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# KNOWLEDGE AND UPTAKE OF UNDER-5 IMMUNIZATION IN ESAN CENTRAL LOCAL GOVERNMENT AREA, EDO STATE, NIGERIA

By
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**ABSTRACT: Background:** Routine childhood immunization is a critical public health intervention for preventing vaccine-preventable diseases among under-five children. Understanding coverage levels and determinants is essential for improving uptake and reducing child morbidity and mortality. This study assessed routine immunization coverage and its determinants among caregivers of under-five children in Esan Central Local Government Area, Edo State, Nigeria.
**Methods:** We conducted a cross-sectional survey of 308 caregivers using structured questionnaires. Data were analyzed with SPSS version 25. Descriptive statistics summarized immunization coverage, while chi-square tests assessed associations between socio-demographic, household and health system factors and immunization status.
**Results:** Overall, 202 (65.6%) of children were fully immunized, 58 (18.8%) were partially immunized, and 48 (15.6%) were not immunized. Coverage was high for individual vaccines, including BCG 284 (92.2%), pentavalent 283 (91.9%) and measles vaccines 281 (91.2%). Caregiver knowledge was significantly associated with immunization status; with good caregiver knowledge associated with higher full immunization ($p < 0.001$). Joint parental decision-making, higher household income, shorter travel time, and use of private vehicle or walking were also significantly associated with full immunization ($p < 0.001$). Major health system-related barriers included clinic hours clashing with caregivers' work schedules (88.0%), facility overcrowding (65.6%), occasional vaccine unavailability (56.1%) and High transport cost (46.8%)
**Conclusion:** Routine immunization coverage among under-five children was moderate, with gaps in full schedule completion. Caregiver knowledge, household decision-making, accessibility and health system factors significantly influenced uptake. Strengthening health education, promoting joint parental involvement and improving service delivery efficiency are essential to increase full immunization coverage and reduce preventable childhood morbidity and mortality in Nigeria.

**KEYWORDS**: Routine Immunization, Under-five, Immunization, Caregivers, Uptake, Knowledge, Edo Central.

## INTRODUCTION

Immunization remains one of the most successful and cost-effective public health interventions. It protects both vaccinated and unvaccinated people through herd immunity. Thus, significantly reducing childhood morbidity and mortality from vaccine-preventable diseases (VPDs).[1] Immunization is the process by which a person is made resistant to an infectious disease. There are generally two types of

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immunization; passive and active immunization. Passive immunization is more of a natural form, which is obtained from the antibodies transferred from the mother to the child in utero, through the placenta, or via feeding, through breast milk. Active immunization is an acquired form of protection that a person produces after an infection, and this is where vaccination comes in.[1, 2]

The World Health Organization (WHO) defines a vaccine as "A biological preparation that improves immunity to a particular disease. A vaccine typically contains an agent that resembles a disease-causing microorganism and is often made from weakened or killed forms of the microbe, its toxins, or one of its surface proteins."[3] Similarly, the U.S. Centers for Disease Control and Prevention (CDC) defines a vaccine as "A preparation that is used to stimulate the body's immune response against diseases. Vaccines are usually administered through needle injections, but can be administered by mouth, or sprayed into the nose."[3]

Vaccines trigger the immune system to recognize and fight the pathogen without causing a full-blown illness. This way, the body produces antibodies and immune cells, and when it encounters the real pathogen, the immune system responds faster and more effectively.[5] The World Health Organization (WHO) estimates that immunization saves about 3.5 million to 5 million lives each year[4]. It is a key aspect of primary health care, human rights and one of the best health investments one can make.[4]

Furthermore, vaccination remains one of the most effective strategies in modern public health, providing protection against numerous life-threatening diseases through various vaccine types including live-attenuated, inactivated, toxoid, subunit, mRNA and viral-vector vaccines.[7] Immunization protects individuals and contributes to herd immunity, thereby safeguarding those who cannot be vaccinated. Guided by the WHO Immunization Agenda 2030, the global vision is to ensure equitable access to vaccines, strengthen health systems, foster innovation, and improve outbreak preparedness.[8]

Despite strong evidence of vaccine effectiveness, global challenges persist. Factors such as poverty, conflict, misinformation, weak health systems and poor cold-chain infrastructure continue to hinder immunization progress.[9] Nigeria remains among the countries with the highest number of zero-dose children, with an estimated 2.1 million infants receiving no vaccines in 2023[4]. Coverage for key vaccines, including DPT3, HepB3, Hib3 and MCV1 remains below global averages, with notable drop-out rates between first and third doses.[5, 6] These gaps reflect ongoing stagnation and inequalities in immunization performance.

To address these challenges, WHO, UNICEF and Gavi have introduced initiatives such as the Big Catch-Up to reach under-immunized and zero-dose children.[7, 8] Efforts are also underway to strengthen vaccine storage, supply chains, health worker capacity, and community engagement. Enhancing these systems is crucial to achieving IA2030 targets and reducing vaccine-preventable deaths.[9] Against this backdrop, this study aims to assess the knowledge and determinants of under-5 immunization among caregivers in Esan Central LGA, with the goal of informing strategies to improve vaccine uptake and child health outcomes.

Vaccine-preventable diseases continue to pose a significant threat in countries like Nigeria due to their high transmissibility, inadequate healthcare infrastructure, and persistent misconceptions among caregivers.[10] Despite the availability of effective vaccines and ongoing efforts by the Nigerian government and global health partners through the Expanded Programme on Immunization (EPI), many under-5 children remain partially immunized or completely unvaccinated.[6, 11] The 2023–2024 National Demographic and Health Survey (NDHS) reported that 31% of children aged 12–23 months received no vaccines, highlighting major coverage gaps.[12]

Immunization rates vary across regions in Nigeria, with the North-West recording the highest proportion of unimmunized children and the South-South showing relatively better coverage. However, significant disparities persist, particularly in rural communities.[13, 14] In Edo State, rural areas continue to face barriers such as low caregiver knowledge, poor access to health facilities, cultural beliefs, misinformation and negative health worker attitudes[15]. These factors contribute to incomplete immunization, especially among children from poorer households, those with limited maternal education and those lacking adequate antenatal care or proximity to healthcare services.[16] Consequently, many children remain vulnerable to diseases such as measles, polio, tuberculosis, and diphtheria, contributing to avoidable morbidity and mortality.[17]

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Broader systemic challenges, including inadequate understanding of the importance of completing vaccine schedules, misconceptions about vaccine safety and effectiveness, weak institutional policies, financial constraints, and logistical difficulties in the vaccine supply chain, further undermine full immunization coverage.[18] Addressing these issues is essential for improving child health outcomes. A deeper understanding of caregivers' knowledge levels and the determinants influencing their immunization decisions is critical for designing targeted health education interventions, strengthening service delivery, and informing policy reforms aimed at enhancing routine immunization in Esan Central LGAs. This study aimed to assess caregivers' knowledge and the determinants of under-5 immunization in Esan Central Local Government Area, Edo State.

## METHODOLOGY

### STUDY AREA.

This descriptive, cross-sectional study was conducted in Esan Central Local Government Area (LGA), Edo State, in Nigeria's South-South geopolitical zone. Esan Central LGA has its administrative headquarters in Irrua, a semi-urban town with an estimated population of 150,000–170,000. The region experiences a tropical climate with distinct rainy and dry seasons, which can influence access to healthcare services. Health services in Esan Central LGA are delivered through a network of primary healthcare centres (PHCs), private clinics, maternity homes, secondary hospitals and a tertiary teaching hospital. Routine immunization services under the National Programme on Immunization (NPI) are primarily provided in PHCs, with periodic outreach programs to underserved and hard-to-reach communities.

The study was carried out between August 2025 and March 2026, among caregivers of children aged 0–59 months (under-five) residing in households within the Esan Central Local Government Area, Edo State. This specifically included caregivers with at least one child aged 0–59 months living in the household; residents of the selected community for at least 6 months before the study; those aged at least 15 years; and those who provided informed consent to participate. Those excluded from the study included caregivers who were mentally unfit and those who declined to participate.

The minimum sample size for this study was determined using the Cochrane formula for sample size determination,[19] $n=Z^2pq/d^2$

n= minimum sample size

z=standard normal deviation (1.96)

p= 76.4% (full immunization coverage of children aged 1–5 years in Nigeria)[5]

q=1-p**;** =0.236

d=degree of precision at the confidence level of 95%=0.05

Substituting into the formula above; $n = 1.92^2 \times 0.764 \times 0.236/ 0.05^2 = 277$

Considering a non-response rate of 10% (31), the estimated sample size was = 308.

A multistage sampling technique was employed for the study.

Stage I: Four wards were selected from the ten wards in Esan Central Local Government Area using simple random sampling by balloting. Thus, Otoruwo, Ewu, Opoji and Ugbegun were selected. Stage II: One community was selected from each selected ward using simple random sampling by balloting, for a total of four communities: Irrua, Ewu, Opoji, and Ugbegun.

Stage III: Two quarters were selected from each of the communities using simple random sampling technique. All eligible householders in these quarters were selected for the study.

Data were collected using a structured, interviewer-administered questionnaire divided into four sections. Section A: Socio-demographic characteristics of the respondents, including age, sex, marital status, education, occupation, household size, number of children, etc.; Section B: Immunization Status of Under-5 Children, categorized into: fully, partially or not immunized, by documenting receipt of routine vaccines, checking vaccination cards where available and recording the timing and completeness of immunization; Section C: Knowledge of Routine Immunization and Vaccine-Preventable Diseases, especially on caregivers' awareness of routine vaccines, understanding of vaccine-preventable diseases, knowledge of immunization schedules, benefits of vaccination and ability to identify misconceptions; Section D: Health System-Related Barriers, such as accessibility of health facilities, availability of vaccines, waiting time, attitude of health workers, cost implications and outreach services.

Scoring and Classification of Study Variables: Knowledge of Routine Immunization and Vaccine-Preventable Diseases. Knowledge of parents and caregivers regarding routine immunization and vaccine-preventable diseases was assessed using

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structured questions consisting of multiple-choice and Yes/No/Don't know responses. Each correct response was awarded one (1) point, while incorrect responses and "Don't know" answers were scored zero (0). The total obtainable knowledge score depended on the number of knowledge questions administered. Based on the cumulative percentage scores, respondents were classified into two categories: those who scored ≥50% were considered to have good knowledge, while those who scored <50% were considered to have poor knowledge.

Immunization Status of Under-Five Children. The immunization status was determined based on information obtained from immunization cards and caregiver recall. Children who had received all age-appropriate vaccines according to the national immunization schedule at the time of the survey were classified as fully immunized**.** Children who had received at least one vaccine dose but had not completed the recommended schedule were classified as partially immunized**,** while children who had not received any vaccine were classified as not immunized.

Household and Socio-Behavioral Factors Influencing Immunization Uptake. Household and socio-behavioural factors influencing immunization uptake were assessed using structured Yes/No and multiple-response questions. Responses were analyzed descriptively and, where applicable, dichotomized into positive and negative influence categories based on whether the factor facilitated or hindered immunization uptake. These variables were not scored cumulatively but were examined individually for their association with immunization status.

Health System-Related Barriers to Complete Immunization. Health system-related barriers to complete immunization were assessed using structured Yes/No questions addressing accessibility, service delivery and facility-related factors. Each reported barrier was coded as present or absent. These variables were analyzed individually and in relation to immunization status to determine their influence on completion of routine immunization schedules. No composite score was generated for health system-related barriers.

Measurement of variables. Immunization status: Immunization status was the primary outcome variable. It was assessed by documenting the vaccines received by each under-five child using the child's immunization card, where available and caregiver report, where the card was unavailable. The assessment included BCG, Oral Polio Vaccine (OPV), the Pentavalent vaccine, and the measles-containing vaccine. A child was classified as fully immunized if the child had received all vaccines and doses appropriate for his or her age according to the recommended routine childhood immunization schedule. A child who had received some, but not all, age-appropriate recommended vaccines or doses was classified as partially immunized, while a child who had received none of the routine childhood vaccines was classified as not immunized.

Caregiver knowledge: Knowledge of routine immunization and vaccine-preventable diseases was assessed using the knowledge questions in Section C of the questionnaire. The questions assessed awareness of routine childhood immunization, the benefits of immunization, timing of the first vaccine, knowledge of vaccine-preventable diseases, completion of the immunization schedule, the effect of delaying vaccination, immunization of a child with mild fever, and the appropriate age for measles vaccination. Each knowledge item was scored according to the predefined correct response, with one (1) point awarded for a correct response and zero (0) points for an incorrect or "Don't know/Not sure" response. The scores obtained from the knowledge items were summed to derive a composite knowledge score for each respondent. The composite score was expressed as a percentage of the maximum obtainable score. Respondents who obtained 50% or more of the maximum obtainable score were classified as having good knowledge, while those who obtained less than 50% were classified as having poor knowledge.

Socio-demographic variables: Socio-demographic characteristics assessed included caregiver age, sex, marital status, educational level, occupation, religion, number of under-five children in the household, relationship to the child, and monthly household income. These variables were measured using the corresponding questions in Section A of the questionnaire and categorized as presented in the results.

Household and socio-behavioural factors: Household and socio-behavioural factors assessed included the person responsible for decisions concerning the child's health, effect of work schedule on immunization attendance, influence of education on understanding vaccines, influence of household income on access to immunization, family or partner support, time taken to reach the immunization site,

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and main mode of transportation to the health facility. These variables were assessed using the relevant questions in the questionnaire.

Health system-related barriers: Health system-related barriers were assessed using questions concerning the distance to the health facility, waiting time, availability of vaccines, attitude of health workers, transportation cost, availability of immunization services, facility overcrowding, and compatibility of clinic hours with the caregiver's work schedule. Responses were recorded mainly as Yes or No and summarized using frequencies and percentages.

The questionnaire was pre-tested among thirty randomly selected participants in Ekpoma. This exercise was conducted to assess clarity, comprehensibility and cultural relevance of the instrument.

Data collected was entered into a spreadsheet and analyzed using the Statistical Package for Social Sciences (SPSS) database program version 23. Summary statistics for mean, percentage, standard deviation and variance were used where appropriate. The chi-square test and the odds ratio were calculated in the bivariate analysis. The level of significance was set at $P < 0.05$.

Ethical approval (ISTH/HREC/20261401/820) was obtained from the Health Research Ethics Committee of Ambrose Alli University, Ekpoma, Edo State, before data collection commenced. The study was conducted in accordance with relevant local, national and international ethical guidelines. Written voluntary informed consent was obtained from respondents before the questionnaire was administered.

**RESULT**

A total of 308 respondents participated in this study, and all the questionnaires were retrieved, giving a response rate of 100%.

Table 1 presents the socio-demographic characteristics of the respondents. The majority were female (92.2%), with the largest proportion aged 25–34 years (38.6%), followed by those aged 35–44 years (30.2%). Most respondents were married (76.9%) and had at least secondary education, with 47.1% having secondary education and 44.2% having tertiary education. Trading (34.4%) and civil service (30.5%) were the most common occupations. Most respondents were Christians (87.7%), while more than half had at least one child under 5 (53.9%). Mothers constituted the majority of respondents (61.4%), followed by guardians (19.5%), grandparents (11.4%) and fathers (7.8%). Regarding monthly income, 38.6% earned above ₦100,000, while 34.4% earned ₦51,000–₦100,000.

Table 2 presents the immunization status of children under five among the respondents. The findings showed that 62.7% of caregivers were able to present their children's immunization cards, while 29.5% reported having cards that were not seen and 7.8% had no immunization cards. Regarding specific vaccines, a high proportion of children received the Bacillus Calmette–Guérin (BCG) vaccine (92.2%), while 6.5% had not received it. Similarly, 73.4% of the children had received all doses of Oral Polio Vaccine (OPV 1–3), whereas 26.6% had not received any doses. For Pentavalent vaccine, 92.2% of children received all recommended doses, 7.1% did not receive the vaccine, and 0.6% of caregivers were unsure.

The uptake of measles vaccine was also high, with 92.2% of children reported to have received the vaccine, while 7.8% had not. Overall, the results revealed that 65.6% of under-five children were fully immunized, 18.8% were partially immunized and 15.6% were not immunized.

Table 3 shows the immunization status of under-five children according to the source of immunization information. Among children whose immunization status was verified using an immunization card, 163 (84.9%) were fully immunized, 7 (3.6%) were partially immunized and 22 (11.5%) were not immunized. Among children whose immunization status was based on caregiver recall, 39 (33.6%) were fully immunized, 51 (44.0%) were partially immunized and 26 (22.4%) were not immunized. Full immunization was higher among children whose status was verified using an immunization card, whereas partial and non-immunization were more common among those assessed by caregiver recall.

Table 4 shows the association between socio-demographic characteristics of respondents and the immunization status of under-five children. The findings revealed that respondents' age had a statistically significant association with immunization status ($p = 0.043$), indicating that immunization completion was better with an increase in the caregivers' age groups. Educational level also demonstrated a strong statistically significant association with immunization status ($p < 0.001$), suggesting that caregivers with higher levels of education were more likely to have fully immunized children. In addition, monthly household income was

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significantly associated with immunization status ($p < 0.001$), indicating that children from higher-income households were more likely to be fully immunized. However, other socio-demographic variables, including sex ($p = 0.015$), marital status ($p = 0.6543$), occupation ($p = 0.564$), religion ($p = 0.4561$), number of under-five children in the household ($p = 0.3641$) and relationship to the child ($p = 0.526$) did not show statistically significant associations with immunization status.

Table 5 presents the level of knowledge of parents and caregivers regarding routine immunization and vaccine-preventable diseases. The findings revealed that a large proportion of respondents (92.2%) were aware of routine childhood immunization, while only 7.8% were not aware. Most respondents (84.4%) knew that immunization protects children from serious diseases. Concerning the timing of the first vaccine, 68.2% correctly identified birth as the appropriate time, whereas 15.3% did not know the correct timing. Knowledge of vaccine-preventable diseases varied among respondents, with measles (36.4%) and polio (29.9%) being the most commonly identified diseases, while fewer respondents identified tuberculosis (11.7%), diphtheria (11.4%), and whooping cough (10.7%). The majority of respondents (81.2%) correctly knew that a child is considered fully immunized only after receiving all recommended vaccines. Additionally, 62.3% of caregivers were aware that delaying vaccines increases the risk of infection. Regarding immunizing children with mild fever, 61.0% correctly stated that immunization can still be given, although 34.4% were unsure. Furthermore, less than half of the respondents (46.8%) correctly identified 9 months as the recommended age for measles vaccination, while others selected incorrect options or did not know. Overall, the findings indicate a generally good level of awareness and knowledge of routine immunization among caregivers, although knowledge gaps still exist in specific areas such as vaccine timing and identification of vaccine-preventable diseases.

Figure 1. presents the level of knowledge of parents and caregivers about routine immunization and vaccine-preventable diseases, assessed using a composite scoring system. Based on this scoring approach, most respondents demonstrated a good level of knowledge, while a smaller proportion had poor knowledge. The findings indicate that most parents and caregivers were aware of routine childhood immunization, its protective role against serious diseases, and key aspects of the immunization schedule. However, gaps remained in specific areas, such as the correct timing of certain vaccines and the eligibility of mildly ill children for immunization. Overall, the figure suggests that although general knowledge about immunization was relatively high, targeted health education is still necessary to address specific misconceptions and improve informed decision-making regarding complete immunization.

Table 6 presents the association between caregivers' level of knowledge and the immunization status of under-five children. The findings revealed a statistically significant association between caregivers' knowledge level and immunization status ($p < 0.001$). Among respondents with good knowledge, the majority of children were fully immunized (77.2%), while 11.6% were partially immunized and 11.2% were not immunized. In contrast, among respondents with limited knowledge, only 38.7% of children were fully immunized, 35.5% were partially immunized, and 25.8% were not immunized. These findings indicate that higher levels of caregiver knowledge are associated with improved completion of routine childhood immunization, suggesting that knowledge plays a significant role in promoting full immunization among under-five children in the study area.

Table 7 presents the Socio-behavioral factors influencing immunization uptake among children under five. The findings showed that in most households, both parents jointly made decisions regarding child health (54.2%), while 27.6% reported that mothers were the sole decision-makers, 13.0% indicated fathers, and 5.2% reported guardians. Half of the respondents (50.0%) reported that work schedule affected attendance at immunization clinics, while the other half indicated no effect. A majority of respondents (69.2%) reported that educational level influenced their understanding of vaccines. Regarding economic factors, 57.8% of respondents reported that household income affected access to immunization services, while 42.2% reported no influence. Concerning accessibility, 41.6% of respondents reported spending between 15–30 minutes to reach immunization sites, 41.2% spent less than 15 minutes, 9.1% spent between 30 minutes and 1 hour and 8.1% spent more than one hour. In terms of transportation, motorcycles were the most commonly used mode (37.7%), followed by walking (31.5%), private cars (21.4%), and public transport

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(9.4%). These findings highlight the influence of household decision-making, socioeconomic conditions and accessibility factors on immunization uptake among caregivers in the study area.

Table 8 shows that several household and socio-behavioral factors were significantly associated with the immunization status of children under five. Decision-making by both parents was strongly linked to full immunization, with a higher proportion of children being fully immunized compared to households where decisions were made by a single parent or guardian ($p < 0.001$). Educational influence on vaccine understanding, household income affecting access to immunization, and family/partner support were also significantly associated with immunization status, as children from households reporting positive influence in these areas were more likely to be fully immunized ($p < 0.001$). In addition, shorter travel time to immunization sites and the main mode of transportation showed significant associations, with children whose caregivers reached facilities within shorter durations and used private or walking modes more likely to be fully immunized ($p < 0.001$). However, work schedule affecting immunization attendance did not show a statistically significant association with immunization status ($p > 0.05$). Overall, the table highlights the important role of household dynamics, socio-economic factors, accessibility, and support systems in determining childhood immunization uptake.

Figure 2 shows that clinic hours clashing with caregivers' work schedules was the most common barrier (88.0%), followed by facility overcrowding (65.6%). Other notable barriers were occasional vaccine unavailability (56.1%), unfriendly health workers (46.8%), High transport cost (46.8%) and distance from the facility (46.1%). Waiting time (35.1%) and unavailable immunization services (22.1%) were less frequently reported. Overall, inconvenient service hours and facility-related challenges were the major barriers to completing childhood immunization.

Table 9 shows a significant association between several health system–related barriers and the immunization status of under-five children. Distance to health facilities, long waiting time, vaccine unavailability, high transportation cost, unavailability of immunization services and facility overcrowding were all significantly associated with immunization status, with children exposed to these barriers being less likely to be fully immunized ($p < 0.001$). In particular, respondents who reported that facilities were far, waiting time was long, or transportation costs were high had a higher proportion of partially or non-immunized children compared to those who did not report these barriers. Conversely, the attitude of health workers did not show a statistically significant association with immunization status ($p > 0.05$). Although clinic hours clashing with work were reported, this factor did not demonstrate a significant association with immunization status. Overall, the findings emphasize that structural and service delivery barriers within the health system play a crucial role in determining completion of childhood immunization schedules.

Table 10 presents the results of the multivariate logistic regression analysis conducted to identify the independent determinants of full immunization status among under-five children, after adjusting for the effects of other variables in the model. Caregiver knowledge level was a significant independent predictor of full immunization; caregivers with good knowledge of routine immunization had approximately 2.7 times higher odds of having a fully immunized child compared to those with poor knowledge (AOR = 2.69, 95% CI: 1.20-6.02, $p = 0.016$).

Household decision-making arrangement was also significantly associated with immunization status. Children from households where both parents jointly made health decisions had over four times higher odds of being fully immunized compared to those where a single parent or guardian made the decision (AOR = 4.40, 95% CI: 2.00-9.71, $p < 0.001$).

Mode of transportation to the health facility remained a strong independent predictor after adjustment: caregivers who walked or used a private car had substantially higher odds of full immunization compared with those using motorcycles or public transport (AOR = 20.76, 95% CI: 8.425-1.20, $p < 0.001$).

The composite access-barrier burden was significantly associated with immunization outcomes. Caregivers reporting a high burden of access barriers (three or more of: distance, waiting time, income constraints, overcrowding, or long travel time) had markedly lower odds of full immunization compared with those reporting fewer barriers (AOR = 0.08, 95% CI: 0.02-0.27, $p < 0.001$), confirming that cumulative structural and economic barriers exert a compounding negative effect on immunization completion.

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Partner or family support was independently associated with lower odds of full immunization in the adjusted model (AOR = 0.05, 95% CI: 0.01-0.20, $p < 0.001$), and high transport cost was also associated with reduced odds of full immunization (AOR = 0.34, 95% CI: 0.14-0.79, $p = 0.012$). Reported vaccine unavailability was associated with higher adjusted odds of full immunization (AOR = 27.95, 95% CI: 8.01-97.49, $p < 0.001$).

Caregiver age, educational level, and monthly household income were not statistically significant in the multivariate model.

**DISCUSSION**

The study involved 308 caregivers, predominantly mothers aged 25–34 years, mostly married, and with at least secondary education. This pattern aligns with findings from other Nigerian communities, where maternal age, education and marital status influence childhood immunization practices. Such socio-demographic factors have been shown to significantly affect caregivers' knowledge and uptake of routine immunization in Nigeria.[20]

The proportion of children who were fully immunized in this study indicates moderate routine immunization coverage with notable proportions of partially immunized and non-immunized children. This finding aligns with national-level evidence from Nigeria, where the Multiple Indicator Cluster Survey (MICS) and Nigeria Demographic and Health Survey (NDHS) have documented persistent gaps between antigen-specific coverage and full immunization completion, particularly across different regions and socio-economic groups.[21, 22] In comparison, a study conducted in Ga East Municipality, Greater Accra Region, Ghana, reported higher full immunization coverage among children aged 24–35 months.[23] Globally, WHO estimates indicate that coverage for individual vaccines such as BCG and measles often exceeds 85%, yet completion of the full immunization schedule remains uneven, particularly in low and middle-income countries, reflecting patterns similar to those observed in this study.[24] The persistence of partially immunized children suggests drop-out between doses, a challenge widely reported in immunization literature.

The statistically significant association between caregiver education, household income and child immunization status observed in this study aligns with evidence from community-based research in north-central Nigeria, where children of caregivers with at least secondary education were significantly more likely to be fully immunized than those of caregivers with lower or no formal education.[20] Conversely, evidence from northern Nigeria, including Kaduna State, shows low immunization coverage in rural communities.[25] Maternal education and household wealth are significantly associated with immunization uptake, illustrating how socioeconomic disadvantage undermines vaccination completion. Similar associations have been reported in Kenya [26], where maternal education and household wealth were among the strongest predictors of full immunization. At the global level, systematic reviews confirm that socio-economic inequalities remain a dominant determinant of childhood immunization coverage worldwide .[27]

Furthermore, the study demonstrated a significant association between caregivers' knowledge of routine immunization and the immunization status of their children. Caregivers with good knowledge were substantially more likely to have fully immunized children. This finding mirrors results from a community-based study in Osun State, where caregivers with good knowledge of routine immunization were significantly more likely to have fully immunized children.[28] Similarly, research in southwest Nigeria identified caregiver ignorance of immunization schedules and missed appointment dates as common reasons for incomplete vaccination coverage. Globally, WHO behavioral studies consistently highlight caregiver knowledge and perception as critical demand-side determinants of vaccine uptake.[29]

The finding that joint parental decision-making was significantly associated with full immunization is consistent with evidence from national analyses in Nigeria showing that joint decision-making between parents significantly increases the likelihood of full childhood immunization.[30] In contrast, to nomadic communities in Yobe State, where significantly lower immunization uptake was reported, with lack of caregiver knowledge and other barriers undermining routine immunization in underserved populations .[31] Comparable evidence from East African settings shows that household and caregiver characteristics, including education level and socioeconomic status, are associated with childhood immunization status.[32] Global UNICEF reports similarly emphasize that household dynamics and social support systems play a crucial role in determining routine immunization outcomes.[33]

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In addition, the significant association between travel time, mode of transportation and immunization status observed in this study reflects well-documented access barriers. Studies in Nigeria have reported that geographic access and distance to health facilities are important barriers to childhood immunization uptake and completion, with greater distance to vaccination sites associated with lower take-up and delays in vaccine timing.[34] Similar challenges were reported in Nadowli-Kaleo District, Ghana, where children in remote communities were less likely to be fully immunized due to distance and transport costs .[35] Globally, geographic accessibility remains a key determinant of immunization coverage, particularly in rural and underserved populations, as documented in WHO global immunization assessments.[36]

Health system barriers identified in this study, including long waiting times, facility overcrowding, transportation costs, and vaccine stock-outs, are consistent with findings from several Nigerian settings. In Nigeria, a study in Ondo State reported long immunization clinic wait times attributed to workflow inefficiencies, which caregivers perceived as a barrier to immunization service use.[37] Across Africa, studies in Addis Ababa, Ethiopia, have also identified overcrowding and vaccine stock-outs as major barriers to routine immunization.[38] At the global level, WHO recognizes supply-chain disruptions and service delivery inefficiencies as persistent obstacles to achieving universal immunization coverage.[39]

Overall, the findings of this study are largely consistent with evidence from named communities in Nigeria, comparable settings across Africa, and the global literature. Socio-demographic factors, caregiver knowledge, household decision-making, accessibility and health system constraints remain key determinants of routine childhood immunization. The convergence of these findings with existing empirical evidence supports the robustness and external validity of the study and underscores the need for integrated interventions addressing both demand- and supply-side barriers to improve full immunization coverage.

The findings of this study have important implications for improving routine childhood immunization coverage in Nigeria. The significant influence of caregiver education, knowledge of immunization and household income highlights the need for sustained investment in health education interventions, particularly during antenatal and postnatal care, as well as through community outreach programs. Strengthening caregiver knowledge can improve adherence to immunization schedules and reduce missed or delayed vaccinations. Additionally, the observed role of household decision-making underscores the importance of involving both parents, especially fathers, in immunization education and advocacy to promote shared responsibility for child health.

The association between accessibility factors, health system barriers, and immunization status suggests the need for improvements in service delivery and health system efficiency. Strategies such as expanding outreach immunization services, reducing waiting times, ensuring consistent vaccine availability, and improving clinic organization may help address barriers related to distance, transportation cost, and overcrowding. Addressing both demand- and supply-side constraints through integrated, multi-sectoral approaches is essential for achieving optimal immunization coverage and reducing preventable childhood morbidity and mortality

## CONCLUSION

This study demonstrates that routine childhood immunization coverage among under-five children in the study area was moderate, with notable proportions of partially immunized and non-immunized children. Caregiver education, household income, knowledge of immunization and joint parental decision-making were key determinants of full immunization, while accessibility and health system barriers including travel time, transportation challenges, long waiting times, overcrowding and vaccine stock outs also influenced uptake. These findings align with evidence from other Nigerian and African settings, as well as global literature, highlighting the multifactorial nature of immunization coverage.

The results underscore the need for targeted interventions to improve immunization coverage. Strengthening caregiver knowledge through health education, promoting shared parental responsibility and enhancing health system efficiency are essential strategies. Addressing both demand and supply-side barriers through integrated approaches can help increase full immunization rates, reduce missed or delayed vaccinations and ultimately lower preventable childhood morbidity and mortality in Nigeria.

## RECOMMENDATION:

Based on the findings of this study, the following recommendations are made to improve routine

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childhood immunization coverage among under-five children in the study area:

Strengthen caregiver education and awareness: The Edo State Primary Health Care Development Agency (ESPHCDA) should strengthen targeted health education on routine immunization during antenatal and postnatal care, immunization clinics and community outreach. Emphasis should be placed on the immunization schedule, vaccine benefits and the importance of completing all recommended doses.

Promote joint parental involvement: Primary health-care workers should promote the involvement of both mothers and fathers in decisions concerning childhood immunization through family-centred health talks, community sensitization and counselling during clinic visits.

Improve accessibility of immunization services: Local Government Health Authorities should expand community outreach immunization services, particularly to communities and households experiencing difficulties with distance and transportation, to improve access to routine vaccination.

Reduce waiting time and improve service organization: Primary Health-Care Facility Managers should improve clinic organization and appointment systems to minimize waiting time and overcrowding during immunization sessions.

Ensure consistent vaccine availability: ESPHCDA should strengthen vaccine supply, distribution and stock-monitoring systems at primary health-care facilities to minimize vaccine stock-outs and missed opportunities for vaccination.

Improve health-worker responsiveness: Primary Health-Care Facility Managers should ensure that health workers provide respectful and clear information to caregivers regarding vaccination schedules, missed doses and return dates.

**Table 1: Socio-Demographic Characteristics of Respondents (n=308)**

| VARIABLE | FREQUENCY | PERCENTAGE (%) |
|---|---|---|
| **Age** | | |
| 1 5-24 | 43 | 14.0 |
| 25-34 | 119 | 38.6 |
| 35-44 | 93 | 30.2 |
| >45 | 53 | 17.2 |
| **Mean Age ± S.D =** | **34.99 ± 9.065** | |
| **Sex** | | |
| Male | 24 | 7.8 |
| Female | 284 | 92.2 |
| **Marital status** | | |
| Married | 237 | 76.9 |
| Single | 60 | 19.5 |
| Divorce | 7 | 2.3 |
| Widowed | 4 | 1.3 |
| **Education Level** | | |
| No formal education | 2 | 0.6 |
| Primary | 25 | 8.1 |
| Secondary | 145 | 47.1 |
| Tertiary | 136 | 44.2 |
| **Religion** | | 87.7 |
| Christianity | 270 | 3.6 |
| Islam | 11 | 5.8 |
| Traditional religion | 18 | 2.9 |
| Others | 9 | |
| **Number of under-5 children in household** | | |
| 1 child | 166 | 53.9 |

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| | | |
|---|---|---|
| 2 children | 87 | 28.2 |
| 3 children | 38 | 12.3 |
| 4 children and above | 17 | 5.5 |
| **Relationship to child** | | |
| Mother | 189 | 61.4 |
| Father | 24 | 7.8 |
| Grandparents | 35 | 11.4 |
| Guardian | 60 | 19.5 |
| **Monthly household income** | | |
| <₦30,000 | 5 | 1.6 |
| ₦30,000–₦50,000 | 78 | 25.3 |
| ₦51,000–₦100,000 | 106 | 34.4 |
| >₦100,000 | 119 | 38.6 |

**Immunization Status of Under-5 Children**

**Table 2. Immunization Status of Under-5 Children (n=308)**

| VARIABLE | FREQUENCY | PERCENTAGE (%) |
|---|---|---|
| **Immunization card** | | |
| Yes (Card seen) | 192 | 62.7 |
| No (Not seen) | 91 | 29.5 |
| No immunization card | 25 | 7.8 |
| **BCG Vaccine** | | |
| Yes | 284 | 92.2 |
| No | 20 | 6.5 |
| Don't know | 4 | 1.3 |
| **OPV 1-3** | | |
| Yes | 22 6 | 73.4 |
| No | 8 | 26.6. |
| **Penta 1-3** | | |
| Yes | 283 | 91.9 |
| No | 22 | 7.1 |
| Don't know | 2 | 1.0 |
| **Measles Vaccine** | | |
| Yes | 281 | 91.2 |
| No | 24 | 7.8 |
| Don't know | 3 | 1.0 |
| **Overall immunization status** | | |
| Fully immunized | 202 | 65.6 |
| Partially immunized | 58 | 18.8 |
| Not immunized | 48 | 15.6 |

**Table 3: Immunization Status According to Source of Immunization Information among Under-Five Children (n=308)**

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| SOURCE OF IMMUNIZATION INFORMATION | FULLY IMMUNIZED N (%) | PARTIALLY IMMUNIZED N (%) | NOT IMMUNIZED N (%) | TOTAL N (%) |
|---|---|---|---|---|
| Immunization card seen | 163 (84.9) | 7 (3.6) | 22 (11.5) | 192 (100.0) |
| Card not seen (recall) | 39 (33.6) | 51 (44.0) | 26 (22.4) | 116 (100.0) |
| Total | 202 (65.6) | 58 (18.8) | 48 (15.6) | 308 (100.0) |

| VARIABLE | IMMUNIZATION STATUS OF CHILDREN | | | $X^2$ | P-Value |
|---|---|---|---|---|---|
| | **Fully immunized** | **Partially immunized** | **Not immunized** | | |
| **Age** | 21(48.8%) | | | 9.402 | 0.0431 |
| 15-24 | 65(54.6%) | 22(51.2%) | 0(0.0%) | | |
| 25-34 | 84(90.3%) | 31(26.1%) | 23(19.3%) | | |
| 35-44 | 32(60.4%) | 5(5.4%) | 4(4.3%) | | |
| >45 | | 0(0.0%) | 21(39.6%) | | |
| **Sex** | | | | 1.1235 | 0.015 |
| Male | 0(0.0%) | 24(100.0) | 0(0.0%) | | |
| Female | 202(71.1%) | 34(12.0%) | 48(16.9%) | | |
| **Marital status** | | | | 3.5869 | 0.6543 |
| Married | 38(60.0%) | 24(40.0%) | 0(0.0%) | | |
| Single | 158(66.7%) | 31(13.1%) | 48(20.3%) | | |
| Divorce | 6(85.7%) | 1(14.3%) | 0(0.0%) | | |
| Widowed | 2(50.0%) | 2(50.0%) | 0(0.0%) | | |
| **Education Level** | | | | 141.688 | <0.001* |
| No formal education | 0(0.0%) | 0(0.0%) | 2(100.0%) | | |
| Primary | | | | | |
| Secondary | 2(8.0%) | 1(4.0%) | 22(88.0%) | | |
| Tertiary | 102(70.3%) | 19(13.1%) | 24(16.6%) | | |
| | 98(72.1%) | 38(27.9%) | 0(0.0%) | | |
| **Religion** | | | | 9.388 | 0.4561 |
| Christianity | 188(69.6%) | 56(20.7%) | 26(9.6%) | | |
| Islam | 0(0.0%) | 0(0.0%) | 11(100.0%) | | |
| Traditional religion | 7(36.8%) | 1(5.3%) | 11(57.9%) | | |
| Others | 7(77.8%) | 1(11.1%) | 1(11.1%) | | |
| **Number of under-5 children in household** | | | | 1.367 | 0.3641 |
| 1 child | | | | | |
| 2 children | 131(69.3%) | 34(18.0%) | 24(12.7%) | | |
| 3 children | 0(0.0%) | 0(0.0%) | 24(100.0%) | | |
| 4 children and above | 35(100.0%) | 0(0.0%) | 0(0.0%) | | |
| | 36(60.0%) | 24(40.0%) | 0(0.0%) | | |
| **Relationship to child** | | | | 1.736 | 0.526 |
| Mother | | | | | |
| Father | 131(69.3%) | 34(18.0%) | 24(12.7%) | | |
| Grandparents | 0(0.0%) | 0(0.0%) | 24(100.0%) | | |
| Guardian | 35(100.0%) | 0(0.0%) | 0(0.0%) | | |
| | 36(60.0%) | 24(40.0%) | 0(0.0%) | | |
| **Monthly household income** | | | | 149.910 | <0.001* |
| <₦30,000 | 0(0.0%) | 0(0.0%) | 5(100.0%) | | |
| ₦30,000–₦50,000 | 43(55.1%) | 29(37.2%) | 6(7.7%) | | |
| ₦51,000–₦100,000 | 29(27.4%) | 29(27.4%) | 37(34.9%) | | |

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| | | | | | |
|---|---|---|---|---|---|
| >₦100,000 | 119(100.0%) | 0(0.0%) | 0(0.0%) | | |

**Table 4. Association between Socio-Demographic Characteristics and Immunization Status**

**Table 5. Knowledge of parents and caregivers about routine immunization and vaccine-preventable diseases (n=308)**

| VARIABLE | FREQUENCY | PERCENTAGE (%) |
|---|---|---|
| **Awareness of routine childhood immunization** | | |
| Yes | 284 | 92.2 |
| No | 24 | 7.8 |
| **Immunization protects children from serious disease** | | |
| Yes | 260 | 84.4 |
| No | 48 | 15.6 |
| **Correct timing of first vaccine** | | |
| At birth | 210 | 68.2 |
| At 6 weeks | 25 | 8.1 |
| At 3 months | 26 | 8.4 |
| Don't know | 47 | 15.3 |
| **Knowledge of vaccine preventable disease** | | |
| Measles | 112 | 36.4 |
| Polio | 92 | 29.9 |
| Tuberculosis | 36 | 11.7 |
| Diphtheria | 35 | 11.4 |
| Whooping cough | 33 | 10.7 |
| **Knowledge that a child is fully immunized only after completing all vaccines** | | |
| Yes | 250 | 81.2 |
| No | 58 | 18.8 |
| **Delaying vaccines increases infection risk** | | |
| Yes | 192 | 62.3 |
| No | 34 | 11.0 |
| Don't know | 82 | 26.6 |
| **Child with mild fever can still be immunized** | | |
| Yes | 188 | 61.0 |
| No | 14 | 4.5 |
| Not sure | 106 | 34.4 |
| **Correct age for measles Vaccine** | | |
| 9 months | 144 | 46.8 |
| 6 months | 72 | 23.4 |
| 1 year | 34 | 11.0 |
| Don't know | 58 | 18.8 |

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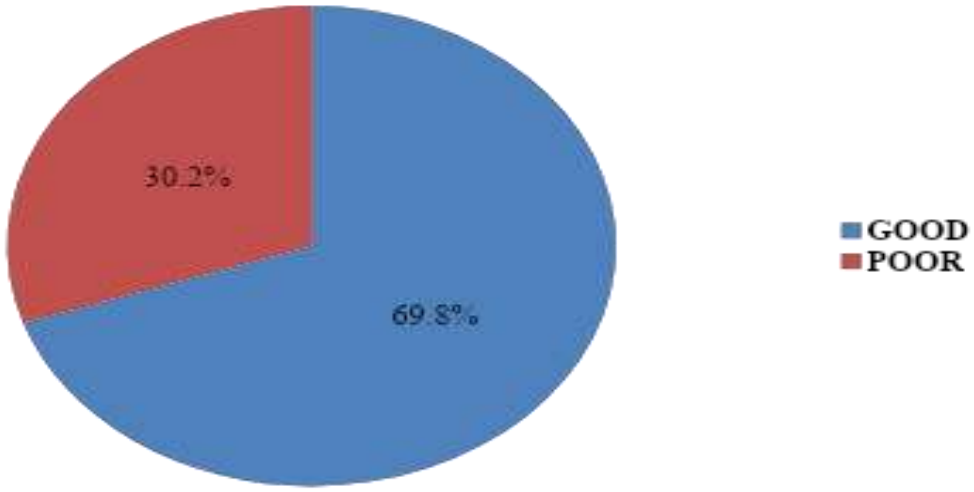


**Figure 1: Level of knowledge of parents and caregivers about routine immunization and vaccine-preventable diseases**

**Table 6. Association between knowledge and Immunization status**

| LEVEL OF KNOWLEDGE | IMMUNIZATION STATUS | | | $X^2$ | P-Value |
|---|---|---|---|---|---|
| | Fully immunized | Partially immunized | Not immunized | | |
| **Good** | 166(77.2%) | 25(11.6%) | 24(11.2%) | 43.234 | <0.001* |
| **Poor** | 36(38.7%) | 33(35.5%) | 24(25.8%) | | |

**Table 7 Socio-behavioural factors influencing immunization uptake among under-5 children (n=308)**

| VARIABLE | FREQUENCY | PERCENTAGE (100%) |
|---|---|---|
| **Decision maker for child health** | | |
| Mother | 85 | 27.6 |
| Father | 40 | 13.0 |
| Both parents | 167 | 54.2 |
| Guardian | 16 | 5.2 |
| **Work schedule affecting immunization attendance** | | |
| Yes | 154 | 50 |
| No | 154 | 50 |
| **Education influencing understanding of vaccines** | | |
| Yes | 213 | 69.2 |
| No | 95 | 30.8 |

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| | | |
|---|---|---|
| **House hold income affecting access to immunization** | | |
| Yes | 178 | 57.8 |
| No | 130 | 42.2 |
| **Family/partner support making immunization easier** | | |
| Yes | 118 | 38.3 |
| No | 130 | 61.7 |
| **Time taken to reach immunization site** | | |
| <15 minutes | 127 | 41.2 |
| 15-30 minutes | 129 | 41.6 |
| 31-60 minutes | 29 | 9.1 |
| >1 hours | 25 | 8.1 |
| **Main mode of transportation to health facility** | | |
| Walking | 97 | 31.5 |
| Motorcycle | 116 | 37.7 |
| Public transport | 29 | 9.4 |
| Private car | 66 | 21.4 |

**Table 8 Association between Socio-behavioral factors and immunization status of under-5 children**

| VARIABLE | IMMUNIZATION STATUS | | | $X^2$ | P-Value |
|---|---|---|---|---|---|
| | **Fully immunized** | **Partially immunized** | **Not immunized** | | |
| **Decision maker for child health** | | | | 120.07 | <0.001* |
| Mother | 50(58.8%) | | 23(27.1%) | | |
| Father | 17(42.5%) | 12(14.1%) | 17(42.5%) | | |
| Both parents | 135(80.8%) | 6(15.0%) | 8(4.8%) | | |
| Guardian | 0(0.0%) | 24(14.4%) | 0(0.0%) | | |
| | | 16(100%) | | | |
| **Work schedule affecting immunization attendance** | | | | 2.219 | 0.330 |
| Yes | 106(68.8%) | 24(15.6%) | 24(15.6%) | | |
| No | 96(62.3%) | 34(22.1%) | 24(15.6%) | | |
| **Education influencing understanding of vaccines** | | | | 35.880 | <0.001* |
| Yes | 131(61.5%) | 58(27.2%) | 24(11.3%) | | |
| No | 71(74.7%) | 0(0.0%) | 24(25.3%) | | |
| **House hold income affecting access to immunization** | | | | 43.803 | <0.001* |
| Yes | 106(59.6%) | 24(13.5%) | 48(27.0%) | | |
| No | 96(73.8%) | 34(26.2%) | 0(0.0%) | | |

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| | | | | | |
|---|---|---|---|---|---|
| **Family/partner support makes immunization easier** | | | | 19.231 | <0.001* |
| Yes | 60(50.8%) | 34(28.8) | 24(20.3%) | | |
| No | 142(74.7%) | 24(12.6%) | 24(12.6%) | | |
| **Time taken to reach immunization site** | | | | 31.269 | <0.001* |
| <15 minutes | 165(82.9%) | 34(17.1%) | 0(0.0%) | | |
| 15-31 minutes | 36(60.0%) | 24(40.0%) | 0(0.0%) | | |
| 31-61 minutes | 1(4.0%) | 0(0.0%) | 24(96.;0%) | | |
| >1 hour | 0(0.0%) | 0(0.0%) | 24(100.0%) | | |
| **Main mode of transportation to health facility** | | | | 186.34 | <0.001* |
| Walking | 82(84.5%) | 11(11.3%) | 4(4.1%) | | |
| Motorcycle | 50(43.1%) | 46(39.7%) | 20(17.2%) | | |
| Public transport | 4(13.8%) | 1(3.4%) | 24(82.8%) | | |
| Private car | 66(100.0%) | 0(0.0%) | 0(0.0%) | | |

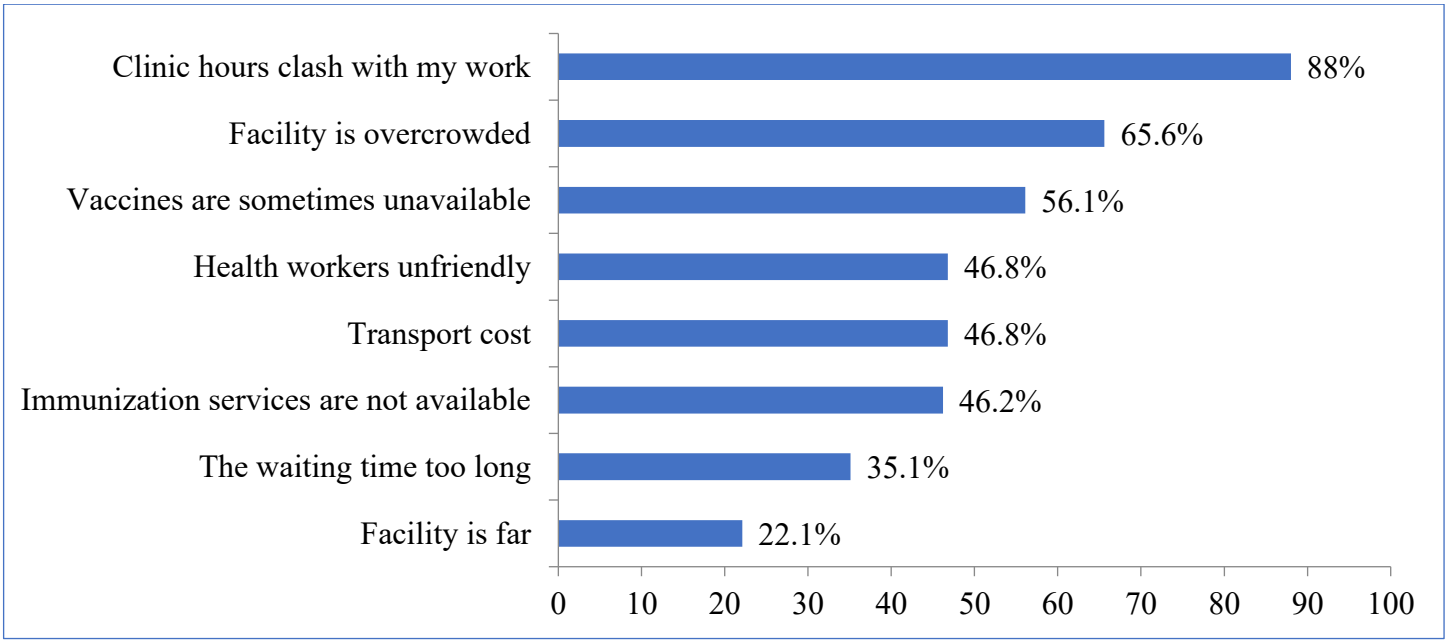


**Figure 3:** Barriers to complete immunization

**Table 9. Association between Barriers and immunization Status**

| VARIABLE | IMMUNIZATION STATUS OF CHILDREN | | | $X^2$ | P-Value |
|---|---|---|---|---|---|
| | **Fully immunized** | **Partially immunized** | **Not immunized** | | |
| **Facility is far** | | | | 67.292 | <0.001 |
| Yes | 70(49.3%) | 24(16.9%) | 48(33.8%) | | |
| No | 132(79.5%) | 34(20.5%) | 0(0.0%) | | |
| **The waiting time too long** | | | | 65.35 | <0.001 |
| Yes | 72(50.0%) | 24(16.7%) | 48(33.3%) | | |
| No | 130(79.3% | 34(20.7%) | 0(0.0%) | | |

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| | | | | | |
|---|---|---|---|---|---|
| **Vaccines are sometimes unavailable** | | | | 105.74 | <0.001* |
| Yes | 94(66.2%) | 0(0.0%) | 48(33.8%) | | |
| No | 108(65.1%) | 58(34.9%) | 0(0.0%) | | |
| **Health workers unfriendly** | | | | 0.924 | 0.630 |
| Yes | 96(66.7%) | 24(16.7%) | 24(16.75) | | |
| No | 106(64.6%) | 34(20.7%) | 24(14.6%) | | |
| **Transportation Cost is high** | | | | 122.60 | <0.001* |
| Yes | 60(55.6%) | 0(0.0%) | 48(44.4%) | | |
| No | 142(71.0%) | 58(29.0%) | 0(0.0%) | | |
| **Immunization services are not available** | | | | 61.852 | <0.001* |
| Yes | 34(50.0%) | 34(50.0%) | 0(0.0%) | | |
| No | 168(70.0%) | 24(10.0%) | 48(20.0%) | | |
| **Facility is overcrowded** | | | | 40.378 | <0.001* |
| Yes | 130(64.4%) | 24(11.9%) | 48(23.8%) | | |
| No | 72(67.9%) | 34(32.1%) | 0(0.0%) | | |
| **Clinic hours clash with my work** | | | | 2.2067 | 0.456 |
| Yes | 165(60.9%) | 58(21.4%) | 48(17.7%) | | |
| No | 37(100%) | 0(0.0%) | 0(0.0%) | | |

**Table 10. Multivariate Logistic Regression Analysis of Determinants of Immunization Status Among Under-Five Children (n = 308)**

| Variable | Category | AOR | 95% CI | p-value |
|---|---|---|---|---|
| **Caregiver age** | < 35 years | 1.00 | Reference | - |
| | ≥ 35 years | 1.00 | 0.36 - 2.76 | 0.999 |
| **Educational level** | Primary or below | 1.00 | Reference | - |
| | Secondary | 2.13 | 0.11 - 41.61 | 0.618 |
| | Tertiary | 6.46 | 0.32 - 128.82 | 0.222 |
| **Monthly household income** | ≤ ₦50,000 | 1.00 | Reference | - |
| | ≥ ₦51,000 | 1.12 | 0.48 - 2.59 | 0.791 |
| **Caregiver knowledge level** | Poor | 1.00 | Reference | - |
| | Good | 2.69 | 1.20 - 6.02 | 0.016* |
| **Household decision-maker** | Single parent/guardian | 1.00 | Reference | - |
| | Both parents | 4.40 | 2.00 - 9.71 | <0.001* |

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| Variable | Category | AOR | 95% CI | p-value |
|---|---|---|---|---|
| **Partner/family support** | No | 1.00 | Reference | - |
| | Yes | 0.05 | 0.01 - 0.20 | <0.001* |
| **Mode of transport** | Motorcycle/Public transport | 1.00 | Reference | - |
| | Walking/Private car | 20.76 | 8.42 - 51.20 | <0.001* |
| **Access-barrier burden** | Low (0–2 barriers) | 1.00 | Reference | - |
| | High (≥3 barriers) | 0.08 | 0.02 - 0.27 | <0.001* |
| **Vaccine unavailability** | No | 1.00 | Reference | - |
| | Yes | 27.95 | 8.01 - 97.49 | <0.001* |
| **Transport cost** | No | 1.00 | Reference | - |
| | Yes | 0.34 | 0.14 - 0.79 | 0.012* |

AOR = Adjusted Odds Ratio; CI = Confidence Interval; * = statistically significant at $p < 0.05$. Outcome variable: fully immunized (1) vs. partially/not immunized (0). Model estimated using Firth's penalized (bias-reduced) logistic regression to account for sparse cells among some predictor categories. Facility distance, waiting time, household-income access constraint, and facility overcrowding were highly intercorrelated (r = 0.5-0.85) and were therefore combined into a single composite "access-barrier burden" score (0-5 reported barriers), dichotomized as low (0-2) versus high (≥ 3), to avoid multicollinearity in the model.

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