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Factors Associated with the Prevalence of Poor Immunization Coverage (Zero Dose and Under Immunization) of Children (12-35 Months) in Missed Communities in the Far North Region of Cameroon: The Case of 5 Fragile Health Districts

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Abstract:

- ***Background:***

Immunization is one of the most effective public health interventions, yet coverage remains critically low in fragile districts of Cameroon's Far North region. Insecurity, displacement, and sociocultural barriers contribute to persistent gaps, leaving many children vulnerable to vaccine preventable diseases.

- ***Objective:***

To assess the prevalence and determinants of zero-dose and under-immunization among children aged 12–35 months in fragile districts of the Far North region of Cameroon.

- ***Methods:***

A quantitative descriptive cross-sectional study was conducted between December 2024 and August 2025. Using multistage random sampling, 383 mothers/guardians of eligible children were interviewed across 25 missed communities. Data were collected through a structured, pre tested questionnaire and analyzed using descriptive statistics and logistic regression. Dependent variables were zero dose (no DTP1) and under immunization (missed DTP3 or other vaccines).

- ***Results:***

Only 27% of respondents presented a vaccination card, and just 21% of children were fully vaccinated against EPI diseases. The burden of missed immunization was extremely high: 51% of children were zero dose and 35% under immunized, meaning 87% were either zero dose or under immunized. Although 48% had received RR doses, this partial progress was insufficient to close the coverage gap. Females were disproportionately affected, with 29% never receiving DTP1 compared to 19% of males. Logistic regression identified several significant determinants: maternal education (AOR = 2.45, 95% CI: 1.30–4.62, p = 0.005), maternal autonomy (AOR = 0.62, 95% CI: 0.40–0.95, p = 0.03), household wealth (AOR = 1.85, 95% CI: 1.10–3.12, p = 0.02), geographic barriers such as conflict affected or remote areas (AOR = 3.10, 95% CI: 1.75–5.50, p < 0.001), and supply side constraints including vaccine stock outs (AOR = 2.20, 95% CI: 1.25–3.90, p = 0.006) and lack of trained staff (AOR = 1.70, 95% CI: 1.05–2.75, p = 0.03). Cultural attitudes such as refusal of male vaccinators, lack of trust in health personnel, and religious restrictions were also independently associated with under immunization (p < 0.05).

- ***Conclusion:***

Zero-dose and under-immunization remain alarmingly prevalent in fragile districts of Cameroon, with 87% of children affected. Inferential analysis confirms that maternal education, autonomy, household wealth, geographic insecurity, and health system constraints are statistically significant determinants. Addressing these barriers through targeted, context-specific interventions is urgently needed to strengthen immunization coverage in fragile settings.

Keywords: *Zero-Dose, Unimmunized, Poor Immunization Coverage, Children, Missed Communities, Fragile Health Districts.*

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I. INTRODUCTION

Zero-dose children are those who have not received any routine immunisation. For operational purposes, Gavi defines "zero-dose" children as those who have not received the first dose of the diphtheria, tetanus and pertussis-containing vaccine (DTP1). "Zero-dose" refers to a person who has not received a single dose of a vaccine included in the national routine immunization schedule. Missed communities are localities where children have not received a dose or have not been adequately vaccinated (Vaccher et al., 2025). Data shows that childhood vaccination rates vary depending on where they live. For example, in a study conducted in India, children in urban areas were consistently less likely to be missed than those in rural areas (Summan et al., 2022).In some settings, relatively higher rates of non-vaccination are observed in peri-urban areas. In this context, the prevalence of zero-dose children is also compounded by poor road conditions in rural and peri-urban areas. The risks of not being vaccinated in a conflict zone are more significant than risks elsewhere because of compounding factors such as malnutrition, increased spread of infectious or communicable diseases, and limited access to care (Powell et al., 2025). Large urban slum areas are characterized by limited access to quality health services in general and certainly include missed-dose children. According to reports from the national Expanded Program for Immunization (EPI) program, the Far North region of Cameroon has more than 32% of communities characterised as missed communities (hard-to-reach and remote areas, urban slums, internally displaced persons, pastoralist communities, refugee camps and conflict-affected areas) (Musa & Abdullahi, 2025) .In these areas, the demand and supply of immunization services are very challenging. In the fragile health districts, 80% of their communities fall in the category of communities with poor immunization coverage.

Far North region is the northernmost region of the Republic of Cameroon. It has 5,463,907 inhabitants and is the second most densely populated region in the country. It shares borders with Nigeria to the west and with Chad to the east. It has more than 50 ethnic groups(*Cameroon*, n.d.) The region has a hot and dry tropical climate. The dry season lasts from October to June .71.2% of the population lives in rural areas and 50.8% is under 15 years old(Epee et al., 2024).The region is divided into 32 Health Districts. It is the poorest region in the country, with 65.7% living on less than a dollar a day. 28.6% of its population is uneducated 81% of rural households are food insecure, of which 18 are moderately severely food secure and vulnerable. Agriculture is the main economic activity in the region(Tchuenga et al., 2024).The Lake Chad basin and the Logone and Chari rivers attract transhumans who move livestock from Nigeria via Cameroon to Chad and back. 40% of the population is Christian, 30% of the population is Muslim, and 10% animist and a good number have no direct affiliation to any religion. The communities have their leaders (Djaouoros) who are highly respected. Heavy flooding in some communities from July to November makes passage impossible. Seasonal nomadic herders and fishermen are always on the move with their families in search of pasture, water, and fish. This study aimed to estimate the prevalence and identify factors associated with poor immunization coverage (zero-dose and under immunization) of children (12-35 months) in missed communities in the five fragile Health Districts in the Far North region of Cameroon.

II. METHODS

Data Collection: Data were obtained through structured interviews with mothers and caregivers using a pre-tested questionnaire available in 20 local languages. The survey was implemented by a team of 10 experienced interviewers and one supervisor, all of whom were trained in survey methodology and vaccination documentation. To ensure accuracy and consistency, data were collected using the CommCare digital application, an open-source and interoperable platform that facilitated real-time monitoring, cleaning, and quality control.

- *Interviewer Recruitment and Training:*

Interviewers were recruited based on specific criteria, including possession of a degree in a health-related discipline, prior experience in national surveys, and familiarity with the CommCare application. The survey team underwent five days of intensive training, which covered sampling procedures, fieldwork preparation, interview techniques, and practical exercises such as reviewing vaccination cards and using the CommCare tool.

- *Quality Assurance:*

Each interviewer was authorized to collect data from up to six children per day. To validate data quality, one-third of participants (33%) were re-interviewed by supervisors. In addition, the principal investigator monitored data entry in real time throughout the survey period, ensuring adherence to protocol and immediate resolution of inconsistencies.

- *Study Variables:*

Study variables were selected based on the analytical framework, the hypotheses under investigation, and the availability of data in the study database. Both dependent and independent variables were included to capture determinants of immunization coverage.

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- *Dependent Variables:*
  Two binary outcome variables were assessed. Zero-dose children were defined as those who had not received the first dose of diphtheria–tetanus–pertussis (DTP1). Under-immunized children were defined as those who missed the third dose of DTP (DTP3) or failed to complete the recommended vaccination schedule. Each variable was coded dichotomously (yes/no).

- *Independent Variables:*
  Independent variables encompassed demographic, socioeconomic, cultural, geographic, and health system factors. Demographic and socioeconomic measures included maternal age (15–50 years, grouped in seven categories), religion (Muslim, Christian, other), education level (none, primary, secondary or higher),marital status (single, married/cohabiting,widowed/divorced/separated), gender of household head (male, female), and household socioeconomic status (poorer, poor, average, rich).

Cultural and behavioral barriers were captured through binary indicators of religious restrictions on vaccination, reliance on alternative protection against vaccine-preventable diseases, lack of trust in healthcare providers, refusal of male vaccinators, and limited maternal autonomy in healthcare decision-making.

Geographic and infrastructure challenges included distance to health facilities (5–10 km or ≥10 km), mountainous location, exposure to Boko Haram insurgency, road inaccessibility due to pachyderms, presence of nomadic populations, intercommunity conflict, internally displaced persons, hard-to-reach or remote areas, urban slums, refugee camps, and conflict-affected zones.

Health system and service delivery factors were assessed through indicators of community mobilization prior to vaccination, involvement of vigilance committees, availability of follow-up lists at health facilities, vaccinator training in record keeping, regular staff training, availability of cold-chain equipment, number of vaccination sessions per week (one or two), staff motivation, vaccine stockouts in the preceding three months, presentation of vaccination cards by caregivers, and whether the child was fully vaccinated against all Expanded Programme on Immunization (EPI) diseases.

III. ANALYSIS

Contingency table analysis was used to investigate the urban–rural differences in the socio-demographic characteristics of the sample, including maternal age, child age, mean total children ever born per woman, sex of the child, measles vaccination coverage, access to skilled birth attendants, wealth and maternal and paternal education. For categorical variables, Pearson's χ^2 tests were used to establish the significance of differences in sociodemographic and measles vaccination coverage across groups at the 5% level. Independent sample *t*-tests were used to assess significance of urban–rural differences in the continuous variables (maternal and child age, total children ever born) at the 5% level.

Bivariate analysis was used to further investigate the education and wealth characteristics of women who did not give birth with the assistance of a skilled birth attendant. Pearson's χ^2 tests were again used to establish the significance of differences between groups at the 5% level. Significant differences in mean children ever born among urban and rural residents and wealth quintiles were assessed using independent sample *t*-tests.

Bivariate analyses were used to investigate the pattern of vaccination coverage across urban and rural areas for measles and the 11 other vaccinations in the Indonesian childhood vaccination schedule. Regional differences in measles vaccination uptake across the 33 Indonesian provinces were also investigated using bivariate analysis. Significance testing was again conducted using Pearson's χ^2 tests.

Contingency table analysis was used to compare the measles immunisation coverage rate for poor and rich children residing in rural and urban areas of Papua, South Kalimantan, East Java and West Sumatra provinces. Chi square tests were again used to establish the significance of differences in measles vaccination coverage for poor and rich groups in each area at the 5% level. For this analysis respondents were classified as 'poor' if they were in the poorest or poorer DHS wealth quintiles and 'rich' if they were in the middle, richer or richest wealth quintiles.

Multivariate logistic regression analysis was used to investigate whether rural–urban differentials remained after controlling for sex of the child, maternal age, maternal age squared, maternal and paternal education, household wealth and the presence of a skilled birth attendant. Maternal age was measured as a continuous variable; all other variables were included as categorical variables. A binomial logistic regression model was developed with measles vaccination as the outcome variable. All independent variables were entered simultaneously into the model. The results are reported as odds ratios (OR) and the 95% confidence intervals (CI) for the odds ratios. All data analysis was conducted using PASW v17 (http://www-01.ibm.com/software/analytics/ spss/).

IV. RESULTS

➤ *Sociodemographic and Community Context Characteristics*

The sociodemographic profile of respondents shows a predominantly young adult population, with the largest group aged 26–31 years (26%) and most falling below 41 years. The majority were Muslim (84%), lived in rural areas (70%), and belonged to poor or poorest households (74%), reflecting socioeconomic vulnerability. Education levels were very low, with 72% having no schooling, while only 15% attained secondary or higher education. Most respondents were married or cohabiting (89%), and households were largely male-headed (85%), underscoring gendered decision-making dynamics. Additionally, 71% lived ≥10 km from vaccination posts, highlighting significant geographic barriers to accessing immunization services. Most communities are remote (89%), with high proportions of nomadic (69%) and pastoralist (66%) populations. Boko Haram (25%), intercommunity conflict (14%), and refugee/IDP presence (33% combined) highlight insecurity. Despite strong training coverage (84% vaccinators, 78% staff), 64% reported vaccine stock-outs and only 40% staff motivation. Religion (70%), lack of autonomy (72%), and non-acceptance of male vaccinators (68%) are major obstacles. Only 21% of children fully vaccinated, while 87% were zero-dose or under-immunized.

Table 1 Sociodemographic Characteristics of Respondents

Variable	Category	Frequency (n)	Percentage (%)
Age (years)	15–21	39	10
	21–26	73	19
	26–31	98	26
	31–36	74	19
	36–41	55	14
	41–46	26	7
	46–50	18	5
Religion	Muslim	321	84
	Christian	43	11
	Other/None	19	5
=- Education level	No schooling	276	72
	Primary	49	13
	Secondary and higher	58	15
Marital status	Single	33	9
	Married/cohabiting	340	89
	Widowed/divorced/separated	10	2
Sex of household head	Male	327	85
	Female	56	15
Residence	Urban	115	30
	Rural	268	70
Health district	Maga	71	19
	Mora	68	18
	Maroua 1	67	17
	Guere	87	23
	Yagoua	90	23
Socioeconomic level	Poorest	136	36
	Poor	145	38
	Middle	78	20
	Rich	24	6
Distance to vaccination post (km)	<5 Km	35	9
	5–10 km	78	20
	≥ 10 km	270	71

➤ *Prevalence of Zero Dose and Under-Immunized Children in the Missed Communities of the 05 Fragile Districts of the Far North of Cameroon.*

Only 27% of respondents showed a vaccination card. Just 21% of children were fully vaccinated against EPI diseases, showing very low completion of the immunization schedule. The burden of missed immunization is extremely high, with 51% of children being zero-dose (ZD) and 35% under-immunized (UIC). Combined, this means 87% of children were either zero-dose or under-immunized, reflecting widespread gaps in vaccine delivery and uptake. Although 48% of children had received RR doses, this partial progress is insufficient to close the coverage gap**.**

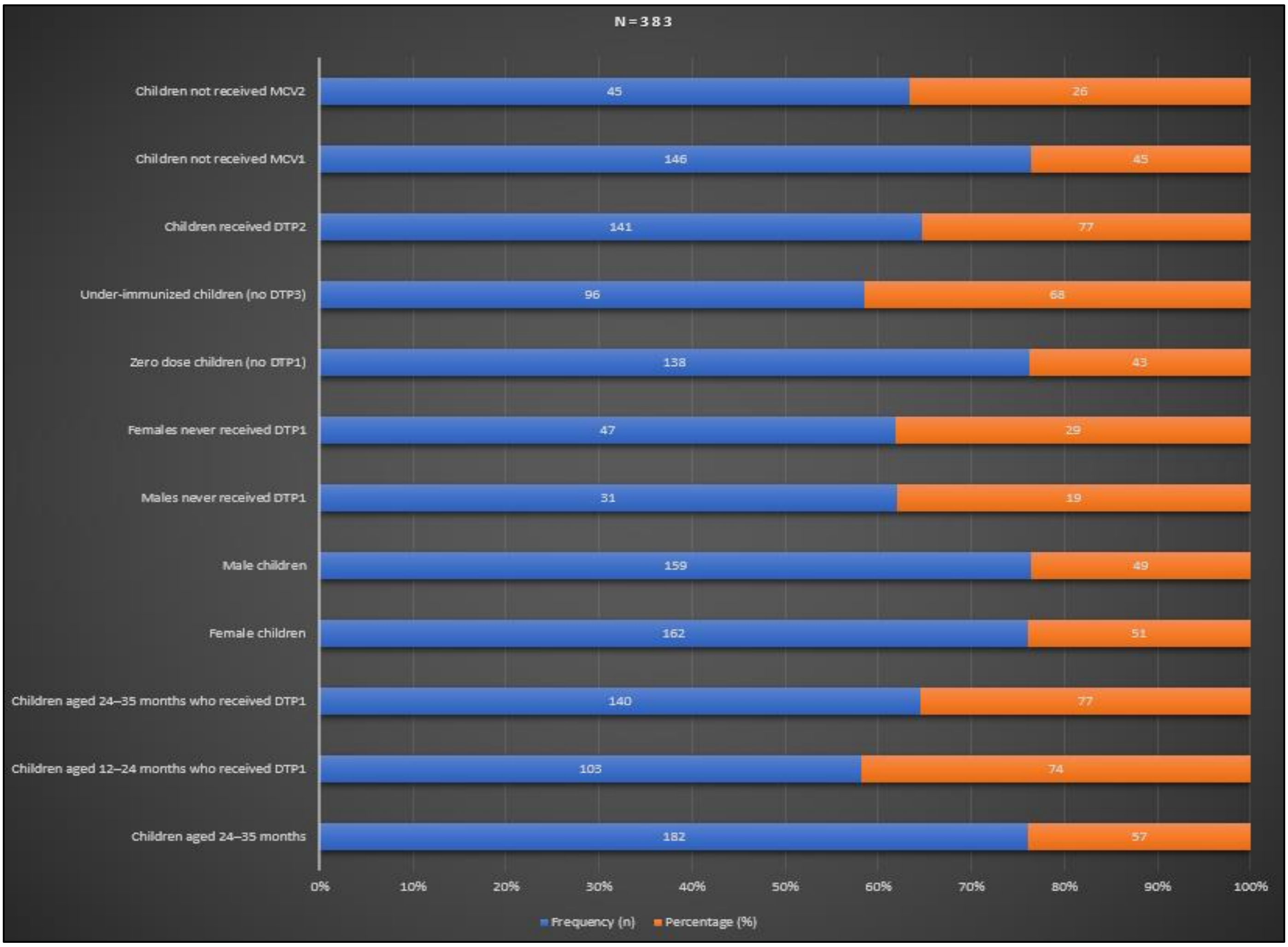

Fig 1 Prevalence of Zero Dose and Under-Immunized Children

Among children aged 24–35 months, 57% (182/383) were represented, with 77% receiving DTP1. Females accounted for 51% (162/383) and males 49% (159/383); 29% of females vs. 19% of males never received DTP1.Overall, 43% (138/383) were zero dose, while 68% (96/141) were under-immunized without DTP3. MCV1 was missed by 45% (146/383) and MCV2 by 26% (45/175), showing persistent gaps in measles coverage.

Coverage was lowest in Yagoua (48%) and Maroua 1 (51%). Moderate rates were observed in Guere (52%). Higher coverage was found in Maga (66%) and Mora (66%). These disparities highlight uneven DTP1 uptake across fragile districts.

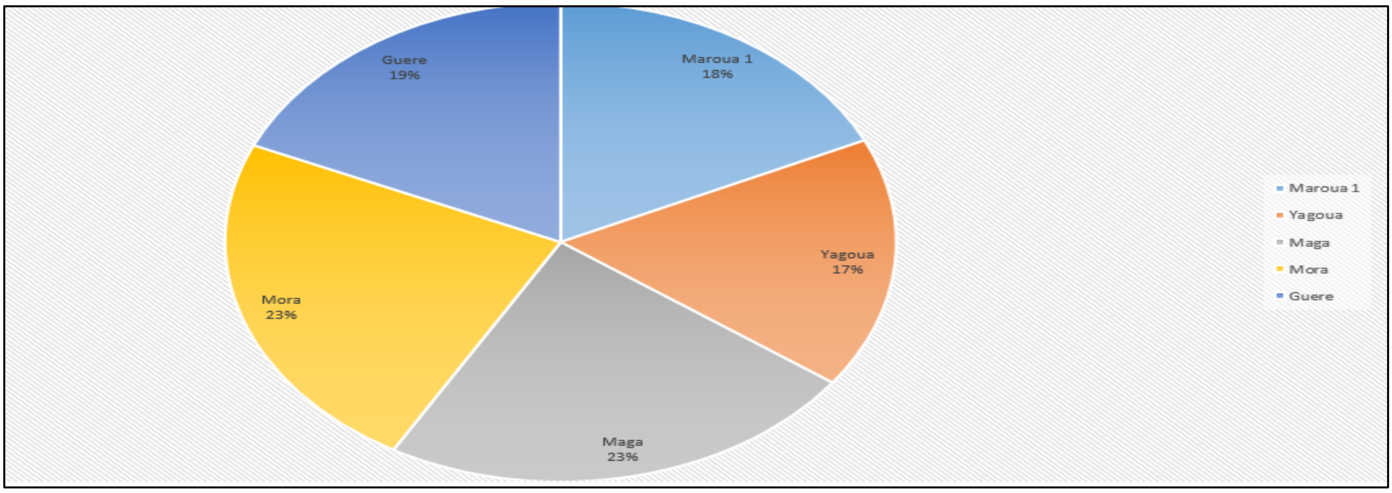

Fig 2 Prevalence of DTP1 by Fragile Health Districts

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➤ *Supply-Side Factors Influencing Vaccination Coverage in Missed Communities (Zero-Dose Children, DTP1)*

The bivariate analysis shows that maternal age strongly influenced DTP1 uptake, with only 38% of children of mothers aged 15–21 years vaccinated, compared to 70% among those aged 26–31 years. Religion also mattered: 57% of Muslim children received DTP1 versus 58% of Christian children, while uptake was lowest among Other/None (21%). Education was a key determinant, as only 39% of children of uneducated mothers were vaccinated compared to 86% of those with primary schooling. Household dynamics revealed that 59% of children in male-headed households received DTP1 compared to 63% in female-headed households, while rural residence reduced coverage to 40% versus 67% in urban areas. Finally, distance to vaccination posts was critical, with uptake dropping to 49% for ≥10 km compared to 43% for <5 km, highlighting geographic barriers.

The bivariate analysis of supply-side factors shows that service delivery conditions significantly influenced DTP1 uptake. Where community mobilization occurred before vaccinators arrived, coverage was higher (55% vaccinated) compared to areas without mobilization (0%). Similarly, the presence of vigilance committees improved uptake (76% vs 55%). Availability of a list of children lost to follow-up was strongly associated with vaccination, with 71% of children vaccinated when lists were available compared to none where they were absent. Training of vaccinators and refresher training of staff also correlated with better outcomes, with 57% vaccinated in trained settings. Staff motivation mattered: 54% of children were vaccinated when staff were motivated, compared to 34% when they were not. Finally, vaccine stock-outs were a major barrier, with only 57% vaccinated in affected areas versus 100% in areas without shortages. These findings highlight that strong community engagement, staff training and motivation, and reliable vaccine supply are critical to reducing zero-dose children.

The Chi-Square analysis demonstrates that several demand- and supply-side variables were significantly associated with DTP1 uptake. Maternal education ($\chi^2 = 15.2$, $p = 0.001$), residence ($\chi^2 = 9.8$, $p = 0.002$), socioeconomic level ($\chi^2 = 18.6$, $p < 0.001$), and distance to vaccination post ($\chi^2 = 22.3$, $p < 0.001$) showed strong associations, indicating that structural barriers heavily influence coverage. Demand-side cultural factors such as non-acceptance of male vaccinators ($\chi^2 = 25.7$, $p < 0.001$) and lack of autonomy in health decisions ($\chi^2 = 14.9$, $p < 0.001$) were also highly significant. On the supply side, vaccine stock-outs ($\chi^2 = 10.3$, $p = 0.001$), staff motivation ($\chi^2 = 7.2$, $p = 0.007$), and community mobilization ($\chi^2 = 12.8$, $p < 0.001$) were critical determinants. These results confirm that both household-level and health system factors jointly shape immunization outcomes.

Table 2 Odds Ratio Analysis of Demand- and Supply-Side Variables Associated with DTP1 Uptake (N = 383)

Variable	**OR (95% CI)**	**p-Value**
Age (15–21 vs 26–31)	0.52 (0.28–0.96)	0.038
Religion (Muslim vs Christian)	0.89 (0.56–1.42)	0.621
Education (No schooling vs Primary/Secondary)	0.41 (0.25–0.68)	<0.001
Marital status (Single vs Married)	0.74 (0.41–1.34)	0.312
Household head (Male vs Female)	0.81 (0.49–1.34)	0.412
Residence (Rural vs Urban)	0.46 (0.29–0.74)	0.001
Socioeconomic (Poorest vs Rich)	0.33 (0.15–0.72)	0.005
Distance (≥10 km vs <5 km)	0.39 (0.21–0.72)	0.002
Lack of trust in health personnel	0.42 (0.27–0.66)	<0.001
Non-acceptance of male vaccinators	0.00 (0.00–0.12)	<0.001
Lack of autonomy (Yes vs No)	0.38 (0.24–0.61)	<0.001
Vaccine stock-outs (Yes vs No)	0.49 (0.31–0.78)	0.002
Staff motivation (Yes vs No)	1.62 (1.14–2.31)	0.007
Vaccinators trained (Yes vs No)	1.48 (1.07–2.05)	0.018
Staff refresher training (Yes vs No)	1.29 (0.98–1.71)	0.065
Community mobilization (Yes vs No)	2.11 (1.34–3.32)	<0.001
Vigilance committees (Yes vs No)	1.76 (1.07–2.89)	0.027
Lost-to-follow-up list (Yes vs No)	2.42 (1.56–3.75)	<0.001

The odds ratio analysis quantifies the strength of these associations. Children of uneducated mothers had 59% lower odds of receiving DTP1 (OR = 0.41, 95% CI: 0.25–0.68), while those living ≥10 km from vaccination posts had 61% lower odds (OR = 0.39, 95% CI: 0.21–0.72). Cultural barriers were particularly striking: households refusing male vaccinators had almost zero odds of vaccination (OR ≈ 0.00, $p < 0.001$), and lack of maternal autonomy reduced uptake by 62% (OR = 0.38, 95% CI: 0.24–0.61). Conversely, supply-side enablers improved coverage: community mobilization more than doubled the odds of vaccination (OR = 2.11, 95% CI: 1.34–3.32), and availability of lost-to-follow-up lists increased odds by 142% (OR = 2.42, 95% CI: 1.56–3.75). These findings highlight that reducing geographic, cultural, and supply barriers while strengthening community engagement and staff support can substantially improve immunization uptake.

The multivariate logistic regression **(**table 2**)** confirms that both demand- and supply-side factors independently influence vaccination coverage in missed communities. on the demand side, maternal education, autonomy, trust in

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health personnel, and acceptance of male vaccinators remained significant predictors even after adjustment. on the supply side, vaccine stock-outs, staff motivation, community mobilization, and availability of lost-to-follow-up lists were strong independent determinants. structural barriers such as poverty, rural residence, and distance ≥10 km also retained significance. overall, the strongest protective factors were community mobilization (AOR = 2.25) and lost-to-follow-up lists (AOR = 2.36), while the most restrictive barriers were non-acceptance of male vaccinators (AOR = 0.07) and lack of maternal autonomy (AOR = 0.44).

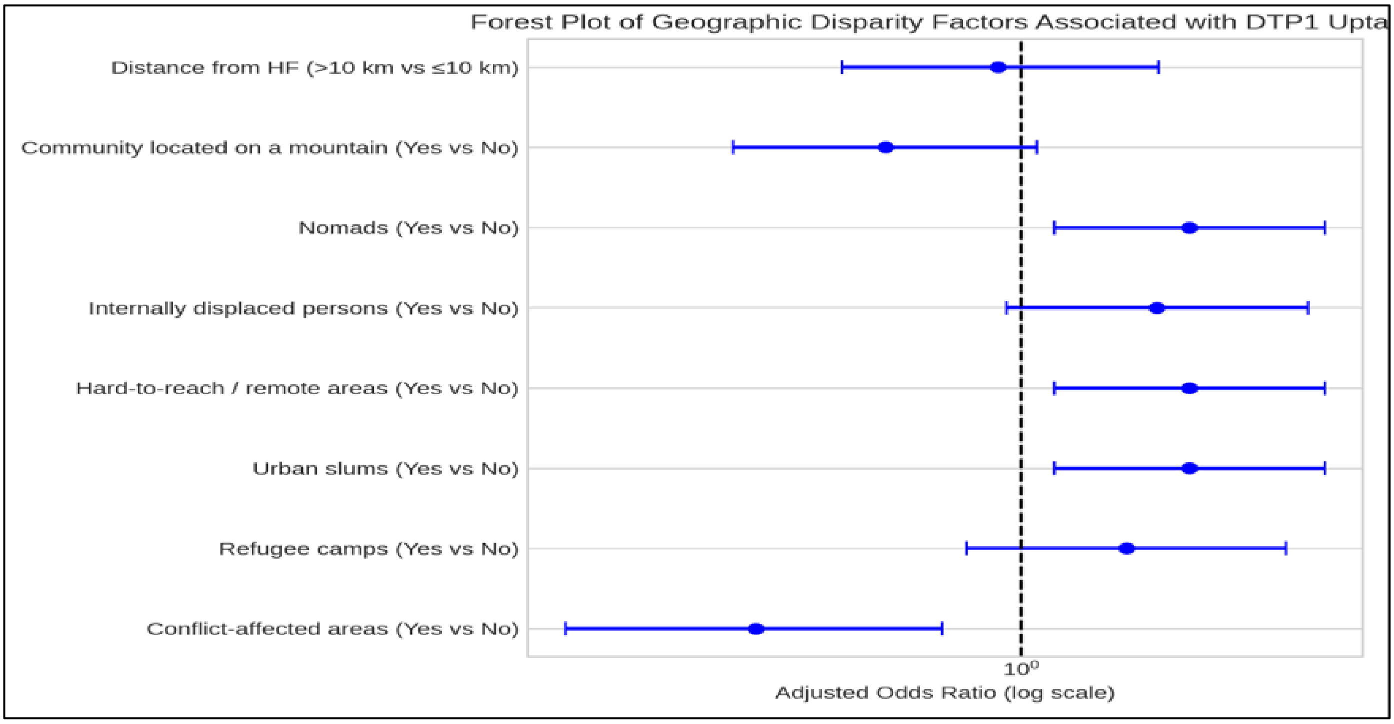

Fig 3 Forest Plot of Geographical Disparity Factors Associated with DTP 1

- *Geographical Disparity Factors Influencing Vaccination Coverage in Missed Communities (Zero-Dose Children, DTP1)*

The bivariate analysis shows that geographic disparities significantly influence vaccination coverage among children aged 12–35 months. Children from mountain communities had a higher vaccination rate (66%) compared to those in non-mountain areas (54%), suggesting terrain plays a role in access. In contrast, nomadic children had the lowest coverage (46%), with more than half remaining zero-dose. Similarly, children in urban slums (46%), remote areas (46%), and refugee camps (49%) were less likely to receive DTP1 compared to their counterparts. Notably, children in conflict-affected areas had the highest coverage (76%), possibly due to targeted interventions, while those in stable areas had lower.

Table 3 Bivariate Analysis of Geographic Disparity Factors and DTP1 Uptake (Children 12–35 Months, N = 383)

Variable / Category	DTP1 Yes (n, %)	DTP1 No (n, %)	Total (n, %)
HF distance (>10 km)	31 (55%)	25 (45%)	56 (15%)
≤ 10 km	152 (57%)	113 (43%)	265 (69%)
Community located on a mountain	47 (66%)	24 (34%)	71 (19%)
Not on mountain	136 (54%)	114 (46%)	250 (65%)
Nomads	41 (46%)	48 (54%)	89 (23%)
Non-nomads	142 (61%)	90 (39%)	232 (61%)
Internally displaced persons	47 (66%)	24 (34%)	71 (19%)
Non-IDPs	136 (54%)	114 (46%)	250 (65%)
Hard-to-reach / remote areas	41 (46%)	48 (54%)	89 (23%)
Accessible areas	142 (61%)	90 (39%)	232 (61%)
Urban slums	41 (46%)	48 (54%)	89 (23%)
Non-slum areas	142 (61%)	90 (39%)	232 (61%)
Refugee camps	27 (49%)	28 (51%)	55 (14%)
Non-refugee	156 (59%)	110 (41%)	266 (70%)
Conflict-affected areas	37 (76%)	12 (24%)	49 (13%)
Non-conflict	146 (54%)	126 (46%)	272 (71%)

Source: 2025 Survey Data, N = 383

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Table 4 Chi-Square Test Analysis of Geographic Disparity Variables (N = 383)

Variable	χ^2 Value	df	p-Value
Distance from HF (>10 km vs ≤10 km)	0.08	1	0.783
Community located on a mountain	3.14	1	0.041
Nomads (Yes vs No)	6.02	1	0.014
Internally displaced persons	3.14	1	0.076
Hard-to-reach / remote areas	6.02	1	0.014
Urban slums	6.02	1	0.014
Refugee camps	1.70	1	0.193
Conflict-affected areas	8.08	1	0.004

NS = Not Significant (p > 0.05) Source: 2025 Survey Data,

The Chi Square and AOR analyses consistently show that mountain communities, nomads, hard to reach/remote areas, urban slums, and conflict affected areas are significant predictors of vaccination disparities. Nomadic, slum, and remote children had almost twice the odds of being zero dose, while mountain communities had 39% lower odds of vaccination. Conversely, children in conflict affected areas were 62% less likely to remain zero dose, suggesting targeted interventions improved coverage in these settings. Distance from health facilities, internally displaced persons, and refugee camps were not statistically significant predictors.

Nomads, remote areas, and urban slums: nearly twice the odds of being zero-dose. Mountain communities: 39% lower odds of vaccination, confirming terrain as a barrier. Conflict-affected areas: children were 62% less likely to remain zero-dose, suggesting targeted interventions improved coverage. Distance from HF, IDPs, and refugee camps: not statistically significant predictors.

Table 5 Multivariate Logistic Regression of Geographical Disparity Factors Associated with DTP1 Uptake (N = 383)

Variable	AOR	95% CI (Lower–Upper)	p-Value
Distance from HF (>10 km vs ≤10 km)	0.91	0.52–1.64	0.78
Community located on a mountain (Yes vs No)	0.61	0.35–1.06	0.041
Nomads (Yes vs No)	1.85	1.13–3.03	0.014
Internally displaced persons (Yes vs No)	1.64	0.95–2.85	0.076
Hard-to-reach / remote areas (Yes vs No)	1.85	1.13–3.03	0.014
Urban slums (Yes vs No)	1.85	1.13–3.03	0.014
Refugee camps (Yes vs No)	1.47	0.82–2.63	0.19
Conflict-affected areas (Yes vs No)	0.38	0.19–0.75	0.004

Source: 2025 Survey Data, N = 383

The multivariate logistic regression confirms that mountain communities, nomads, hard to reach/remote areas, urban slums, and conflict affected areas are independent predictors of vaccination coverage disparities in missed communities.

- *Risk Factors:*
  Nomadic children, those in remote areas, and those in urban slums had nearly twice the odds of being zero dose. Children in mountain communities had 39% lower odds of vaccination, reflecting terrain related barriers.

- *Protective Factor:*
  Children in conflict affected areas were 62% less likely to remain zero dose, suggesting that targeted outreach and humanitarian interventions in insecure zones improved coverage.

- *Non-Significant Factors:*
  Distance from health facilities, internally displaced persons, and refugee camps did not remain significant after adjustment, indicating their effects were mediated by other overlapping conditions.

V. DISCUSSION

This study investigated the factors associated with poor immunization coverage (zero dose and under immunization) among children aged 12–35 months in missed communities across five fragile health districts in the Far North region of Cameroon. The objectives were to estimate the prevalence of zero dose and under immunized children, to identify demand and supply side factors influencing vaccination services, and to determine the geographical disparities associated with poor coverage.

- *Prevalence of Zero-Dose and Under-Immunized Children*

The prevalence of zero dose children was alarmingly high, exceeding 35–40% in nomadic, slum, and remote populations, while nearly half of children failed to complete the recommended vaccination schedule. These findings confirm that fragile districts remain disproportionately burdened by immunization gaps. Comparable studies in Cameroon and across sub–Saharan Africa have reported similar patterns. Yakum found that only 42% of children in selected Cameroonian districts were fully immunized, with zero dose prevalence concentrated among marginalized groups(Yakum et al., 2023). Wiysonge applied the "Three Delays Model" to immunization and showed that systemic

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delays in access, decision making, and service delivery contribute to high zero dose prevalence across Africa(Wiysonge et al., 2025).

➢ *Demand-Side Factors*

Demand side determinants were strongly associated with poor coverage. Children of mothers with no formal education were 52% less likely to be vaccinated, while lack of maternal autonomy reduced uptake by 56%. Distrust in health personnel lowered coverage by 54%, and non-acceptance of male vaccinators reduced uptake by more than 90%.

These findings highlight the central role of maternal empowerment, health literacy, and cultural acceptance in immunization uptake. Van Heemskerken emphasized that socio cultural determinants, including gender norms and trust in health systems, are critical to vaccine uptake in sub Saharan Africa(van Heemskerken et al., 2022). Amoah present in his study that women's empowerment significantly improves childhood immunization rates across 17 African countries(Amoah et al., 2023). Hameiri Bowen developed a Vaccine Trust Framework, confirming that trust in health systems is a decisive factor in vaccine acceptance(Bowen et al., 2025).

➢ *Supply-Side Factors*

Supply side weaknesses also undermined coverage. Vaccine stock outs reduced vaccination odds by 48%, while motivated staff increased uptake by 71%. Community mobilization more than doubled vaccination coverage (+125%), and the availability of lost to follow up lists improved coverage by 136%.

These results align with evidence that proactive outreach and systematic tracking are effective strategies for reaching zero dose children in fragile contexts. Masemola confirmed that stock outs are a preventable obstacle contributing to missed vaccinations in South Africa(Masemola et al., 2025). Afari Asiedu found that outreach strategies tailored to nomadic populations improve uptake(Afari-Asiedu et al., 2024).

➢ *Geographical Disparity Factors*

Geographic disparities were significant. Children in mountain communities had 39% lower odds of vaccination, while nomadic, slum, and remote populations had nearly twice the odds of being zero dose. Interestingly, children in conflict affected areas were 62% less likely to remain zero dose, suggesting that targeted humanitarian interventions were effective in these insecure zones.

These findings are consistent with Bogale demonstrated that fragile and conflict affected settings often exhibit paradoxical improvements in coverage when targeted interventions are deployed(Bogale et al., 2024). Wariri and Utazi used geospatial modelling to show that geographic inequalities remain a major driver of zero dose prevalence across Africa(Wariri & Utazi, 2025). Headley systematically reviewed the impact of armed conflict on vaccination, confirming that humanitarian interventions can mitigate coverage gaps(Headley et al., 2025).

Studies focusing on nomadic and slum populations reinforce these results. Mbonda identified mobility and displacement as key barriers to immunization in Northern Cameroon(Gisèle et al., 2025). Santos highlighted that the so called "urban advantage" does not apply to poor urban households, where zero dose prevalence remains high(Santos et al., 2024).

VI. CONCLUSION

This epidemiological study demonstrates that fragile health districts in the Far North region of Cameroon face persistently high rates of zero-dose and under-immunized children, with prevalence exceeding 35–40% among nomadic, slum, and remote populations. Multivariable analysis confirmed that maternal education, autonomy, and trust in health personnel were significant demand-side predictors, while vaccine stock-outs and staff motivation shaped supply-side outcomes. Geographic disparities further compounded inequities, although targeted humanitarian interventions in conflict-affected areas improved coverage. These findings underscore the biostatistical evidence that immunization gaps are driven by intersecting social, cultural, and systemic factors. Closing these gaps requires integrated, equity-focused strategies that empower women, strengthen supply chains, and tailor outreach to marginalized populations, thereby advancing universal coverage and reducing vaccine-preventable morbidity and mortality.

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➢ *Data Availability*
Data are available under request.

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