JOURNAL OF ENVIRONMENTAL SCIENCES AND BUILT ENVIRONMENT RESEARCH (JESBER)
2026, Vol. 1, No. 2, pp. 346–354
Published by Faculty of Environmental Sciences, University of Calabar, Nigeria
Print ISSN: 3141-5547 | OPEN ACCESS

Research article

STATE-LEVEL SPATIAL PATTERN OF CAREGIVER-REPORTED ACUTE RESPIRATORY INFECTION SYMPTOMS AMONG CHILDREN UNDER FIVE IN NIGERIA: EVIDENCE FROM THE 2021 MICS

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ABSTRACT

Acute respiratory infections (ARIs) remain a leading cause of under-five mortality in Nigeria, yet interventions often overlook localized spatial dynamics and healthcare barriers. This study examines geographic variations, socioeconomic risk factors, and healthcare-seeking behaviors associated with caregiver-reported childhood ARIs symptoms in Nigeria. Utilizing cross-sectional data from the 2021 Multiple Indicator Cluster Survey, caregiver-reported ARI symptoms spatial distribution was analyzed using Moran's I techniques. An Ordinary Least Squares (OLS) regression model assessed the impact of structural vulnerabilities on state-level caregiver-reported ARI prevalence, while descriptive statistics evaluated healthcare utilization. A stark North-South divide was identified (Global Moran's I = 0.377, $p < .001$), with critical hotspots clustered in Katsina, Zamfara, and Yobe. The OLS regression explained 36.6% of state-level variance ($F(2, 34) = 11.41$, $p < .001$), isolating poverty ($\beta = 0.025$, $p = .034$) and household crowding ($\beta = 1.667$, $p = .032$) as key predictors whose inclusion absorbed all spatial autocorrelation. Formal healthcare utilization was critically low (39.4%). Care-seeking failure reached 36.3% among urban caregivers compared to 22.1% in rural areas due to indirect costs. Private providers and pharmacies outpaced public facilities (39.1% vs. 34.7%), while high wealth and maternal education significantly reduced non-seeking behavior. The northern ARI burden is driven by concentrated socioeconomic and infrastructural deprivation rather than geography alone. Low care-seeking rates reveal severe financial barriers and heavy reliance on informal private networks. Interventions must prioritize targeted funding for northern hotspots, enforce ventilation building codes, subsidize clean-cooking stoves, and integrate private vendors into formal health networks.

KEYWORDS

Caregiver-reported ARI symptoms; Spatial autocorrelation; Healthcare utilization; State-level poverty; Household crowding; Under-five mortality; Nigeria.; Nigeria

Introduction

Acute respiratory infections (ARI) affect the upper and lower respiratory tracts and represent an important correlate of childhood illness in population surveys. In household surveys such as the Multiple Indicator Cluster Survey (MICS), "symptoms of ARI" are not a clinical diagnosis. The indicator is based on a mother's or caregiver's report that a child had cough with fast or difficult breathing attributable to a chest problem during the preceding two weeks (NBS & UNICEF, 2022). This distinction is essential because caregiver-reported symptoms are subject to recall and classification error. Pneumonia, a severe form of lower respiratory infection, is documented as a leading infectious cause of death among children under five in global burden estimates. Established correlates of childhood respiratory illness in cross-sectional and ecological evidence include prematurity, low birth weight, inadequate breastfeeding, malnutrition, incomplete immunisation, overcrowding, household air pollution, and delayed access to appropriate care (Agbor et al., 2026; Rudan et al., 2008; Savitha et al., 2007; World Health Organization, 2022). These factors vary geographically and may co-occur with spatial inequalities in reported symptoms and care-seeking.

Previous cross-sectional analyses in Nigeria and other low- and middle-income settings have reported associations between reported ARI symptoms and child age and sex, maternal education, household wealth, residence, immunisation, nutritional status, and environmental conditions (Adesanya et al., 2017; Adesanya et al., 2017; Orimadegun & Myers, 2019; Tesema et al., 2022; Eneyo, 2025). Care-seeking is also associated with socioeconomic position, distance, transport, perceived severity, and the availability and cost of health services (Chilot et al., 2022; Ketema et al., 2024; Titaley et al., 2020; Eneyo, 2026a). Spatial studies have reported non-random geographic variation in childhood ARI symptoms. In Nigeria, Osayomi et al. (2020) identified northern hotspots using earlier survey data, while Gayawan et al. (2022) described geographic patterns in the comorbidity of diarrhoea, ARI symptoms, and stunting. Oluwaseun et al. (2025) reports significant geographical disparities in childhood ARIs across Nigeria, identifying poor sanitation as the primary correlate. Comparable clustering has been reported in Ethiopia (Amsalu et al., 2019; Tesfaye et al., 2023). These studies support the value of spatial description, but the validity of hotspot and correlate findings depends on the survey design, spatial weights, local significance testing, and the scale of analysis.

The 2021 Nigeria MICS provides more recent state-level estimates. The survey report, however, cautions that the reported two-week symptom percentages are not measures of clinically confirmed disease and should not be used uncritically to infer epidemiological characteristics (NBS & UNICEF, 2022). Accordingly, state values should be interpreted as short-period caregiver-reported symptom estimates, with attention to unequal precision, rounding, and the ecological nature of the data. This cross-sectional ecological study aimed to describe the state-level distribution of reported ARI symptoms among children aged 0–59 months, assess global and local spatial autocorrelation, and explore whether selected state-level characteristics were associated with the reported symptom estimates

Methods

Study area

Nigeria comprises 36 states and the Federal Capital Territory (FCT) and is commonly grouped into six geopolitical zones. The country has marked climatic, environmental, socioeconomic, and health-system diversity (Addie & Seun-Addie, 2025) In the 2021 MICS, state estimates were designed for all states and the FCT; however, the Borno sample covered only seven accessible local government areas because of insecurity (NBS & UNICEF, 2022).

Data collection

This ecological, cross-sectional study used the state- and FCT-level percentages reported in Table TC.2.1 of the 2021 Nigeria MICS. The outcome was the percentage of children aged 0–59 months whose mother or caregiver reported cough with fast or difficult breathing attributed to a chest problem during the two weeks preceding the survey. The outcome is therefore a two-week caregiver-reported symptom estimate at the areal level, not clinically confirmed infection, incidence, or individual-level risk. National subgroup care-seeking percentages were drawn from Table TC.5.1 and are conditional on the child having reported symptoms (NBS & UNICEF, 2022). The independent variables were state-level poverty (Table SR.2.3) and household crowding (Table SR.2.1). State-level poverty was operationalized as the cumulative percentage of households within each state falling into the bottom two wealth quintiles (Poorest and Second) of the MICS Wealth Index, capturing the bottom 40% of the household asset distribution. Household crowding was defined as the state-level mean number of persons per room used regularly for sleeping (MPSR). This indicator serves as an index of domestic physical density, capturing the micro-environmental proximity that facilitates aerosol and droplet-borne transmission of childhood respiratory pathogens, independently of asset-based poverty metrics.

2021 Nigeria MICS sample design

The 2021 Nigeria MICS used a multistage, stratified cluster design based on the 2006 census enumeration-area frame. States and the FCT were the principal sampling strata. Enumeration areas were selected with probability proportional to size, households were listed, and 20 households were systematically selected per sampled enumeration area. The main MICS targeted 1,850 clusters and 37,000 households. A supplemental immunisation sample was added for the NICS, producing a combined sampled total of 41,532 households; the ARI symptom and care-of-illness indicators derive from the main MICS under-five questionnaire (NBS & UNICEF, 2022). The analytic ecological sample comprised 37 areal units (36 states and the FCT). At the child level, Table TC.2.1 was based on 26,640 children aged 0–59 months, while the national care-seeking table included 530 children with reported ARI symptoms. State estimates were survey-weighted and rounded to one decimal place in the published report. The poverty and the MPSR were based on the published tables of the 2021 Nigeria MICS report.

Data analysis

State estimates were joined to a Nigeria administrative boundary file (eHealth Africa & GRID3, 2024; WGS 84 (EPSG:4326)) and mapped using tmap version 3.3-2 (Tennekes, 2018). Global Moran's I was used to assess overall spatial autocorrelation, and Local Moran's I was used to classify significant High–High, Low–Low, High–Low, and Low–High locations (Anselin, 1995; Eneyo, 2026b), with the aid of spdep version 1.1-8 (Bivand & Wong, 2018) and rgdal (Bivand, 2023). The neighbour definition was Rook contiguity; two polygons are considered neighbors only if they share a common linear boundary, but polygons that meet only at a single point (a corner or vertex) are not counted as neighbors. The spatial-weight style was row-standardized, with the sum of all weights in any single row equal exactly 1. This ensures that regions with many neighbors do not artificially distort global spatial autocorrelation statistics compared to isolated regions. The result was inspected for islands in the dataset, with 999 permutation counts and a random seed of 1234. Benjamini–Hochberg false discovery rate adjustment was applied. To prevent overfitting given the areal sample size (n = 37), a parsimonious, theory-driven, two-variable ordinary least squares (OLS) framework was specified, pairing state-level poverty with an environmental proxy: Mean Persons per Sleeping Room (MPSR). A formal collinearity diagnostic was performed between the two independent variables, followed by a Variance Inflation Factor (VIF) test. All analyses were done at $\alpha < 0.05$.

Results

State-level reported two-week ARI-symptom estimates ranged from 0.0% (rounded) to 6.5%. Katsina had the highest estimate (6.5%), followed by Zamfara (5.5%) and Yobe (5.4%). Seven states—Delta, Kogi, Lagos, Ogun, Ondo, Osun, and Rivers—had published estimates rounded to 0.0%; this does not mean that no ARI-symptom cases occurred in those states. The national estimate was 2.0% (NBS & UNICEF, 2022). Among the 530 children with reported ARI symptoms in the national MICS care-seeking table, advice or treatment was reported from a public source for 34.7%, a private source for 39.1%, a community health provider for 2.4%, and another source for 6.8%; 25.5% had no advice or treatment sought. Source categories can overlap, so the separate percentages should not be summed. The combined percentage for whom advice or treatment was sought from a health facility or provider was 39.4% (NBS & UNICEF, 2022).

Descriptively, no care was reported for 36.3% of symptomatic urban children compared with 22.1% of symptomatic rural children. The corresponding percentages were 28.0% for females and 23.3% for males. Care-seeking patterns varied across age, maternal education, and wealth groups.

Table 1: Reported sources of advice or treatment among children aged 0–59 months with reported ARI symptoms, Nigeria MICS 2021

Characteristics	Variable	P_HF	Pr_HF	CH_P	O_S	NA/TS
Sex	Male	34.7	41.1	4.1	8.2	23.3
	Female	34.7	36.8	0.6	5.2	28.0
Area	Urban	33.4	29.8	0.8	5.2	36.3
	Rural	35.1	42.0	3.0	7.3	22.1
Age (in months)	0-11	35.7	39.8	0.0	4.5	25.9
	12-23	34.9	36.3	4.0	6.8	26.6
	24-35	36.5	43.3	4.8	5.3	20.9
	36-47	27.8	31.4	0.8	8.9	35.0
	48-59	37.9	43.9	2.7	9.2	19.9
Mother’s education	None	31.6	42.1	1.9	8.2	24.8
	Primary	36.7	30.5	4.2	5.4	34.0
	Junior secondary	34.6	14.8	0.0	12.7	37.9
	Senior secondary	39.0	49.6	2.5	3.0	17.0
	Higher/tertiary	46.9	44.7	4.5	0.0	8.7
Wealth index quintile	Poorest	33.8	33.8	2.7	8.4	31.2
	Second	31.8	46.2	3.5	8.6	20.3
	Middle	33.1	37.2	2.5	5.7	29.4
	Fourth	44.2	39.4	0.0	0.0	17.5
	Richest	44.3	36.3	0.0	6.0	20.7

Note: P_HF = public health facility/provider; Pr_HF = private health facility/provider; CH_P = community health provider; O_S = other source; NA/TS = no advice or treatment sought. Percentages are conditional on reported ARI symptoms and source categories may overlap. Several subgroup estimates are based on small unweighted counts; see the source table for caution markers.
Source: NBS & UNICEF (2022), Table TC.5.1.

Figure 1A shows higher reported symptom estimates in parts of northern Nigeria than in most southern states. Katsina (6.5%), Zamfara (5.5%), Yobe (5.4%), Borno (seven accessible LGAs; 4.6%), and Kano (4.3%) were among the highest published estimates. Cross River (3.8%) was a notable southern exception.

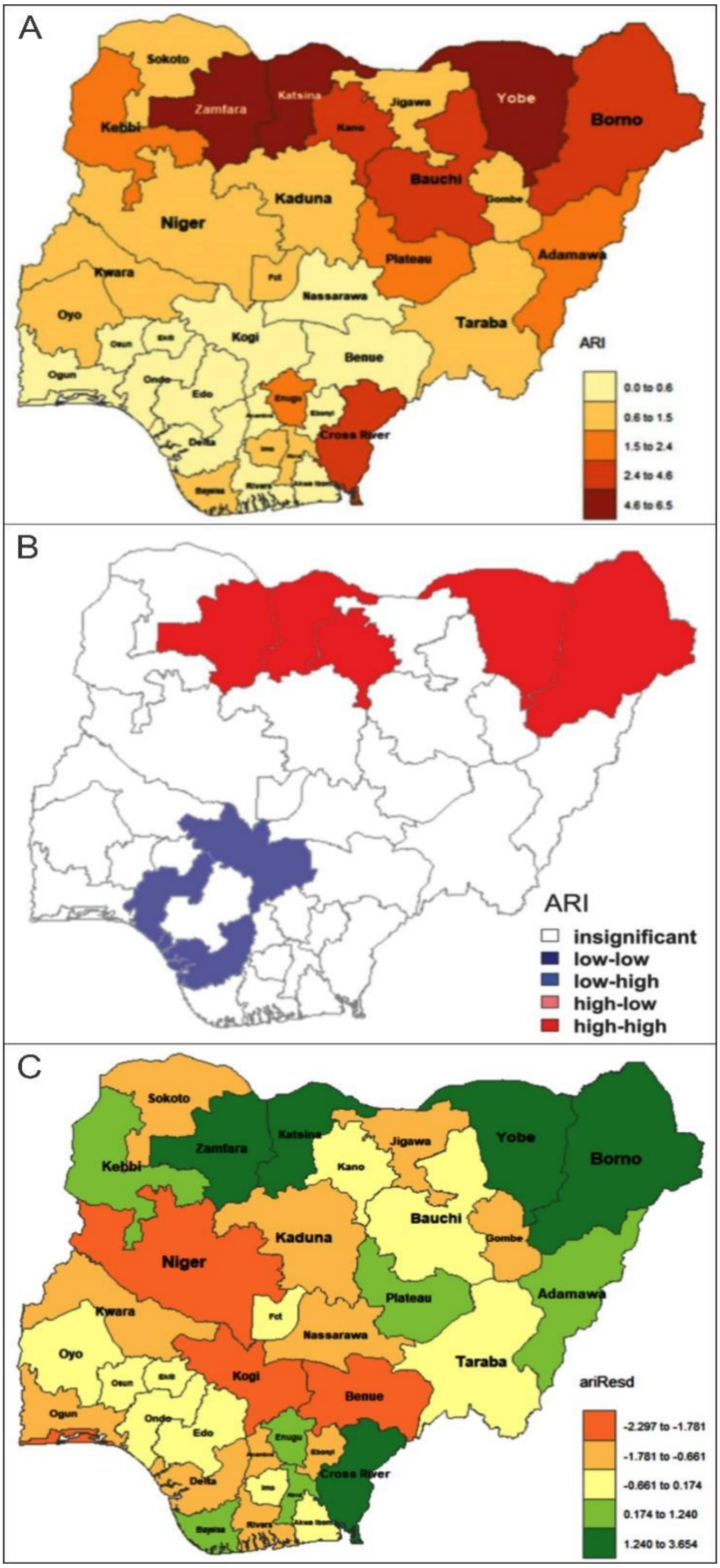

***Figure 1:** (A) State-level distribution of caregiver-reported ARI symptoms among children aged 0–59 months; (B) Local Moran cluster classification; and (C) residuals from the unvalidated exploratory model.*

Source: Authors' analysis of NBS & UNICEF (2022), Table TC.2.1.

Table 2: Global Moran's I test for spatial autocorrelation in ARI-symptom estimates and OLS residuals

Variable	Moran I statistic	Expectation	Variance	z-score	p-value
ARI-symptom	0.37722582	-0.02777778	0.01096723	3.8673	5.502e-05
OLS residuals	-0.10110463	-0.02657982	0.01099715	-0.71066	0.7614

Source: Author-supplied analysis.

Global Moran's I was 0.377 (expected I = −0.0278; z = 3.867; p = 5.502e-05), indicating positive spatial autocorrelation under the row-standardized weights (Table 2). The Local Moran map classified Borno, Yobe, Kano, Katsina, and Zamfara as High–High locations and Kogi, Delta, and Ondo as Low–Low locations. However, utilizing a False Discovery Rate (FDR) multiple-comparisons correction, the result of the Benjamini-Hochberg test (Table 3) showed that Borno might be a false hotspot.

Table 3: Result of Benjamini-Hochberg false discovery rate adjustment

State	Moran's I	Expectation	Variance	std z-score	Unadjusted p	Adjusted p
Kano	1.44310	-0.02777778	0.2129017	3.187764	0.0007	0.0133
Katsina	2.61077	-0.02777778	0.2129017	5.718415	< 0.0001	< 0.0001
Yobe	1.24441	-0.02777778	0.2129017	2.757171	0.0029	0.0304
Zamfara	1.07785	-0.02777778	0.1654663	2.718042	0.0033	0.0304

At $\alpha < 0.05$, the Ordinary Least Squares (OLS) linear regression of ARI-symptom estimates on state-level poverty and mean persons per sleeping room (MPSR) yielded a statistically significant overall model that explained 36.6% of the variance in ARI symptom estimates after adjustment, $F(2, 34) = 11.41$, $p < .001$, adjusted $R^2 = .366$.

As shown in Table 4, state-level poverty was a statistically significant positive predictor of ARI ($\beta = 0.025$, $t(34) = 2.214$, $p = .034$), indicating that higher levels of state-level poverty are associated with increased ARI symptom prevalence. Similarly, MPSR was a significant predictor ($\beta = 1.667$, $t(34) = 2.23$, $p = .032$).

Diagnostic testing of the OLS residuals (Table 2) revealed no significant spatial autocorrelation (Moran's I = −0.101, p = .7614), indicating that the OLS model did not violate the assumption of independent errors. Therefore, no spatial regression framework is required to obtain unbiased estimates.

Table 4: Result of OLS regression

	OLS regression					
	Estimate	**Std. Error**	**t value**	**p-value**	**R^2**	**Adj R^2**
(Intercept)	-3.741	1.732	-2.160	0.038	0.402	0.366
poverty	0.025	0.011	2.214	0.034		
MPSR	1.667	0.746	2.234	0.032		

Source: Author-supplied analysis.

Discussion

This cross-sectional ecological analysis describes geographic variations, socioeconomic correlates, and healthcare-seeking patterns associated with caregiver-reported childhood acute respiratory infection (ARI) symptoms in Nigeria.

Healthcare utilization for caregiver-reported childhood ARI symptoms is low and unevenly distributed. Nationally, 39.4% of symptomatic children received care from an official health facility or provider, and 25.5% received no treatment or advice. These figures align with a multi-country evaluation by Adeoti et al. (2022), which reported that appropriate, timely care-seeking for childhood respiratory infections is uncommon across Nigeria's socio-demographic strata, with approximately 25% to 35% of caregivers not seeking medical consultation.

Non–care-seeking was more common among urban caregivers (36.3% sought no care) than among rural caregivers (22.1%). While standard sub-Saharan African models associate urban residency with reduced respiratory risks due to proximity to clinics, decomposition analyses by Tesema et al. (2022) describe a divergence in actual behavior. Urban poverty margins are associated with severe indirect costs, prolonged clinic wait times, and fragmented options that deter formal visits, contributing to a distinct urban–rural care gap.

Among those who sought care, private health providers (39.1%) were used more frequently than public health facilities (34.7%). This pattern matches behavioral trends documented by Adeoti et al. (2022), who found that caregivers often bypass public infrastructure in favor of private patent medicine vendors (PMVs) and local pharmacies due to flexible drug pricing, geographic proximity, and perceived immediate availability of treatments.

Healthcare utilization increased with structural advantages: households in the highest wealth quintile and mothers with tertiary education reported the lowest non–seeking rates (8.7%). Behavioral regressions mapping child health in Nigeria indicate that wealthier households face fewer liquidity constraints during medical emergencies, which is associated with a higher likelihood of formal care utilization (Adeoti et al., 2022).

A pronounced north–south gradient in caregiver-reported ARI symptoms among children under five was observed, with higher prevalence across northern states such as Katsina, Zamfara, and Yobe. This macro-regional pattern is accompanied by a statistically significant Global Moran's I of 0.377 ($p < .001$), indicating positive spatial autocorrelation. Local Moran cluster analysis identifies specific "High–High" zones concentrated in the extreme north. This spatial configuration is consistent with contemporary epidemiological descriptions of childhood respiratory illness in Nigeria (Oluwaseun et al., 2025).

A national cross-sectional study by Oluwaseun et al. (2025) reported a similar north–south differentiation in under-five respiratory symptoms, with hotspots clustered within northwestern and northeastern states. In descriptive terms, northern states are characterized by prolonged dry seasons, sandstorms, and high dust loads associated with the Saharan Harmattan wind, conditions that have been documented in relation to respiratory tract vulnerability. Large-scale modeling of Nigerian children by Bakare et al. (2023) indicates that geographical location co-occurs with environmental exposures, and that northern states show concurrent infrastructure deficits that align with intense spatial clustering.

After applying the Benjamini–Hochberg False Discovery Rate (FDR) adjustment to the MICS dataset, Borno State's hotspot classification appears potentially attributable to statistical artifact rather than a distinct epidemiological cluster. This observation underscores a methodological consideration for spatial analyses: without correction for multiple localized comparisons, public health interventions may be misdirected, particularly in conflict-affected zones where survey data are structurally constrained.

The Ordinary Least Squares (OLS) regression shows that state-level structural and socioeconomic indicators are associated with regional caregiver-reported ARI prevalence, accounting for 36.6% of the variance in state-level ARI symptoms ($F(2, 34) = 11.41$, $p < .001$, adjusted $R^2 = .366$). State-level poverty ($\beta = 0.025$, $p = .034$) and household crowding, measured as Mean Persons per Sleeping Room (MPSR) ($\beta = 1.667$, $p = .032$), were statistically significant positive correlates. Diagnostic testing of the OLS residuals showed no spatial autocorrelation (Moran's $I = -0.101$, $p = .761$), indicating that poverty and MPSR account for the spatial patterns evident in the raw data, such that a more complex spatial regression framework is not required for unbiased estimation in this specification.

These patterns are consistent with a social determinants of health perspective in the Nigerian context. Cross-sectional literature indicates that overcrowded living conditions and low economic status are among the strongest independent correlates of childhood ARIs (Oluwaseun et al., 2025; Islam et al., 2024). A study evaluating pediatric respiratory risk profiles in Nigeria reported that high-density household environments are associated with increased potential for aerosol transmission of pathogens among young children (Osayomi et al., 2020). This structural vulnerability commonly co-occurs with other conditions: low household wealth scores are frequently associated with sub-optimal ventilation, poor sanitation, and greater reliance on biomass fuels for cooking inside main living quarters (Oluwaseun et al., 2025; Sani et al., 2024). The OLS model's capacity to capture spatial variance using only poverty and crowding suggests that the "northern problem" is, in descriptive terms, a reflection of concentrated infrastructural and economic deprivation.

Conclusion

This study describes a marked north–south geographic differentiation in under-five acute respiratory infections (ARIs) across Nigeria. Significant spatial clustering (Global Moran's $I = 0.377$, $p < .001$) identifies extreme northern hotspots in Katsina, Zamfara, and Yobe; however, the Ordinary Least Squares (OLS) model indicates that this pattern is aligned with infrastructural and socioeconomic conditions, as state-level poverty and household crowding account for 36.6% of the variance. Formal healthcare utilization remains low (<40%), with low-income families facing substantial out-of-pocket costs and indirect clinic barriers, leading caregivers to predominantly use private vendors and pharmacies rather than public facilities. In light of these patterns, geographically targeted resource allocation that prioritizes high-risk northern states may be considered. State-level policies could include enforcement of localized building codes mandating proper household ventilation and subsidies for clean-cooking stoves to address the co-occurrence of indoor smoke and high-density sleeping quarters. Public health boards could formally integrate private patent medicine vendors (PMVs) into the pediatric care network through standardized ARI diagnostic training and clear referral protocols. Finally, expansion of fully subsidized National Health

Insurance Authority (NHIA) premiums to the lowest wealth quintiles may reduce financial barriers that currently deter impoverished families from seeking timely medical care.

Strengths and limitations

A strength of the study is the use of a nationally implemented survey and a transparent state-level spatial perspective. Important limitations include the ecological unit of analysis; inability to infer individual-level associations; caregiver-reported rather than clinically confirmed symptoms; potential recall and classification error; a short two-week reporting window; rounded state estimates; unequal and unreported state precision; incomplete coverage of Borno; possible multiple-testing error in Local Moran analysis; uncertainty about the source and derivation of candidate predictors; compositional covariates; severe overfitting with 37 areas and 34 predictors; invalid numeric coding of geopolitical zone; and untested residual spatial dependence.

Ethical Statement

This study presents a cross-sectional analysis of secondary data and published estimates from the 2021 Nigeria Multiple Indicator Cluster Survey (MICS) report. The MICS protocol received approval from the survey Steering Committee and a Review Committee constituted from the Technical Committee in August 2021. Verbal informed consent was obtained from respondents, participation was voluntary, and confidentiality and anonymity were assured (NBS & UNICEF, 2022). The authors' institutions did not require additional ethical approval.

Data Availability Statement

The 2021 Nigeria MICS report is publicly available from the National Bureau of Statistics and UNICEF. The relevant published tables for the study are reported in the methods section.

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