results were not significant for other age brackets (20-24, 25-29, 30-34, 45-49) with the odds of incomplete immunization going back up for the latter age

bracket. Media exposure was found to be a risk factor in incomplete immunization when only considering individual and family factors, but the same factor loses significance when considering the community factors. As for the educational level, the higher the educational level, the lower the odds of incomplete immunization. In fact, when compared to children of mothers with higher education, those whose mothers had primary education only were 4.715 (95% CI = 2.201 - 10.101) at higher odds of incomplete immunization. Similarly, for those with mothers that attained secondary education 2.686 (95% CI = 1.465 - 4.922). Unsurprisingly, children with a wealthier household situation were at 0.336 (95% CI = 0.178 - 0.634) lower odds of having incomplete immunization when compared to poorer families. Other significant family factors that our analysis identified were the number of children in the household, with those living in households with 2 (AOR = 1.391; 95% CI = 1.001 - 1.932), three or more (AOR = 1.562; 95% CI = 1.029 - 2.373) children under five were at higher odds of having an incomplete immunization status. The place of delivery and the and access to prenatal care were also risk factors for incomplete vaccination in children. In fact, Children whose mothers do not have access to prenatal care were found to be 5.175 (95% CI = 2.456 - 10.904) at higher odds of not being completely immunized when compared to those with mothers who had access to prenatal care facilities. Similarly, children with mothers that delivered at home were 1.714 (95% CI = 1.178 - 2.493) at higher odds of being not fully immunized when compared to those with mothers that delivered in a healthcare facility. This last finding is of particular interest since the odds of having incomplete vaccinations when mothers did not have access to prenatal care were the highest (AOR = 5.175). Added to that the higher odds of incomplete immunization we observed when mothers delivered at home when compared to those who delivered in a healthcare facility and when mothers have “problems” getting to a healthcare facility (AOR =1.471; 95% CI = 1.000 - 2.163) compared to those who did not have that issue point out to a potential issue in the health care facilities and more specifically to the access to health care around birth, be it before, during, or after giving birth to the child. This observation is further confirmed when among the community factors considered for this study, only

the rate of mothers with low access to prenatal care in the community was statistically significant with an increase of 5% in the odds of lack of complete immunization for each 1% increment in the rate of mothers facing that issue in the community.

5.3 Implications of Findings

Our findings show that the lack of access to prenatal care facilities, coupled with low education of mothers, and lack of resources are correlated with the children's incomplete immunization levels and are therefore important to explain the differences in the immunization coverage in Nigeria. While in previous studies, ethnic differences were incremented in the lack of immunization with the Igbo ethnic group having higher odds of receiving full immunization(Antai, 2009b), our analysis did not show this difference or at least no statistical significance was attributed to the appurtenance to an ethnic group.

The socio-economic status (i.e., education level and wealth status) has been studied as influencing the health-seeking behavior that consequently affects the child's survival. A cross-sectional survey conducted in Nigeria in an emergency room in a tertiary healthcare facility found that "maternal education and high family socio-economic status were strong predictors of early care-seeking and care-seeking outside the home" for childhood illnesses (Ogunlesi & Olanrewaju, 2010). Our finding is then in accordance with the literature and other empirical studies that ascertain that the higher the educational level and the wealth status of the mother and, subsequently, the family, the better the health outcomes of the child, in this case, a complete immunization.

Since access to prenatal care was found to be a risk factor for incomplete immunization in children in our analysis, we explored the existing literature on that subject. Multiple resources were found addressing the importance of the mothers having access to prenatal care and its impact on higher children immunization via prenatal vaccination education. A propensity score matching analysis that assessed strategies to improve child immunization thought prenatal care visits found that a truly positive effect was

observable after 1 to 2 visits to the healthcare facility. These visits are an opportunity to "educate pregnant women on the importance and benefits of child immunization" (Dixit et al., 2013). In fact, these prenatal vaccination education interventions can effectively improve the knowledge around the importance of immunization, especially when mothers have a low education level. Additionally, these interventions "increase the coverage, the completeness, and the timeliness of childhood vaccination" (Hu et al., 2017). A cross-sectional study involving 480 mother-infant pairs conducted in Nigeria found that hospital delivery and attendance at prenatal care visits were two of the determinants factors that influenced the timeliness of the administration of the first vaccination dose of the newborn (within 24 hours) (Ibraheem et al., 2019). Another study, qualitative this time, was conducted at prenatal care centers in Nigeria to assess the perception of healthcare workers and caregivers on the communication strategies employed to encourage childhood vaccination in children. Among the strategies discussed in focus groups and in-depth interviews, media delivered information, town announcers, and home visits were expressed by most respondents (Oku et al., 2017). The authors then conclude that communication strategies should be tailored to the specific setting. Some relevant points can be incorporated into our findings; the lack of access to media outlets by mothers, given how it was significant in our models, is an important factor in the care-seeking behavior attitude since this medium helps raise awareness of the importance of early childhood vaccination. Added to that, this paper bolsters our ascertainment that access to prenatal care is an important factor when it comes to complete immunization since it can be a knowledge source for pregnant women on the importance of vaccinating their newborns. Added to the prenatal care access, delivery in a healthcare setting serves a similar purpose and ensures that mothers have a closer connection to the healthcare system and the vaccination centers, in particular, ensuring better early childhood health outcomes (Alexander & Kotelchuck, 2001; Kifle et al., 2018; Nahom, 2019)

5.4 Study Strengths and Limitations

This study presents some limitations that need to be noted when taking into consideration the results of the analysis. The quality of the analysis and the results are contingent on the quality of the NDHS data collection, although it is considered as a reliable source of data worldwide. Added to that, a direct causal relationship between the outcome and the independent variables is not possible since the survey used is cross-sectional. Besides the limitations inherent to the datasets obtained, the choice of PSUs as community proxy, although commonly used, is contingent on the PSU creation process that the NDHS used. Since we aimed to have a better granularity in our results, we refrained from using state limits instead. In addition, the selection of potential risk factors for the analysis was based on previous studies, and other factors could have been overlooked. Having said that, our study used a representative dataset that ensures that the results are generalizable to the studied population and to some neighboring countries that share the same issues or cultural characteristics.

5.5 Recommendations and Prevention Strategies

Although previous work, using NDHS datasets and focusing on risk factors of incomplete immunization, recommend a focus on immunization programs in a vertical manner, this work takes a different approach in recommending a diagonal approach that puts an emphasis on health systems strengthening.

A paper developed by Dr. Frieden, former director of the Center for Disease Control and prevention, proposed a pyramid that describes the impact level of public health interventions with five tiers (Frieden, 2010). Each tier decreases the individual effort needed while increases the population impact Figure 11.

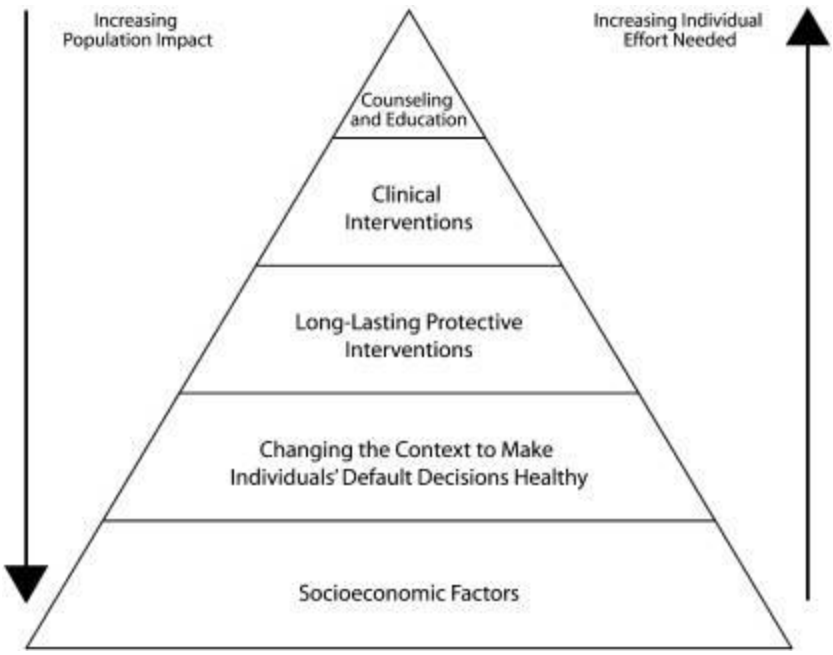

Figure 11:The health impact pyramid. (Frieden, 2010)

Based on the health impact pyramid, addressing the socio-economic factors and the social determinants of health affecting vaccination needs to precede any strengthening of targeted immunization campaigns. This is due to the negative effects of SDH on routine immunization programs. "Recognizing the magnitude of the effect of social determinants on immunization programs is essential for designing appropriate and effective interventions" (Glatman-Freedman & Nichols, 2012). Our work is then the first step into understanding the missed opportunities to address. From theory to action, our recommendations include policy changes, a research component, and building strategic partnerships (Dean et al., 2013).

5.5.1 Policy change to address Social Determinants of Health

From a health economics point of view, vaccination produces public goods considered a positive externality, apparent in herd immunity (Ibuka et al., 2014). An experimental study found that the immunization decision made by parents is influenced by the vaccination status of other children in the community, driven by a free-riding motive (Ibuka et al., 2014). This phenomenon could entice governments to make vaccinations compulsory, but several studies argue against the need to require

parents to vaccinate their children since not enough evidence supports this intervention (Brito et al., 1991). Our goal is to recommend legislation that increases the cost of having children not fully vaccinated or that incentivizes vaccination by reducing its cost.

That being said and knowing that the current legislation in Nigeria states that child vaccination is "mandatory" for public health and child protection reasons, a push towards "compulsory" vaccination might yield positive results. Currently, parents who fail to vaccinate their children are subject to penalties. A compulsory vaccination scheme, prescribed in the face of very low immunization coverage, would increase the cost of having unvaccinated children. This policy would increase the burden on the Nigerian government to enforce the law, and needs sufficient and available supply of vaccines ("Compulsory Vaccination and Conscientious or Philosophical Exemptions," 2006). Another approach would involve gleaning from the Australian experience in providing incentives to vaccinating children (Onyemelukwe, 2016). Financial rewards were accorded to parents, family doctors, and health workers, providing funds for childcare to parents and yielding an increase from 75% in 1997 to 94% in 2001 in immunization coverage (Hull et al., 2003; Salmon et al., 2006). This type of policy would put a financial burden on the Nigerian government. Choosing either policy approaches must involve a collaborative process to ensure synergy between public health actors and community partners. Added to that, cost-benefit analysis and operational research activities need to precede the implementation of either intervention.

5.5.2 Research, research translation

Evaluation of the current prenatal care facilities, policies, and routine immunization programs is primordial in understanding potential existing barriers to complete immunization. This evaluation process must be undertaken by an independent research entity that works to systematically assess the situation and disseminate results. The goal of the proposed evaluation is to assess the impact of prenatal care services on early childhood vaccination and setup up performance indicators adapted to the cultural and

social setting of each community or region in the country. The current Surveillance, Monitoring, and Reporting are performed through several parallel systems that monitor vaccine-preventable diseases: Integrated Disease Surveillance and Response (IDSR), EPI Routine Surveillance System, AFP Surveillance, and Accelerated Disease Control Surveillance (Federal Ministry of Health, 2016). It is crucial to link these surveillance systems to research capacities and institutions to make use of the data and inform policies and locally targeted interventions. That being said, the comprehensive multi-year plan 2016 – 2020 included a focus on research and development to "To conduct operational research to generate evidence for informed decision to improve RI system" (Federal Ministry of Health, 2016). Unfortunately, we weren't able to find the results of the plans of two Knowledge, Attitude and Practice (KAP) studies that were planned in 2017 and 2018 at the time of this analysis. This points out the importance of anchoring the belief that research and translation to public health practice is an important component to tackle the lack of immunization issue in the country and reduce vaccine preventable deaths.

5.5.3 Health systems, strategic partnerships, and capacity building

The Nigerian ministry of health coordinated the immunization activities in the country through the Interagency Coordination Committee (ICC) (Federal Ministry of Health, 2016). "The ICC is chaired by Federal Minister of Health and comprises FMoH, NPHCDA, Association of Local Governments of Nigeria (ALGON), WHO, UNICEF, United States Agency for International Development (USAID), Rotary International (Polio Plus), UK Department for International Development (DFID), European Union (EU-Delegation), Center for Disease Control (CDC), Embassy of Japan (JICA), Embassy of Canada, Embassy of Norway, World Bank, Clinton Health Access International (CHAI), Rotary International and IVAC, HERFON, and SCI. The mandate of the ICC covers polio eradication and routine immunization."(Federal Ministry of Health, 2016). These stakeholders are in charge of: Human Resource Management, Costing and financing, Vaccine and Cold Chain Management, Immunization Service delivery, Surveillance, Monitoring and Reporting, Demand Generation, and Communication and Advocacy. The last function is primordial and

can be linked to our findings where the lack of immunization in children is correlated to a lack of access to prenatal care facilities and media access. The 2016 – 2020 Nigerian strategic plan for vaccination does include a communication component that includes capacity building of 80% of the health workforce on communication and advocacy, and demand creation through raising awareness of the public using media outlets. The issue in this plan is that most mothers did not have access to any media outlet, a factor linked to the lack of immunization, and getting to healthcare services, prenatal care facilities included, seems to pose a problem to pregnant women. This can be explained by the lack of coverage of health care facilities, the rough terrain that some remote, rural families live in, or the violent setting that the northern region of the country suffered from. The Nigerian strategic plan 2016 – 2020 contains, under "reducing the percentage gap in Penta 3 between highest and lowest socio-economic quintiles from 70% in 2013 to 30% by 2020", plans to (Federal Ministry of Health, 2016):

- Scale-up outreach and mobile sessions to reach the hard-to-reach communities at least four (4) times a year
- Increase immunization services (fixed and outreaches) in the hard-to-reach communities

These strategies have also been documented in Nigeria as effective. A study evaluating a vaccination intervention that uses mobile health teams between July 2014 to September 2015 found that "the oral polio vaccine (OPV)3 coverage among children under one year of age improved from 23% at baseline to 61% and OPV coverage among children aged 1–5 years increased from 60 to 90%, while pentavalent vaccine (penta3) coverage increased from 22 to 55%" (Bawa et al., 2018). This intervention is conducted as part of the Nigerian polio eradication plan (National Primary Health Care Development Agency, 2019) to address vaccination is hard to reach and non-compliant areas. Added to that, "health camps" and house-to-house vaccination that showed positive results in ensuring higher complete and timely immunization rates (National Primary Health Care Development Agency, 2019) in Security Compromised

areas and Internally Displaced Persons (IDP) camps (Federal Ministry of Health, 2016). These interventions depend heavily on donor funding and are considered vertical programs. Our recommendation is to move towards a diagonal approach and strengthen the health system instead (WHO, 2007). A diagonal approach involves “addressing health systems bottlenecks and in such a way that ensures the attainment of the desired outcomes while “system-wide” effects are achieved. Added to that, a diagonal approach also pushed towards reducing the investment in “isolated plans” and work towards funneling those funds towards the WHO building blocks (WHO, 2007). In fact, the health system can be viewed as a cube where vertical programs lie on one axis and the WHO building blocks on the other. The third axis represents performance drivers such as “policies and regulations, organizational structures, and relationships across the health system to motivate changes in behavior” (Chee et al., 2013). The example of funding to support cold chain equipment, although of absolute importance, is limited in time and does not support the health system as a whole. That being said, funds to implement these mobile vaccination teams and health camps should be expanded, away from only focusing on polio, to include other vaccine preventable diseases and other health issues and vertical programs that suffer from or need to tackle the lack of access to healthcare facilities. That way, funds are shared, and the overall cost is reduced, and the Federal Ministry of Health can avoid donor fatigue. The longevity and sustainability of such services is then guaranteed.

6 CONCLUSIONS

Using the NDHS data from the year 2018, we identified risk factors such as lack of access to prenatal care, home delivery, lack of access to media outlets, the lack of mothers education, and the low economic status that influence incomplete immunization in Nigeria in children aged between 12 – 23 months old. This study also showed the influence of family and community factors on immunization coverage, in accordance with the Social Determinants of Health concept. Interventions that aim to increase the uptake of child immunization should focus on these factors and act on three axes: a policy, research, and health systems strengthening components. The proposed interventions and past recommendations made by other authors need to be considered in a national discussion/ debate that involves the impacted communities and the concerned parties. A belief of the importance of collaboration, the importance of research and translation to policies, and the health systems thinking is primordial to ensure that a national discussion can yield a harmonious body of interventions to tackle the issue of low immunization coverage in the country. This study contributes to the current knowledge about incomplete immunization risk factors and integrates the concept of health systems strengthening, while focusing on primary healthcare delivery when addressing the lack of immunization.

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