

Demographic and Socioeconomic Disparities in Yellow Fever Vaccine Coverage Among Children in Chad: A Multilevel Analysis of a National Survey

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Abstract

Background/Objective: Yellow fever is a vaccine-preventable hemorrhagic disease that causes morbidity and mortality in affected individuals. The burden of yellow fever is disproportionately borne by people in tropical regions worldwide, primarily in sub-Saharan Africa and South America. This study examined the contributions of individual- and contextual socioeconomic factors, as well as demographic and healthcare-use variables, to yellow fever vaccine coverage among children in Chad. **Methods:** We used data from the most recent Chad Demographic and Health Survey (CDHS). Multilevel modelling techniques were applied to data on 8,039 children aged 12–59 months across 626 communities to estimate the odds ratio (OR) for receiving the yellow fever vaccine. **Results:** Children born to mothers who were professionals had 116% higher odds of receiving the yellow fever vaccine compared to those whose mothers were not working (OR = 2.16; 95% CI, 1.04–3.18). In addition, analysis shows that the odds of receiving the yellow fever vaccine were 128% higher (OR = 2.28; 95% CI, 1.80–3.24) among children from the richest households and those born in a healthcare facility (OR = 1.80; 95% CI, 1.40–2.20) than among their counterparts from poorer households and born at home. Children born to mothers with at least secondary education had 11% higher odds of receiving the yellow fever vaccine (OR = 1.11; 95% CI: 0.74–1.42) than those born to illiterate mothers. Children living in a low socioeconomic deprived community had 31% higher odds (OR = 1.31; 95% CI: 1.06 to 2.08) when compared to their peers living in a highly socioeconomic deprived community. **Conclusions:** This study indicates disparities stemming from healthcare service use and socioeconomic differentials at the individual, household, and community levels and their independent contributions to yellow fever vaccine coverage among children in Chad.

Keywords

Inequity, yellow fever, coverage, socioeconomic deprivation, child health

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Introduction

Yellow fever (YF) is an acute viral zoonotic disease primarily transmitted by mosquitoes.¹ YF affects both humans and non-human primates, particularly in the tropical regions of Africa and South America, and continues to pose a significant threat to global public health.^{2,3} According to findings from a recent study, it was estimated that no fewer than 200,000 cases were being reported annually, of which nearly 50,000 result in deaths.⁴ As with most infectious diseases of global health importance, sub-Saharan Africa (SSA) continues to bear the disproportionate burden of this disease, accounting for most cases and around 90% of deaths attributed to YF globally.^{5,6} While the morbidity and mortality associated with the incidence of YF are huge in tropical regions, its devastating impact on the economy and healthcare systems is global.^{7,8} Currently, there is no cure for the disease.

The only preventive measure is vaccination.^{9,10} The YF vaccine has been in use since the 1940s and is effective in protecting individuals against the YF virus.¹¹

The World Health Organisation (WHO) has part of its efforts, planned to eliminate the YF virus in affected countries by 2026.¹² However, Sub-Saharan Africa remains a global hotspot for yellow fever virus transmission.^{8,13} Following the unprecedented outbreak of the virus in Angola in 2016 and, most recently, cross-national outbreaks involving 13 African countries between March 2022 and 2023, around 600 million people, including children, residing in 33 countries across SSA are now at risk of further outbreaks.^{13,14} The ongoing trend of recurrent outbreaks and re-emerging clusters of the yellow fever virus is concerning and poses a significant threat to public health and health security in SSA.^{1,15} Although significant improvements have been made in childhood vaccination coverage worldwide, the proportion of children with incomplete vaccination remains inadequate in SSA.¹⁶⁻¹⁸

Despite having an established childhood vaccination program through the Expanded Programme on Immunization (EPI), Chad, a country of over 13 million people located south of the Sahara Desert, continues to record low immunization rates for certain childhood infectious diseases.¹⁹ Yellow fever is highly endemic in Chad, and the country is considered at risk of enabling the transmission of the yellow fever virus among the entire population.^{1,8,20,21} The recurring epidemic pattern of the YF virus across several regions of the country, especially those bordering countries in the yellow fever belt, necessitated that the government of Chad roll out a nationwide mass vaccination programme for eligible children.^{4,21} Despite the guarantee of universal access and the vaccine's immense benefits, knowledge of YF prevention through immunization appears limited.^{8,11} As of 2021, country-specific estimates of routine childhood immunization coverage in Chad were 67%, which is significantly below the 80% threshold required to confer population immunity against vaccine-preventable childhood diseases.¹⁹ At least 35 countries, including Chad, introduced yellow fever vaccination for individuals aged 9 months or older as part of their routine infant immunization programmes.²²⁻²⁴ Several studies have examined the uptake of the YF vaccine,^{17,25} and it is well established that socioeconomic disparities in vaccine uptake for various childhood infectious diseases exist in some countries in SSA.^{16,17,25,26} However, it is unclear whether the situation is the same for children in Chad regarding YF vaccine uptake, as no research has examined this issue. To reverse the increasing trend in yellow fever transmission and improve preventive measures in Chad, it is essential to examine the determinants of YF vaccine coverage, particularly whether socioeconomic status is associated with children's participation in the YF vaccination program. Thus, the primary objective of this study was to investigate, for the first time in Chad, the coverage level of the yellow fever vaccine and to examine contributions of individual and contextual socioeconomic, demographic, and healthcare-use factors to yellow fever vaccine uptake.

Materials and Methods

Study Design and participants

The population for this cross-sectional study comprised 8,039 children aged 1-5 years and their mothers residing in 626 PSUs across the country. The sample size for this analysis was determined by the availability of data on all variables of interest and by participants meeting the inclusion criteria of being between the ages of 1 and 5 years and having a mother aged 15-35+ years.

Data Collection and Sources

The data used in this study were drawn from the 2015 Chad Demographic and Health Survey (CDHS). The 2015 CDHS was a nationally representative survey that employed a two-stage stratified design. The 2015 CHDS is one of a series of demographic and health surveys usually conducted in several low- and middle-income countries (LMICs) by various in-country population data organizations with financial support from international agencies such as the USAID. In Chad, the National Institute of Statistics, Economic and Demographic Studies conducted the survey and data collection with technical support

from ICF International. The survey sample was selected using a stratified, two-stage cluster design. In the first stage, primary sampling units (PSUs) were selected based on data from the country's population census. In the second stage, systematic sampling was employed to select a fixed number of households from each PSU. Detailed information on the steps used in the CDHS is provided in a previous publication.²⁷

Ethical Approval

This study is based on an analysis of secondary survey data, with all participant identifiers removed. The National Ethics Committee approved the survey of the Ministry of Health, Chard, and the Ethics Committee of ICF Macro, Inc., Calverton, USA. Informed consent was obtained from each participant before they participated in the survey. Specifically, an informed consent statement was read to each respondent, who could accept or decline to participate. Data collection from the survey participants proceeded only after the respondents provided consent and was conducted confidentially. Permission to use the DHS survey data in this study was obtained from ICF Macro, Inc. As permission to utilise the data was granted to the authors by ICF Macro (Data custodian), there is no requirement for the authors to obtain additional approval/permission from their own educational institutions to conduct the research or carry out the analysis.

Statistical Analysis

Outcome Variable

The outcome variable in this study was the receipt of the yellow fever vaccine, as determined by the CDHS question on “YF vaccine” uptake among children. Responses were categorized as “Yes” if a child had been vaccinated against yellow fever and “No” if a child had not been vaccinated at the time of the survey. The interviewers assessed the validity of the responses using the child's immunization card report provided by the primary caregiver.

Explanatory Variables

We included the child's age, gender, maternal age, maternal occupation, maternal level of education, maternal marital status, parity, place of delivery, religion, access to mass media, place of residence, household wealth, and community socioeconomic disadvantage index. Wealth index constructed by the DHS based on durable assets and consumer goods (such as mobile phones, televisions, and radios), flooring type, and other indicators, using a methodology reported elsewhere.²⁸

The community socioeconomic index was calculated using principal component analysis (PCA) of the proportions of respondents who were uneducated, unemployed, and in the lowest household wealth group.²⁹ The standardised score computed via PCA was subsequently used to classify households into low or high categories of community socioeconomic deprivation.³⁰⁻³² The definitions and categorisations of all included variables are presented in [Supplementary Table S1](#).

Statistical Analysis

Model specification

A two-level multilevel logistic regression model was fitted, and the analysis was completed in three steps. Three models were as follows: the first model (null model) has no variables but separates the total variance into its components. Model 1 included individual- and household-level variables, whereas Model 2 included community-level variables, in addition to all the variables included in the first two models.

All model results, including fixed-effects estimates, were reported as odds ratios (ORs) with 95% confidence intervals (CIs). Random-effects estimates, also known as measures of variation, were presented as the inter-cluster correlation coefficient (ICC) and proportional change in variance (PCV) for each successive model [27]. We assessed model fit using the deviance information criterion (DIC).³³ All analyses were conducted using STATA 16.1 (College Station, TX, USA).

The variance partition coefficient (VPC) estimates the odds of a child receiving the YF vaccine, attributable to community-level explanatory variables. The PCV evaluates the proportional difference in community-level variance across the models (Models 0-2).

Results

Sociodemographic characteristics of study participants

A total of 8039 children were included in this study. Of these, approximately 18% were born in healthcare facilities, and 76% were older than 2 years. Approximately 96% of the mothers were Christian, while 3.4% had no religious affiliation (Table 1). Regarding household wealth, nearly 20% of caregivers were from the poorest households, and approximately 90% were married (Table 1).

Individual and community-level factors associated with yellow fever vaccine uptake among children

Table 2 presents the results of all three models. The first model, that is, the null model, included only the outcome variable, and the findings indicated that the odds of a child receiving the YF vaccine varied across the communities. Specifically, the results revealed a statistically significant difference in the odds of YF vaccine uptake across communities ($\tau = 1.60$, $p < 0.001$). In this model, the ICC indicates that 33% of the total variance in yellow fever vaccine uptake was attributable to differences between communities. The second model (Model 1) included all child-, household-, and maternal-level variables. As the null model, it continues to indicate statistically significant variation in the odds of a child receiving the YF vaccine across communities ($\tau = 1.38$, $p < 0.001$). The ICC computed in this model indicates that 29.5% of the variation in the odds of receiving the YF vaccine among children was attributable to differences across communities. However, the PCV revealed that nearly 14% of the observed variance in vaccination across communities was due to individual child characteristics. Specifically, the findings indicate that children whose mothers worked in a highly skilled occupation had 116% higher odds of being vaccinated against YFV. In contrast, for children whose mothers are not employed, the odds of vaccination are only 20% higher than those for children whose mothers are manual workers. Older age (>24 months) was positively associated with YF vaccination. Specifically, children aged 36–47 months and those aged 48 months and above had odds of 14% and 12%, respectively, of receiving the YF Vaccine. The number of live births was not associated with YF vaccination. However, this model showed that children whose mothers did not practice any religion had 8% odds of receiving the YF vaccine and that being born to a Christian mother reduced the odds of being vaccinated with the YF vaccine by 13%. For children whose mothers gave birth in the hospital, the odds of receiving the YF vaccine were 80% higher than those born at home. Household wealth confers a positive advantage to children born to the richest households, as measured by the wealth index. The findings show that children from the richest households had 128% higher odds of receiving the YF vaccine than children from all other households. Although children born to mothers with only primary education had 4% lower odds of receiving the YF vaccine, those born to mothers with at least secondary education had 11% higher odds of receiving the vaccine.

The final model (Model 2) included both individual- and community-level variables. The results show that children whose mothers live in areas with low community socioeconomic deprivation and in rural parts of the country have 31% and 20% higher odds of receiving the YF vaccine, respectively, than those who live elsewhere. Finally, the full model showed that, controlling for all other factors, there was a statistically significant 27% variation in the odds of children receiving the YF vaccine ($\tau = 1.24$, $p\text{-value} < 0.001$), which can be ascribed to individual-, household-, healthcare-, and community-level variables in Model 2.

Discussion

This study investigated the correlates of YF vaccine coverage using nationally representative retrospective data from 8,039 Chadian children and their caregivers. The 2015 CDHS data provided the best opportunity to examine historical caregiver characteristics associated with ensuring that their children received the YF vaccine. The results revealed low YF vaccine coverage, with approximately 43% of the children vaccinated. Maternal education has been widely reported to be positively associated with parents' propensity to ensure their children are immunized against vaccine-preventable childhood infectious diseases in most low- and middle-income countries (LMICs).^{26,34} This analysis revealed that children who received the YF vaccine had mothers with higher levels of education. The evidence is not new and aligns with other research on childhood vaccine uptake.³⁵ Being educated creates the opportunity to assimilate health information; this finding is not surprising, as caregivers usually want to use such information to benefit their own and their children's health.⁷ We observed higher odds of receiving the YF vaccine among children whose mothers are working professionals. This observation aligns with the findings of other population-based studies in Kenya and Colombia examining YF vaccine uptake.^{7,17,36} Being a working professional is associated with higher educational attainment, a better understanding of healthcare utilization, and adequate knowledge of preventive interventions to improve children's health. Therefore, the nature of caregivers' work aligns well with expectations.

Table 1. Sociodemographic Distribution of Children, according to Yellow Fever Vaccine Coverage Status 2015 CDHS

Variables	Vaccination status		Total N (%)
	Yes	No	
	N (%)	N (%)	
Child's gender			
Male	1,733(49.7)	2,264 (49.8)	3,997 (49.7)
Female	1,757 (50.3)	2,285(50.2)	4,042 (50.3)
Child's age (months)			
12–24	784(22.5)	1,164 (25.5)	1,948 (24.2)
25–35	823 (23.6)	1,043(22.4)	1,866 (23.2)
36–47	950(27.2)	1,162 (25.5)	2,112 (26.3)
48+	1,180(26.7)	933(26.6)	2,113(26.3)
Religion			
Islam	8(0.2)	14(0.3)	22(0.3)
Christianity	3,328(95.7)	4,413 (97.3)	7,741(96.3)
Others	179 (4.1)	97(2.4)	276(3.4)
Maternal age (years)			
15–24	912(26.1)	1,247(27.4)	2,159(26.9)
25–34	1,785(51.2)	2,222(48.9)	4,007(49.8)
35+	793(22.7)	1,080 (23.7)	1,873 (23.3)
Maternal educational level			
No education	27(0.7)	8(0.1)	35(0.4)
Primary	2,211(63.5)	3,810(83.7)	6,021 (74.9)
Secondary and higher	1,252(35.8)	731 (16.2)	1,983(24.7)
Place of delivery			
Home	2,502(72.0)	4,129 (91.2)	6,631(82.5)
Hospital	1,011 (28.)	397(8.8)	1,408 (17.5)
Media access			
None	2,375 (68.1)	3,709(81.5)	6,084(75.7)
1	568(16.3)	480(10.5)	1,048(13.)
2	143(4.1)	152(3.3)	295 (3.6)
3	404(11.6)	208(4.6)	612(7.6)
Maternal occupation			
Not working	1,626(46.3)	2,716(59.9)	4,342 (54.1)
Manual	1,756(50.0)	1,735(38.4)	3,491(43.4)
Professional	128(3.7)	78(1.7)	206(2.5)
Marital status			
Unmarried	29(0.8)	12(0.3)	41(0.5)
Married	3,259(93.4)	4,327(95.1)	7,586(94.3)
Ever married	202(5.8)	210(4.6)	412(5.2)
Household Wealth			
Poorest	604(17.3)	933(20.5)	1,537 (19.1)
Poorer	628(17.9)	979(21.5)	1,607(19.9)
Middle	659(18.8)	1,034(22.7)	1,693(21.2)
Richer	790(22.6)	1,093(24.1)	1,883(23.4)
Richest	809(23.4)	510(11.2)	1,319(16.4)
Parity			
1-3	1,232(35.3)	1,616(35.5)	2,848(35.4)
4+	2,258(64.7)	2,933(64.5)	5,191(64.6)
Place of residence			
Urban	928(26.6)	671(14.8)	1,599(19.9)
Rural	2,562(73.4)	3,878(85.2)	6,440(80.1)
Community socio-economic Deprivation			
High	1,269(36.7)	2,351 (51.7)	3,620(45.3)
Low	2,221 (63.6)	2,198 (48.3)	4,419 (54.7)

Table 2. Mixed and fixed effect models of Variables Associated with Yellow Fever Vaccine Coverage Among children based on the 2015 CDHS

Variables	Model 0 OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Individual Characteristics			
Child's gender		1(reference)	1(reference)
Male		0.85 [0.67-0.96]	0.86 [0.70-0.91]
Female			
Child's age (months)			
12-24		1(reference)	1(reference)
25-35		1.09 [0.87-1.56] **	1.08 [0.90-1.48] **
36-47		1.14 [1.07-1.51] ***	1.12 [1.10-1.63] ***
48+		1.12 [1.09-1.60] **	1.11[1.10-1.70] **
Maternal age(years)			
35+		1(reference)	1(reference)
25-34		0.94[0.88-1.10] *	0.92[0.90-1.20] *
15-24		0.99 [0.86-1.12] *	0.98[0.90- 1.16] *
Maternal Occupation			
Not working		1(reference)	1(reference)
Manual		1.20 [1.04-1.40] **	1.15[1.06-1.30] **
Professional		2.16 [1.04-3.18] ***	2.06[1.02-2.20] ***
Parity			
1-3		1(reference)	1(reference)
4+		0.84 [0.77-0.90]	0.81[0.69-0.89]
Maternal education			
No education		1(reference)	1(reference)
Primary		0.96 [0.84-1.22] **	0.95[0.78-1.21] **
Secondary and Higher		1.11 [0.74-1.42] ***	1.10[0.72-1.62] ***
Place of delivery			
Home		1(reference)	1(reference)
Healthcare facility		1.80 [1.40-2.20] ***	1.50 [1.32-2.32] ***
Household wealth index			
Poorest		1(reference) 0.97[0.82-1.02]	1(reference) 0.96 [0.91-1.10]
Poorer		1.12 [1.04-1.34]	1.10[1.20-1.28]
Middle		1.15 [1.03-1.24] **	1.12[1.04-1.20] **
Richer		2.28 [1.80-3.24] ***	2.19[1.26-3.13] ***
Richest		1(reference) 0.97[0.82-1.02]	1(reference) 0.96 [0.91-1.10]
Access to Mass Media			
None		1(reference)	1(reference)
1		0.97 [0.96-1.08] 1.11 [0.84-1.20]	0.93[0.88-1.00]
2		1.24 [1.15-1.40] ***	1.08[0.72-1.10]
3			1.21 [1.10-1.38] ***
Marital status			
Unmarried		1(reference)	1(reference)
Married		0.74 [0.70-1.10] *	0.79 [0.72-1.21] *
Ever married		0.91 [0.81-1.17]	0.90 [0.83-1.12]
Religion			
Islam		1(reference)	1(reference)
Christianity		0.87 [0.66-0.89] **	0.84 [0.70-0.94] **
Others,		1.08 [0.87-1.19] **	1.01[0.96-1.16] **
Fixed effects model (Community level Characteristics)			
Community-level variables			
Place of residence			
Urban			1
Rural			1.20 [1.08-1.60] ***
Community Socio-Economic Deprivation			
High deprivation			1
Low deprivation			1.31[1.06-2.08] ***

(continued)

Table 2. (continued)

Variables	Model 0	Model 1	Model 2
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Random effects			
Intercept	0.19 [0.18–0.20] ***	0.42 [0.31–0.50] ***	0.48[0.39–0.51] ***
Community-level variance (SE)	1.60[0.05] ***	1.38[0.03] ***	1.24 [0.03] ***
VPC (%)	33	29.5	27.0
Explained variation PCV (%)	Reference	13.7	19.9
Model fit statistics			
DIC (-2log likelihood)	3651.40	3012.20	2601.10

Abbreviations: deviance information criterion(DIC). * $p < 0.05$ ** $p < 0.001$; *** $p < 0.000$.

Evidence consistently shows that the level of economic development in a place of residence affects healthcare utilization, particularly preventive care.³⁷ This study shows that children residing in communities with a low level of economic deprivation have 31% higher odds of being vaccinated against the YF virus. Less deprived communities usually have access to healthcare centers and sometimes benefit from rollouts of life-saving preventive interventions; therefore, it is not surprising that children living in such areas were able to be vaccinated compared with those residing in poorer communities. Economic ability, especially caregivers' household wealth, has been documented as a significant factor in childhood immunisation uptake.^{26,38} This analysis is no exception. The analysis revealed that children from well-off families had 2.28 times higher odds of receiving the YF vaccine than their peers from poorer backgrounds. This finding aligns with evidence from a study conducted in Brazil.³⁹ A likely reason is that richer households can devote time to their children's health by taking time off work to attend immunization centers.²⁶ The utilization of healthcare facilities for prenatal care by pregnant women has been shown to have a greater influence on women's propensity to use preventive child healthcare services after giving birth.^{37,40} The findings of this study confirm this inference. Specifically, children born in a healthcare facility had higher odds of receiving the YF vaccine than those born at home. These findings echoed those from another country with similar demographics, where vaccination uptake was higher among children whose mothers gave birth in healthcare facilities.^{7,25} The mother's age at birth has been well documented to influence the uptake of life-saving preventive interventions, including vaccine uptake.⁴¹ This study demonstrates that, relative to children whose mothers were aged 35 and above, those whose mothers were aged 25–34 had a 6% odds of receiving the YF vaccine. This finding is consistent with a previous study.¹⁷ This may be attributable to the fact that older mothers, due to their age, are more likely to be involved in childcare and more knowledgeable about the importance of adequate vaccination coverage for their children.

Policy Implications

Enhancing vaccination coverage and reducing inequalities require expanding access to quality, affordable, and acceptable preventive health services for all. YF infection requires a targeted vaccination campaign to reduce inequities in the health impacts of its burden across the population. Policymakers and relevant stakeholders should collaborate to expand the effective reach of vaccination programs to avert a resurgence of yellow fever outbreaks in Chad.

Study strengths & limitations

Although there are many strengths to this analysis, a few shortcomings mean that the findings must be interpreted with caution. *First, the authors utilized data from an existing survey, which may be prone to sampling errors in selecting the study sample.* Second, the authors did not conduct a power analysis for sample size calculation but instead relied on the full availability of maternal and child sociodemographic, health, and household characteristics of interest, as is usual in secondary data analyses of existing surveys. Third, the analysis used the 2015 CDHS data, which is the most recent; however, the temporal gap between data collection and the publication of this analysis's findings could affect the current applicability of its findings. Despite this, the findings of this study remain valuable.

Fourth, our use of PCA to estimate household wealth may be subject to criticism. However, this method is not new; it has been the most widely used measure for estimating household wealth in LMICs.²⁸ All these limitations notwithstanding, the study's strengths lie in its cross-national design, large sample size, and appropriate statistical techniques.

Conclusions

Findings from this analysis clearly affirm the importance of maternal reproductive healthcare use variables, such as institutional delivery, and the influencing roles of individual-, household-, and community-level variables. Socioeconomic attributes are the major drivers of YF vaccine uptake among children in Chad. The findings from this study have several implications for future research on the uptake of the yellow fever vaccine and other vaccines aimed at preventing infectious disease outbreaks. First, any future research that seeks to understand the drivers of childhood vaccine uptake, particularly yellow fever, should identify those who are disadvantaged in accessing vaccination services and how to better prioritise them. Furthermore, any future intervention aimed at improving the yellow fever vaccine must consider the individual, household, and community-level characteristics of children and their caregivers in Chad. Doing so would enable optimal uptake of yellow fever vaccines and other vaccines to protect children against childhood infectious diseases. In summary, continued efforts are needed to improve access to vaccination services and uptake in Chad and other LMICs.

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Consent to Participate

Data collection for the original survey received full ethical clearance. All participants in the original ICF Macro survey gave their consent to participate. Each participant, that's the caregiver of the children whose data were included, gave their consent. Informed consent statements were read aloud to each caregiver, after which participants were allowed to indicate whether they wished to participate in the survey. All interviews were conducted confidentially, with only the interviewer and respondent present.

Author Contributions

“Conceptualisation, O.A. and methodology, O.A.; software, O.A.; validation, O.A., O.C. D.; K.D formal analysis, O.A.; investigation, O.A.; O.C.D, K.D resources, O.A, O.C.D; K.D data curation, O.A.; writing—original draft preparation, O.A., O.C.D., O.C.D.K.D; writing—review and editing, O.A, O.C.D., K.D; project administration, O.A.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability Statement

The datasets supporting the conclusions are available from the corresponding author upon reasonable request. The original raw data were obtained from the following link: <https://dhsprogram.com/data/available-datasets.cfm> (accessed on 1st October 2025).

Institutional Review Board Statement

Existing population-based survey data, where all personal information was encoded, were analysed. The CDHS review committee approved the study. The study was based on the analysis of anonymised secondary data available in the public domain of CDHS; therefore, no additional approval was necessary. All participants provided informed consent before participating in the interview. Chad. Respondents gave their informed consent, and all information was collected confidentially. Relevant guidelines and regulations were followed in all methods, and data were sourced from the following link: <https://dhsprogram.com/data/available-datasets.cfm> (accessed on 1st October 2025).

Supplemental Material

Supplemental material for this article is available online.

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Appendix

List of Abbreviations

CDHS	Chad Demographic and Health Survey
CI	Confidence Intervals
DIC	Deviance information criterion
EPI	Expanded Programme on Immunization
ICC	Inter-cluster correlation coefficient
ICF	Inner City Fund
LMICs	Low- and middle-income countries
OR	Odd Ratios
PSUs	Primary sampling units
PCA	Principal component analysis
PCV	Proportional change in variance
USAID	United States Agency for International Development
USA	United States of America
YF	Yellow Fever
VPC	Variance partition coefficient.