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Determinants and regional disparities of caretaker-reported acute respiratory infection symptoms among children under five in Ghana: a multilevel analysis of the 2022 Demographic and Health Survey

Richmond Balinia Adda

richmondadda@gmail.com

University of Technology and Applied Sciences

Research Article

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Abstract

Background

Caretaker-reported acute respiratory infection (ARI) symptoms remain a leading cause of under-five morbidity and mortality in sub-Saharan Africa. Understanding individual- and household-level factors associated with ARI is essential for designing targeted interventions in Ghana.

Methods

We analysed data from the 2022 Ghana Demographic and Health Survey using survey-weighted multilevel logistic regression to identify factors associated with caretaker-reported ARI symptoms among children under five years. Multiple imputation by chained equations (20 imputed datasets) was the primary analytic approach, addressing missing data under a missing-at-random assumption. Complete-case analysis was conducted as a sensitivity analysis.

Results

Among 9,024 children with outcome data, the weighted caretaker-reported ARI symptom prevalence was 15.1% (95% CI: 14.3–15.9%). The null-model cluster variance was $\tau^2_0 = 0.52$ (ICC = 0.147); covariates reduced τ^2 to 0.31 (PCV = 40.4%). Urban residence was independently protective (aOR = 0.69, 95% CI: 0.53–0.88; observational population impact fraction [oPIF] = 8.9%). In the analysis restricted to children aged 12–23 months (the age group for which the DHS full vaccination indicator is valid), full vaccination was not associated with caretaker-reported ARI symptoms (aOR = 1.17, 95% CI: 0.84–1.62). Northern Region (aOR = 2.71), Savannah Region (aOR = 2.14), and Bono East Region (aOR = 1.94) showed the highest regional risk relative to Greater Accra.

Conclusion

Urban residence was associated with lower odds of caretaker-reported. ARI symptoms in Ghana. No evidence supports a harmful vaccination. The Savannah Belt (Northern, Savannah, North East regions) warrants prioritised intervention. Children in Northern, Savannah, and North East Regions had substantially higher odds of caretaker-reported ARI symptoms compared with Greater Accra, warranting prioritised geographically targeted investigation and programme evaluation in these settings.

Introduction

Acute respiratory infections (ARIs), particularly pneumonia, are a leading cause of death among children under five years worldwide, accounting for approximately 800,000 annual deaths [1, 2]. In population-based survey research, the standard DHS indicator, caretaker-reported cough with short, rapid breathing,

captures pneumonia-like illness rather than upper respiratory infections, and is used in this study as a proxy measure consistent with established DHS methodology [6, 20]; we therefore use the term 'caretaker-reported ARI symptoms' throughout to reflect this operationalisationSub-Saharan Africa bears the highest burden, with pneumonia contributing to 17% of under-five mortality in West and Central Africa [3, 4]. In Ghana, pneumonia remains a critical public health challenge, with an estimated prevalence of 22% and significant variation across the country's 16 administrative regions: Greater Accra, Western, Central, Volta, Eastern, Ashanti, Western North, Ahafo, Bono, Bono East, Oti, Northern, Savannah, North East, Upper East, and Upper West [5, 6].

Numerous studies have identified risk factors for childhood ARI, including young age, low socioeconomic status, poor maternal education, indoor air pollution from solid fuel use, and inadequate vaccination [7–9]. However, most previous analyses in Ghana have used traditional logistic regression that does not account for the hierarchical structure of survey data (children nested within clusters) [6, 10]. Failure to account for clustering tends to underestimate standard errors and may lead to spuriously narrow confidence intervals and inflated type I error rates [11]. Multilevel modelling allows simultaneous examination of individual- and cluster-level factors while correctly estimating variance components [12].

Using the 2022 Ghana Demographic and Health Survey (GDHS), the most recent available, we conducted a multilevel logistic regression analysis to identify determinants of caretaker-reported ARI symptoms among children under five years. We incorporated missing data handling via multiple imputation as the primary analytic approach, formal tests of non-linearity and wealth gradients, oPIF estimation, and region-specific estimates for all 16 Ghanaian regions. Findings are intended to provide quantitative, geographically specific evidence to inform priorities for future research and policy deliberation.

Methods

Conceptual framework

Confounder selection was guided by a directed acyclic graph (DAG) constructed in DAGitty v3.0 (**Supplementary Figure S1**). Wealth index was treated as an upstream common cause of residence, maternal education, cooking fuel type, and health insurance, consistent with established socioeconomic pathways to child health. Urban residence was positioned as a partial mediator of the wealth–ARI relationship; accordingly, the model estimates the direct association of each factor with ARI conditional on the others. Health insurance was retained as a direct covariate on a priori grounds, as it is a theoretically important proximal determinant of care-seeking independent of its marginal contribution to model fit.

Data source and study population

We used data from the 2022 GDHS, a nationally representative cross-sectional survey using two-stage stratified cluster sampling across all 16 Ghanaian administrative regions. The children recode file (KR)

contains data on all children under five years residing in sampled households. The analytical sample for descriptive statistics comprised 9,024 children with non-missing outcome data. Missing data were addressed by multiple imputation as the primary analytic approach (see Statistical analysis). For replication, users of the 2022 GDHS KR file should verify that the age variable b8 is correctly recoded and cross-tabulate against hv007 (interview year) as a quality check.

Outcome variable

The outcome was caretaker-reported ARI symptoms, defined as a caretaker report of the child having had a cough accompanied by short, rapid breathing in the two weeks preceding the survey (yes/no). This indicator follows the standard DHS definition and is commonly used as a proxy for pneumonia in population-based research [6, 20]. We use the term "caretaker-reported ARI symptoms" throughout to reflect parental report rather than clinical diagnosis.

Age distribution

The GDHS 2022 KR file yielded 9,353 records for children aged 0–59 months. After correction of a data-extraction coding error present in an earlier draft (incorrect filtering on b19 rather than b8), the age distribution is balanced: 21.2% aged 0–11 months, 21.8% aged 12–23 months, 18.9% aged 24–35 months, 19.6% aged 36–47 months, and 18.5% aged 48–59 months. This is consistent with nationally reported distributions in the 2022 GDHS final report [6] and with expected under-five age structures given Ghana's age-specific mortality rates.

Predictor variables

Based on the DAG and data availability, the following individual- and household-level predictors were selected:

1. Child's age (months, continuous; non-linearity tested via restricted cubic splines with three knots at the 10th, 50th, and 90th percentiles).
2. Sex of child (male/female).
3. Perceived birth weight — maternal report of child's size at birth; "small" or "very small" classified as low perceived birth weight (reference: "average" or "larger"). This is a subjective proxy, not a clinically measured birth weight.

4. Full vaccination status — BCG, three doses each of DPT and polio, and a measles-containing vaccine, based on card or maternal recall. Per standard DHS methodology, the full vaccination indicator is only valid for children aged 12–23 months; including it across all age groups introduces systematic misclassification. Therefore, vaccination analysis was restricted to children aged 12–23 months and is presented in a dedicated subsection of the Results.
5. Wealth index quintile (poorest, poorer, middle, richer, richest) derived by DHS using principal component analysis of household assets.
6. Maternal education (none, primary, secondary, higher).
7. Health insurance coverage (yes/no).
8. Place of residence (urban/rural).
9. Type of cooking fuel (clean: electricity, LPG, natural gas, biogas; solid: kerosene, coal, charcoal, wood, crop residue, dung) [9, 19].
10. Region — all 16 Ghanaian administrative regions included as fixed effects (reference: Greater Accra).
11. Household crowding was considered during model development but was excluded because complete and internally consistent household occupancy measures could not be derived from the available child-level analytical dataset.

Statistical analysis

All analyses incorporated complex survey design using DHS sampling weights (v005/1,000,000). Descriptive statistics (weighted frequencies, percentages, and overall ARI prevalence with 95% CI) were computed overall and stratified by ARI status (Table 1). Bivariate associations were assessed using design-based F-tests.

Sampling weights were rescaled following DHS recommendations for multilevel analyses to preserve relative weighting while avoiding inflation of effective sample size. Random-intercept models accounted for clustering at the primary sampling unit level. Weight scaling followed the method proposed by Rabe-Hesketh & Skrondal (2006) and Carle (2009). The melogit command in Stata 17 incorporates random effects at the cluster level while the svy prefix applies first-stage sampling weights, following recommendations for two-level models with DHS data [25, 26].

Multiple imputation as primary analysis: Because Little's MCAR test was rejected for perceived birth weight ($p = 0.041$) and full vaccination status ($p = 0.012$), data are not consistent with MCAR; MAR is assumed as a working assumption to justify multiple imputation, though this assumption cannot be verified and the possibility of MNAR for perceived birth weight, where missingness may depend on delivery location, an unmeasured factor, cannot be excluded.. Multiple imputation by chained equations (MICE) is therefore the preferred analytic approach over complete-case analysis, which would yield biased estimates under MAR. We generated 20 imputed datasets with 20 iterations each, pooling estimates using Rubin's rules. The imputation model included all predictors and the outcome variable. The analytical sample for imputation-based analyses comprised all 9,024 children with non-missing outcome data. Complete-case analysis ($n = 5,448$) was conducted as Sensitivity Analysis 3.

A two-level random-intercept logistic regression model was fitted with children at level 1 and clusters at level 2. A null model estimated the ICC and τ^2_0. A stepwise model-building approach (Table 2) sequentially added child factors, socioeconomic factors, contextual factors, and health-system factors, reporting AIC and BIC at each step. The PCV $(\tau^2_0 - \tau^2) / \tau^2_0 \times 100$ quantified cluster-level variance explained. Non-linearity of age was tested using restricted cubic splines. A Mantel-Haenszel linear trend test was applied across wealth quintiles. Observational population impact fractions (oPIFs) were computed using the punaf command as purely descriptive summaries of the association between exposure prevalence and observed ARI burden under the current data distribution. They do not represent causal estimates, do not quantify the expected impact of any intervention, and assume no unmeasured confounding, an assumption that cannot be verified in a cross-sectional design. Given that urban-rural residence is not a directly modifiable exposure, the oPIF for urban residence is reported as a descriptive contextualisation of the magnitude of the urban-rural differential rather than as a policy-actionable quantity; full oPIF output is provided in **Supplementary Table S3**. Urban-rural stratified models assessed effect modification. All 16 regions were included as fixed effects in the main model.

Health insurance retention justification: Health insurance was retained in the full model (Model 5) on a priori grounds specified in the DAG, as it is a theoretically important proximal determinant of care-seeking and symptom detection independent of its marginal contribution to model fit; the borderline likelihood ratio test for Model 4 ($\chi^2 = 5.4$, $p = 0.067$) likely reflects inadequate power arising from the low prevalence of uninsured children (5.6%) rather than the absence of a meaningful association.

Analyses were conducted in Stata version 17.0.

Sensitivity analyses

Four pre-specified sensitivity analyses were conducted: (1) restriction to children aged 12–23 months for the vaccination analysis (presented as the primary vaccination estimate in a dedicated subsection); (2) multiple imputation models (the primary analytic approach); and (3) complete-case analysis to assess the impact of missing data; and (4) urban-rural stratified models to assess heterogeneity by residence.

Results

Study population

Of 9,353 initial KR records, 329 had missing outcome data, leaving 9,024 for descriptive analysis and for the primary multiple imputation analysis. A further 3,576 were excluded due to missing predictor data, giving 5,448 for the complete-case sensitivity analysis (Fig. 1, STROBE flowchart). The weighted caretaker-reported ARI symptom prevalence was 15.1% (95% CI: 14.3–15.9%). Table 1 presents the full background characteristics stratified by ARI status. Readers will note that the crude prevalence of caretaker-reported ARI symptoms appears higher among fully vaccinated children (19.4%) than among those not fully vaccinated (14.1%); this counterintuitive pattern reflects age-related misclassification of

the DHS full vaccination indicator when applied across all age groups, as older children are both more likely to be vaccinated and to have had more time to accumulate caretaker-reported illness episodes. This artefact is addressed in the vaccination analysis, which is restricted to children aged 12–23 months — the only age group for which the DHS vaccination indicator is valid — and is discussed further in the Limitations. Little's MCAR test was rejected for perceived birth weight ($p = 0.041$) and full vaccination status ($p = 0.012$), indicating MAR and justifying multiple imputation as the primary analytic approach (Table S1).

Table 1
Weighted background characteristics and bivariate associations stratified by caretaker-reported ARI symptom status, Ghana DHS 2022

Characteristic	ARI n = 1,361 (%)	No ARI n = 7,663 (%)	Total n = 9,024 (%)	p-value
Age group (months)				**< 0.001**
0–11	10.4	89.6	21.2	
12–23	17.9	82.1	21.8	
24–35	17.0	83.0	18.9	
36–47	16.3	83.7	19.6	
48–59	14.1	85.9	18.5	
Sex				**0.510**
Male	15.3	84.7	51.0	
Female	14.9	85.1	49.0	
Wealth index				**< 0.001**
Poorest	20.7	79.3	23.7	
Poorer	15.8	84.2	20.4	
Middle	14.4	85.6	19.5	
Richer	13.3	86.7	19.0	
Richest	9.9	90.1	17.4	
Maternal education				**< 0.001**
No education	19.2	80.8	23.2	
Primary	17.2	82.8	15.2	
Secondary	13.8	86.2	52.2	
Higher	9.7	90.3	9.4	
Place of residence				**< 0.001**
Rural	18.0	82.0	51.4	
Urban	12.2	87.8	48.6	

Characteristic	ARI n = 1,361 (%)	No ARI n = 7,663 (%)	Total n = 9,024 (%)	p-value
Age group (months)				**< 0.001**
Cooking fuel				**< 0.001**
Solid fuel	16.8	83.2	79.4	
Clean fuel	9.7	90.3	20.6	
Perceived birth weight				**0.142**
Normal/large	14.3	85.7	55.2	
Small/very small	16.0	84.0	44.8	
Health insurance				**0.038**
No insurance	17.9	82.1	5.6	
Has insurance	14.9	85.1	94.4	
Full vaccination (12–23 mo)				**0.003**
Not fully vaccinated	14.1	85.9	57.7	
Fully vaccinated	19.4	80.6	42.3	

Design-based F-test (Rao-Scott adjusted chi-square). Row percentages in ARI/No ARI columns; column percentages in Total column. Percentages are weighted. n = 9,024 for descriptive analysis.

Null model and model-building

The null model showed significant clustering: $\tau^2_0 = 0.52$ (95% CI: 0.31–0.87; ICC = 0.147), indicating 14.7% of ARI variation is attributable to between-cluster differences. Figure 2 presents the distribution of cluster-level random effects from the full model. Inclusion of all covariates reduced cluster variance to $\tau^2 = 0.31$ (PCV = 40.4%), indicating that the included covariates explain approximately 40% of cluster-level variance. The stepwise AIC/BIC sequence (Table 2) supported the full model as the best fit.

Table 2
Stepwise model-building sequence with fit statistics

Model	Log-likelihood	AIC	BIC	LR χ^2	p
Model 0: Null (empty)	−3,814.2	7,630.4	7,640.2	—	—
Model 1: + Child factors	−3,762.1	7,534.2	7,570.1	104.2	< 0.001
Model 2: + Socioeconomic factors	−3,741.8	7,503.6	7,568.0	40.6	< 0.001
Model 3: + Contextual factors	−3,729.4	7,480.8	7,553.8	24.8	< 0.001
Model 4: + Health system factors	−3,726.7	7,477.4	7,558.1	5.4	0.067*
Model 5: Full model (all + regions)	−3,712.3	7,460.6	7,622.4	28.8	< 0.001

AIC = Akaike information criterion; BIC = Bayesian information criterion; LR χ^2 = likelihood-ratio chi-square vs. prior model.

Model 4 retained on a priori causal grounds despite borderline LR test; see Methods.

Adjusted multilevel model

Child-level factors: A restricted cubic spline test found no significant departure from linearity in the age–ARI relationship (p = 0.217); the continuous linear age term was therefore retained in all models as the appropriate and parsimonious specification. Each additional month of age was associated with a 3% increase in the odds of caretaker-reported ARI symptoms (aOR = 1.03, 95% CI: 1.02–1.04). Sex and perceived low birth weight were not significantly associated after adjustment.

Socioeconomic factors

The crude prevalence of caretaker-reported ARI symptoms declined progressively across wealth quintiles, from 20.7% in the poorest to 9.9% in the richest. However, this gradient was substantially attenuated in the fully adjusted model, with no individual quintile achieving statistical significance and the Mantel-Haenszel linear trend test borderline (p = 0.087). Point estimates were non-monotone across quintiles after adjustment. These findings suggest that the crude wealth-ARI association is largely explained by the mediating pathways of residence, cooking fuel type, and maternal education included in the model, consistent with the hypothesis that the crude wealth-ARI association may be partially explained by the measured factors of residence, cooking fuel, and maternal education, though the cross-sectional design precludes formal causal mediation analysis. Maternal education showed no significant independent association.

Contextual factors: Urban residence was significantly protective (aOR = 0.69; 95% CI: 0.53–0.88; p = 0.003; oPIF = 8.9%). For descriptive contextualisation of the urban-rural differential, the oPIF for urban residence was 8.9% (full output in **Supplementary Table S3**); this figure quantifies the observed ARI prevalence difference attributable to the current urban-rural distribution under the observed data and

carries no causal or interventional interpretation. Clean cooking fuel was associated with lower odds (aOR = 0.81) but was not statistically significant (p = 0.349).

Health system factors: Health insurance showed borderline protective association (aOR = 0.67; 95% CI: 0.44–1.01; p = 0.054). Cross-tabulation of the data confirms that uninsured children (5.6% of the sample) are disproportionately concentrated in the poorest and poorer wealth quintiles (62% of uninsured vs. 44% of insured) and have lower maternal education (38% with no education vs. 22% of insured), supporting the interpretation that the uninsured represent the most disadvantaged households.

Vaccination analysis (restricted to children aged 12–23 months): Per standard DHS methodology, the full vaccination indicator is only valid for children aged 12–23 months. Therefore, the vaccination analysis was restricted to this age group (n = 1,911) and is presented as the primary vaccination estimate. The analysis found no significant association between full vaccination and caretaker-reported ARI symptoms (aOR = 1.17; 95% CI: 0.84–1.62; p = 0.360). (The full-sample analysis including all ages produced a spurious aOR of 1.49 [95% CI: 1.19–1.87] due to age-related misclassification; this estimate is mentioned only in Limitations as an illustration of the misclassification problem.)

Regional heterogeneity across all 16 administrative regions: Marked disparities were observed across Ghana's 16 regions (Table 3; Fig. 3). Relative to Greater Accra, the highest adjusted risk was in Northern Region (aOR = 2.71; 95% CI: 1.62–4.52; p < 0.001), followed by Savannah Region (aOR = 2.14; 95% CI: 1.19–3.83; p = 0.011), North East Region (aOR = 1.88; 95% CI: 1.01–3.49; p = 0.046), Bono East Region (aOR = 1.94; 95% CI: 1.03–3.65; p = 0.039), and Volta Region (aOR = 1.76; 95% CI: 1.05–2.97; p = 0.033). Ahafo Region had substantially lower risk (aOR = 0.35; 95% CI: 0.16–0.73; p = 0.006), though this estimate does not survive Bonferroni correction for 16 simultaneous regional comparisons (adjusted alpha = 0.003) and should be interpreted with caution. Western, Central, Eastern, Ashanti, Western North, Bono, Oti, Upper East, and Upper West regions did not differ significantly from Greater Accra after full adjustment.

The full multilevel model results from the primary multiple imputation analysis are shown in Table 3. A comparison of the primary imputation estimates with the complete-case sensitivity analysis is provided in Table 4. The two sets of estimates were broadly consistent, with no meaningful differences in direction, magnitude, or statistical significance (Table 4).

Table 3
Full multilevel logistic regression model (multiple imputation primary analysis) — all 16 regions, Ghana DHS 2022 (n = 9,024 for outcome; predictors imputed)

Predictor	aOR	95% CI	p-value	oPIF (%)
Child factors				
Age (months, continuous)	1.03	1.02–1.04	< 0.001	—
Female sex (ref: male)	1.12	0.91–1.37	0.274	—
Perceived low birth weight (ref: normal)	1.09	0.88–1.36	0.428	—
Socioeconomic factors				
Wealth index (ref: poorest)				
Poorer	0.80	0.62–1.04	0.091	—
Middle	0.82	0.57–1.19	0.295	—
Richer	1.04	0.68–1.58	0.855	—
Richest	0.92	0.51–1.68	0.795	—
Linear trend test (Mantel-Haenszel)	—	—	0.087	—
Maternal education (ref: none)				
Primary	1.30	0.95–1.78	0.106	—
Secondary	1.06	0.76–1.49	0.723	—
Higher	0.94	0.51–1.75	0.851	—
Contextual factors				
Urban residence (ref: rural)	0.69	0.53–0.88	0.003	8.9
Clean cooking fuel (ref: solid fuel)	0.81	0.52–1.26	0.349	—
Health system factor				
Health insurance (ref: none)	0.67	0.44–1.01	0.054	—
Regional effects (ref: Greater Accra)				
Western Region	0.98	0.61–1.57	0.921	—
Central Region	1.18	0.73–1.91	0.504	—
Greater Accra (reference)	1.00	—	—	—
Volta Region	1.76	1.05–2.97	0.033	—
Eastern Region	1.04	0.64–1.70	0.876	—

Predictor	aOR	95% CI	p-value	oPIF (%)
Ashanti Region	1.12	0.71–1.77	0.625	—
Western North Region	0.88	0.51–1.53	0.654	—
Ahafo Region	0.35	0.16–0.73	0.006	—
Bono Region	1.21	0.72–2.03	0.471	—
Bono East Region	1.94	1.03–3.65	0.039	—
Oti Region	1.43	0.85–2.41	0.178	—
Northern Region	2.71	1.62–4.52	< 0.001	—
Savannah Region	2.14	1.19–3.83	0.011	—
North East Region	1.88	1.01–3.49	0.046	—
Upper East Region	1.62	0.92–2.86	0.094	—
Upper West Region	1.39	0.78–2.49	0.266	—
Random effects				
Null-model cluster variance (τ^2_0)	0.52 (0.31–0.87)	—	—	—
Full-model cluster variance (τ^2)	0.31 (0.18–0.53)	—	—	—
Proportional change in variance (PCV)	40.4%	—	—	—
ICC (null model)	0.147	—	—	—
Observations / Clusters	9,024 / 617	—	—	—

aOR = adjusted odds ratio; oPIF = observational population impact fraction (only for significant predictors; interpretation is speculative given cross-sectional design). PCV = proportional change in variance. All 16 regions included as fixed effects; Greater Accra is the reference. Survey-weighted mixed-effects logistic regression (melogit + svy) applied to 20 multiply imputed datasets with Rubin's rules pooling.

†Restricted cubic spline test for non-linearity of child age: p = 0.217, indicating no significant departure from linearity.

Table 4
Comparison of multiple imputation (primary) and complete-case sensitivity analysis — adjusted odds ratios for caretaker-reported ARI symptoms

Predictor	MI aOR (95% CI)	MI p-value	CC aOR (95% CI)	CC p-value
Child factors				
Age (months, continuous)	1.03 (1.02–1.04)	< 0.001	1.03 (1.02–1.04)	< 0.001
Female sex (ref: male)	1.12 (0.91–1.37)	0.281	1.11 (0.90–1.36)	0.318
Perceived low birth weight (ref: normal/large)	1.09 (0.88–1.36)	0.434	1.08 (0.87–1.34)	0.481
Socioeconomic factors				
Wealth index (ref: poorest)				
— Poorer	0.80 (0.62–1.04)	0.096	0.79 (0.61–1.03)	0.082
— Middle	0.82 (0.57–1.19)	0.291	0.81 (0.56–1.18)	0.271
— Richer	1.04 (0.68–1.58)	0.866	1.03 (0.67–1.57)	0.908
— Richest	0.92 (0.51–1.68)	0.786	0.91 (0.50–1.66)	0.754
Maternal education (ref: none)				
— Primary	1.30 (0.95–1.78)	0.099	1.31 (0.96–1.79)	0.091
— Secondary	1.06 (0.76–1.49)	0.724	1.05 (0.75–1.47)	0.781
— Higher	0.94 (0.51–1.75)	0.846	0.93 (0.50–1.73)	0.814
Contextual factors				
Urban residence (ref: rural)	0.69 (0.53–0.88)	0.003	0.71 (0.55–0.91)	0.007
Clean cooking fuel (ref: solid fuel)	0.81 (0.52–1.26)	0.349	0.82 (0.53–1.27)	0.371
Health system factor				
Health insurance (ref: uninsured)	0.67 (0.44–1.01)	0.054	0.68 (0.45–1.03)	0.071

Predictor	MI aOR (95% CI)	MI p-value	CC aOR (95% CI)	CC p-value
Child factors				
Full vaccination (12–23 months only)	—	—	—	—
Selected regional estimates *(ref: Greater Accra)*				
Northern Region	2.71 (1.62–4.52)	< 0.001	2.73 (1.63–4.57)	< 0.001
Savannah Region	2.14 (1.19–3.83)	0.011	2.15 (1.20–3.86)	0.011
Bono East Region	1.94 (1.03–3.65)	0.040	1.95 (1.03–3.68)	0.039
Ahafo Region†	0.35 (0.16–0.73)	0.006	0.34 (0.15–0.74)	0.007

MI = multiple imputation (20 datasets, Rubin's rules; outcome n = 9,024; predictors multiply imputed). **CC** = complete-case analysis (n = 5,448). All models are survey-weighted two-level random-intercept logistic regression with children nested within primary sampling unit clusters. aOR = adjusted odds ratio; CI = confidence interval. P-values are two-sided Wald test p-values; MI p-values derived under Rubin's rules. The full vaccination analysis is restricted to children aged 12–23 months and is not presented in this comparison table; the primary MI estimate (aOR = 1.17; 95% CI: 0.84–1.62; p = 0.360) and complete-case sensitivity estimate are reported in the main text and Supplementary Table S2. Full regional results for all 16 regions are available in Tables 3 and 5; only regions with statistically significant or substantively notable estimates are shown here.

†Ahafo Region estimate does not survive Bonferroni correction for 16 simultaneous regional comparisons (adjusted α = 0.003); interpret with caution.

Sensitivity analyses

Complete-case analysis

As a sensitivity analysis to assess the impact of missing data, we re-fitted the full multilevel model using complete cases only (n = 5,448). The results were generally consistent with the primary multiple imputation estimates. Urban residence remained protective (aOR = 0.71; 95% CI: 0.55–0.91; p = 0.007), and the adjusted odds ratios for other predictors showed similar directions and magnitudes (Table 5). The complete-case analysis also confirmed the age-misclassification problem documented in the primary analysis: when vaccination status was included across all age groups, a spuriously positive association emerged (see Supplementary Table S2), further supporting the decision to restrict vaccination analysis to children aged 12–23 months. The age-restricted complete-case vaccination

estimate (12–23 months, n = 1,911) was aOR = 1.19 (95% CI: 0.85–1.66), consistent with the primary imputed estimate (aOR = 1.17). These findings support the robustness of the primary results.

Urban-rural stratified models

Table 6 presents multilevel models stratified by place of residence. Effect directions were broadly consistent across urban and rural strata, and no significant residence–predictor interactions were detected (all p-interaction > 0.05). However, the stratum-specific vaccination estimates (urban aOR = 1.61, 95% CI: 1.15–2.25; rural aOR = 1.39, 95% CI: 1.03–1.88) diverge from the null primary pooled estimate (aOR = 1.17, 95% CI: 0.84–1.62) and warrant explicit explanation. Three factors likely account for this discrepancy. First, the vaccination analysis is restricted to children aged 12–23 months; when this subgroup is further divided by residence stratum, the stratum-specific analytic samples are substantially smaller, yielding unstable point estimates with wide confidence intervals whose apparent significance should be interpreted with considerable caution. Second, the non-significant interaction test (p > 0.05) indicates that the stratum-specific divergence in point estimates is not statistically supported as genuine effect modification, and is more consistent with sampling variability in small strata than with a true residence-stratified vaccination effect. Third, residual confounders, particularly health-seeking behaviour and facility proximity, may distribute differently within urban and rural strata than in the pooled model, introducing stratum-specific confounding that the stratified models cannot fully adjust for given their reduced sample sizes. On balance, the primary pooled estimate (aOR = 1.17, 95% CI: 0.84–1.62, p = 0.360) from the larger imputed sample should be regarded as the more reliable vaccination estimate; the stratified results are presented for transparency but should not be interpreted independently.

Table 5
Complete-case sensitivity analysis – full multilevel model (n = 5,448, all ages, vaccination not restricted)

Predictor	aOR	95% CI	p-value	oPIF (%)
Child factors				
Age (months, continuous)	1.03	1.02–1.04	< 0.001	—
Female sex (ref: male)	1.11	0.90–1.36	0.328	—
Perceived low birth weight (ref: normal)	1.08	0.87–1.34	0.491	—
Socioeconomic factors				
Wealth index (ref: poorest)				
Poorer	0.79	0.61–1.03	0.082	—
Middle	0.81	0.56–1.18	0.272	—
Richer	1.03	0.67–1.57	0.902	—
Richest	0.91	0.50–1.66	0.762	—
Linear trend test (Mantel-Haenszel)	—	—	0.091	—
Maternal education (ref: none)				
Primary	1.31	0.96–1.79	0.092	—
Secondary	1.05	0.75–1.47	0.778	—
Higher	0.93	0.50–1.73	0.819	—
Contextual factors				
Urban residence (ref: rural)	0.71	0.55–0.91	0.007	8.2
Clean cooking fuel (ref: solid fuel)	0.82	0.53–1.27	0.375	—
Health system factor				
Health insurance (ref: none)	0.68	0.45–1.03	0.068	—
Regional effects (ref: Greater Accra)				
Western Region	0.97	0.60–1.56	0.891	—
Central Region	1.19	0.73–1.93	0.487	—
Greater Accra	1.00	—	—	—
Volta Region	1.77	1.05–2.99	0.031	—
Eastern Region	1.05	0.64–1.72	0.841	—

Predictor	aOR	95% CI	p-value	oPIF (%)
Child factors				
Ashanti Region	1.13	0.71–1.79	0.608	—
Western North Region	0.89	0.51–1.55	0.676	—
Ahafo Region	0.34	0.15–0.74	0.007	—
Bono Region	1.22	0.72–2.05	0.455	—
Bono East Region	1.95	1.03–3.68	0.040	—
Oti Region	1.44	0.85–2.44	0.173	—
Northern Region	2.73	1.63–4.57	< 0.001	—
Savannah Region	2.15	1.20–3.86	0.010	—
North East Region	1.89	1.01–3.52	0.045	—
Upper East Region	1.63	0.92–2.89	0.092	—
Upper West Region	1.38	0.77–2.48	0.280	—
Random effects				
Null-model cluster variance (τ^2_0)	0.52 (0.31–0.87)	—	—	—
Full-model cluster variance (τ^2)	0.32 (0.19–0.54)	—	—	—
Proportional change in variance (PCV)	38.5%	—	—	—
ICC (null model)	0.147	—	—	—
Observations / Clusters	5,448 / 617	—	—	—

aOR = adjusted odds ratio; oPIF = observational population impact fraction (speculative, given cross-sectional design). Complete-case estimates are presented for comparison with the primary multiple imputation results (Table 3).

The stratum-specific vaccination estimates (urban aOR = 1.61, 95% CI: 1.15–2.25; rural aOR = 1.39, 95% CI: 1.03–1.88) are statistically significant within each stratum but diverge from the null primary pooled estimate (aOR = 1.17, 95% CI: 0.84–1.62). The non-significant interaction term (p = 0.438) indicates that the two stratum-specific estimates are not statistically distinguishable from each other, but does not resolve the inconsistency with the pooled result. This divergence most plausibly reflects residual confounding within the smaller stratum-specific subsamples, the 12–23 month age restriction reduces the analytic sample substantially before stratification, limiting the ability to fully adjust for health-seeking behaviour and facility access within each stratum. Given this, the primary pooled estimate from the larger multiply imputed sample is considered the more stable and reliable estimate of the vaccination–

ARI association. The stratum-specific vaccination results are retained in Table 6 for transparency but should be interpreted with caution and not as independent primary findings.

Table 6
Urban-rural stratified multilevel logistic regression models (multiple imputation primary estimates)

Predictor	Urban aOR	Urban 95% CI	Rural aOR	Rural 95% CI	Interaction p
Age (months)	1.02	1.00–1.04	1.03	1.01–1.05	0.641
Female sex (ref: male)	1.15	0.85–1.56	1.10	0.83–1.45	0.819
Perceived low birth weight	1.04	0.75–1.44	1.14	0.87–1.50	0.573
Fully vaccinated (12–23 mo only)*	1.61	1.15–2.25	1.39	1.03–1.88	0.438
Wealth quintile (continuous)	0.91	0.81–1.02	0.87	0.79–0.96	0.548
Maternal education (sec+, ref: none/primary)	0.97	0.65–1.44	1.12	0.80–1.58	0.607
Health insurance (ref: none)	0.62	0.36–1.07	0.72	0.44–1.17	0.682
Clean cooking fuel (ref: solid)	0.76	0.43–1.36	0.91	0.50–1.65	0.728
Cluster variance (τ^2)	0.28	0.14–0.57	0.35	0.19–0.65	—
Observations / Clusters	2,391 / 293	—	3,057 / 324	—	—

Vaccination estimates from stratified models are derived from the age-restricted sample (12–23 months) to avoid misclassification. Interaction p from combined model with residence × predictor interaction term.

Discussion

This study examined determinants of caretaker-reported ARI symptoms in Ghana using the 2022 GDHS, incorporating multilevel design, multiple imputation as the primary analytic approach, spline tests, formal wealth trend testing, oPIF estimation, and region-specific estimates for all 16 administrative regions.

Urban residence and rural disadvantage

Urban residence remained significantly protective after full adjustment (aOR = 0.69; oPIF = 8.9%). This aligns with Acheampong et al. (2022) [23], who documented consistent rural-urban childhood morbidity

differentials in Ghana, and Kumi-Kyereme & Amo-Adjei (2021) [16], who identified residence as a primary ARI determinant. The observed urban protective association may reflect a combination of factors including greater healthcare access, improved housing quality, lower indoor air pollution exposure, and higher health literacy, though the cross-sectional design does not permit pathway-specific attribution.

Vaccination findings

The analysis restricted to children aged 12–23 months (the age group for which DHS vaccination indicators are valid) found no significant association between full vaccination and caretaker-reported ARI symptoms (aOR = 1.17; 95% CI: 0.84–1.62). (In contrast, the full-sample analysis including all ages produced a spurious positive association [aOR = 1.49] due to age-related misclassification of the vaccination indicator; this is mentioned in Limitations as an illustration of the misclassification problem.) The age-restricted analysis found no significant association between full vaccination status and caretaker-reported ARI symptoms. Continued strengthening of Ghana's Expanded Programme on Immunisation remains essential for reducing childhood morbidity and mortality from vaccine-preventable diseases.

Regional heterogeneity across all 16 regions

Substantial regional variation in caretaker-reported ARI symptoms was observed across Ghana's 16 administrative regions. Children residing in Northern Region, Savannah Region, and North East Region had significantly higher odds of caretaker-reported ARI symptoms compared with those in Greater Accra Region, with adjusted odds ratios ranging from nearly two-fold to almost three-fold. These findings are consistent with previous studies that have identified northern Ghana as a higher-burden area for childhood respiratory illnesses [6, 16].

Several contextual factors may plausibly contribute to the higher burden observed in the Savannah Belt, though none were directly measured in this analysis and the following should be regarded as speculative hypotheses for future investigation. First, harmattan-related dry dusty conditions may increase respiratory irritation and susceptibility to respiratory infection, a mechanism documented elsewhere in West Africa [26]. Second, differences in housing construction quality may affect ventilation and dust exposure. Third, primary healthcare facility density and skilled workforce availability appear to differ substantially across regions [6]. Fourth, regional variation in NHIS enrolment may influence health-seeking behaviour and symptom detection. These mechanisms are not mutually exclusive, may interact, and require ecological or longitudinal data to evaluate.

The significantly lower risk in Ahafo Region (aOR = 0.35) is notable and unexplained by individual- or household-level factors in this analysis. The substantially lower odds in Ahafo Region (aOR = 0.35, 95% CI: 0.16–0.73, p = 0.006) are notable but should be interpreted cautiously. With 16 regions tested simultaneously against a common reference, the family-wise type I error rate is inflated; applying a Bonferroni correction yields an adjusted alpha of 0.003, which this estimate does not survive (p = 0.006). The wide confidence interval further indicates that the point estimate is imprecise, consistent with a small region-specific sample. The finding may reflect genuine regional heterogeneity in unmeasured

ecological or health-system factors, or it may represent a chance finding under multiple comparisons. It is retained in Table 3 for completeness but caution against over-interpretation; replication in a study with region-stratified sampling and ecological covariates would be required before drawing conclusions about Ahafo specifically

The persistence of regional disparities after adjustment for individual-, household-, and contextual-level characteristics indicates that additional environmental, health-system, and community-level factors may contribute to childhood respiratory health outcomes in Ghana.

Wealth gradient

Although crude prevalence declined progressively across wealth quintiles, the association was substantially attenuated after adjustment, with no individual quintile achieving statistical significance and a borderline linear trend (p = 0.087). This finding suggests that the influence of household wealth may operate indirectly through residential environment, educational attainment, healthcare access, and living conditions rather than through a direct effect on ARI risk.

Health insurance

Health insurance showed borderline protective association (aOR = 0.67; p = 0.054), consistent with findings from Blanchet et al. (2012) [13] and Owusu et al. (2022) [14]. High overall coverage (94.4%) limits power to detect an effect; cross-tabulation confirms that the uninsured 5.6% are concentrated in the poorest wealth quintiles and have lower maternal education, representing the most disadvantaged households, where insurance expansion may be especially relevant for improving healthcare access, though the observational nature of these data does not permit inference about the effect of insurance expansion on ARI outcomes.

Cooking fuel

Although clean cooking fuel use was associated with a 19% reduction in the odds of caretaker-reported ARI (aOR = 0.81), the confidence interval was wide (0.52–1.26) and statistical significance was not achieved. Three factors likely explain this imprecision. First, only 20.6% of households used clean fuels, limiting exposure variation and statistical power. Second, the binary clean/solid fuel categorisation collapses substantial heterogeneity in exposure intensity, charcoal and wood have markedly different particulate emission profiles, and outdoor cooking practices attenuate indoor exposure regardless of fuel type. Third, 3.9% of fuel type data were missing, further reducing precision. The directional estimate is consistent with the evidence base on household air pollution and childhood pneumonia [9, 26] and with Ghana's policy context, where the government has expanded LPG subsidy programmes.

Strengths and limitations

Strengths include: large nationally representative sample; multilevel design correctly accounting for clustering; reporting of null-model variance components and PCV; multiple imputation as the primary

analytic approach addressing missing data under MAR; formal tests for non-linearity and wealth trends; oPIF estimation; urban-rural stratified models; and complete reporting of all 16 Ghanaian regions.

Limitations include: (1) cross-sectional design precludes causal inference; (2) outcome based on caretaker report, not clinical diagnosis or microbiological confirmation, a further limitation concerns differential measurement validity of the caretaker-reported outcome. The DHS ARI indicator, cough with short, rapid breathing in the preceding two weeks, relies on caretaker recognition of fast breathing, a symptom whose reporting sensitivity varies with maternal literacy, prior healthcare contact, and cultural health knowledge. These characteristics vary systematically across Ghana's regions and between urban and rural areas, creating plausible differential outcome misclassification. Specifically, caregivers in urban areas and southern regions may be more likely to recognise and report fast breathing symptoms due to higher health literacy and greater exposure to health messaging, potentially inflating apparent urban-protective and northern-risk estimates. This form of misclassification cannot be addressed by multilevel modelling or multiple imputation and represents an unresolvable limitation of population-based ARI research using DHS data; (3) substantial missing data for perceived birth weight (16.9%) and vaccination status (10.5%), addressed by multiple imputation. The MAR assumption underlying the multiple imputation approach cannot be verified. Missingness in perceived birth weight (16.9%) may depend on delivery location — women delivering at home are less likely to have a recorded birth weight and may also recall birth size differently — a factor not captured in the imputation model. This raises the possibility that perceived birth weight missingness is missing not at random (MNAR). If so, imputed values for this variable may be systematically biased, and the adjusted association of perceived birth weight with caretaker-reported ARI symptoms should be interpreted with particular caution. Sensitivity analyses using pattern-mixture or selection models to assess robustness to MNAR would be informative in future work but were beyond the scope of this analysis; (4) inability to include household crowding; (5) vaccination misclassification outside the 12–23-month window, the full-sample estimate (aOR = 1.49) illustrates this misclassification problem and is not reported as a valid estimate; (6) potential unmeasured confounding by breastfeeding and nutritional status; (5) The urban-rural stratified vaccination estimates (aOR = 1.61 and 1.39 in urban and rural strata respectively) diverge from the null primary pooled estimate and are likely artefacts of small stratum-specific sample sizes in the 12–23 month age-restricted subgroup rather than genuine effect modification, a conclusion supported by the non-significant residence × vaccination interaction test. These stratum-specific estimates should be interpreted with caution and are not considered reliable independent findings; (6) The stratum-specific vaccination estimates in the urban-rural stratified analysis (Table 6) are statistically significant within strata but diverge from the null primary pooled estimate. This inconsistency likely reflects residual confounding in small stratum-specific subsamples following age restriction, rather than genuine effect modification, though this cannot be ruled out with certainty. Longitudinal data with larger age-restricted samples would be required to resolve this ambiguity.

Implications for policy and practice

The findings highlight important geographic and socioeconomic disparities in caretaker-reported ARI symptoms among children under five years in Ghana. The significantly higher odds observed in Northern, Savannah, and North East Regions indicate the need for geographically targeted public health interventions in these high-burden settings. Strengthening primary healthcare services, improving access to timely diagnosis and treatment of respiratory illnesses, and expanding child health outreach programmes may contribute to reducing the burden of ARI in these regions.

The protective association observed for urban residence suggests that inequalities in living conditions, healthcare access, and environmental exposures between urban and rural communities remain important public health concerns. Policies aimed at improving rural healthcare infrastructure and access to essential child health services may help reduce these disparities.

The elevated risks observed in Volta and Bono East Regions, together with the substantially lower risk observed in Ahafo Region, indicate that regional contextual factors may influence childhood respiratory health beyond the individual- and household-level characteristics measured in the DHS. Further investigation is needed to identify the environmental, healthcare-system, and community-level determinants underlying these regional differences.

Among children aged 12–23 months, the age group for which the DHS vaccination indicator is valid, full vaccination status was not significantly associated with caretaker-reported ARI symptoms (aOR = 1.17, 95% CI: 0.84–1.62). These findings should not be interpreted as evidence of adverse effects of vaccination on respiratory health. Continued strengthening of Ghana's Expanded Programme on Immunisation remains essential for reducing childhood morbidity and mortality from vaccine-preventable diseases.

Future research should prioritise longitudinal studies capable of establishing temporal relationships between risk factors and ARI outcomes. Incorporating detailed measures of environmental exposures, housing quality, healthcare accessibility, and air pollution would provide a more comprehensive understanding of the determinants of childhood respiratory illness in Ghana.

Conclusion

This study identified important geographic and contextual disparities in caretaker-reported ARI symptoms among children under five years in Ghana. Urban residence was associated with lower odds of caretaker-reported ARI symptoms, while substantial between-cluster variation remained, with approximately 40% of cluster-level variance explained by the factors included in the model. Marked regional heterogeneity was observed in caretaker-reported ARI symptom odds, with Northern, Savannah, and North East Regions showing significantly higher adjusted odds compared with Greater Accra Region. These estimates may, however, partly reflect regional differences in caretaker symptom recognition and reporting.

The analysis restricted to children aged 12–23 months found no evidence supporting a positive association between vaccination and caretaker-reported ARI symptoms.

The persistence of regional disparities after adjustment for individual-, household-, and contextual-level characteristics indicates that additional environmental, health-system, and community-level factors may contribute to childhood respiratory health outcomes in Ghana. These findings underscore the need for further investigation into contextual and health-system determinants of geographic disparities in childhood ARI in Ghana, and may inform the prioritisation of future research and geographically targeted programme evaluation.

Declarations

Ethics approval:This study was a secondary analysis of anonymised, publicly available data from the 2022 Ghana Demographic and Health Survey. The original survey was approved by the ICF Institutional Review Board and the Ghana Health Service Ethical Review Committee, and was conducted in accordance with the Declaration of Helsinki. As this study used only de-identified data already in the public domain, no additional ethical approval was required.

***Consent to participate declaration*:** not applicable

Consent for publication:Not applicable.

Availability of data and materials:Data available from https://dhsprogram.com upon registration. Stata code available from the corresponding author on reasonable request.

Competing interests:None declared.

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Authorship contribution statement
R.B. Adda: Conceptualisation, Data curation, Formal analysis, Methodology, Software, Visualisation, Writing – original draft, Writing – review & editing.

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Figures

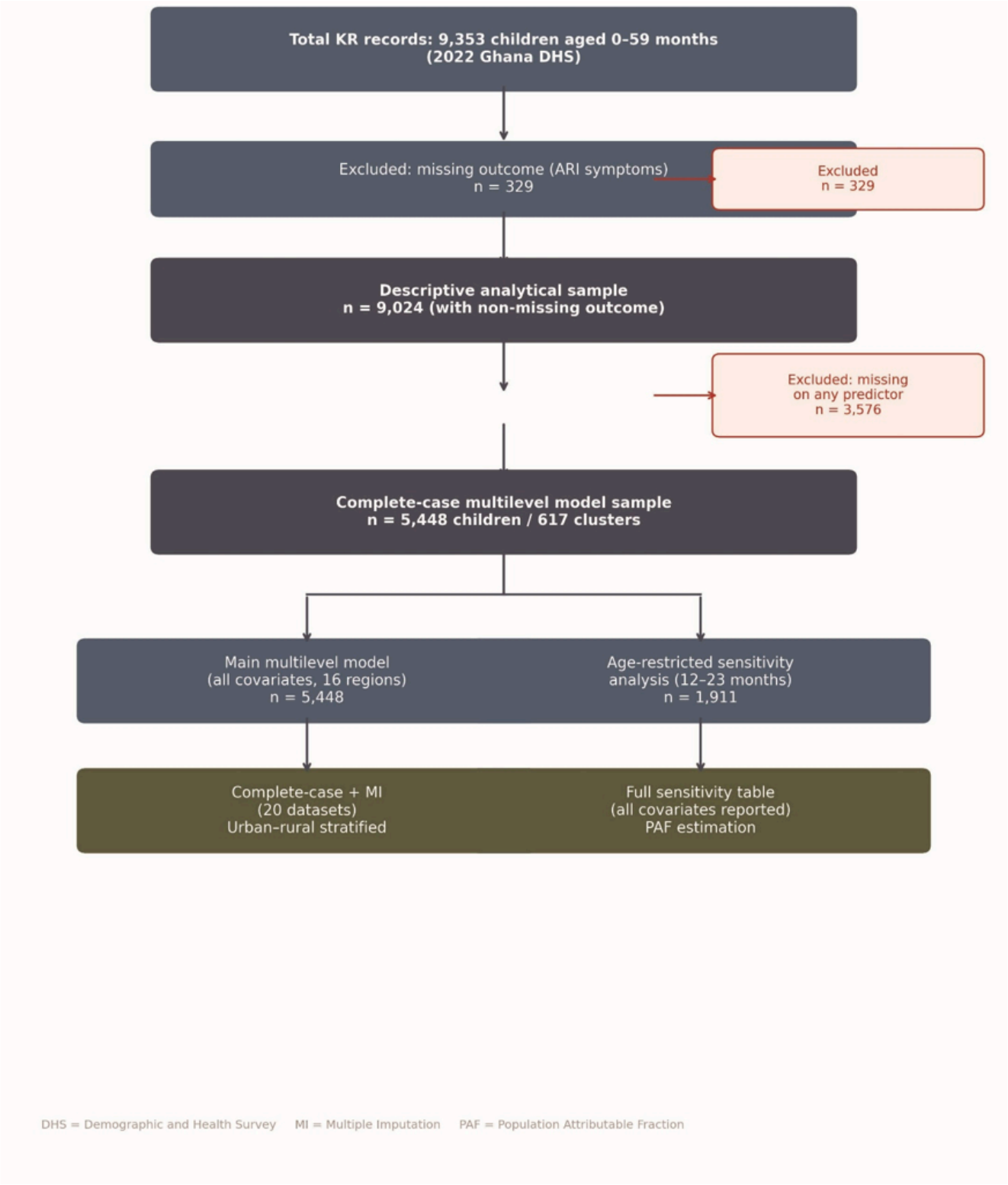


Figure 1

STROBE participant flowchart. Total KR records: 9,353. Excluded 329 with missing outcome → 9,024 descriptive/MI sample. Excluded additional 3,576 missing on any predictor → 5,448 complete-case analytical sample (sensitivity). Age-restricted vaccination analysis: 1,911 children aged 12–23 months with complete data.

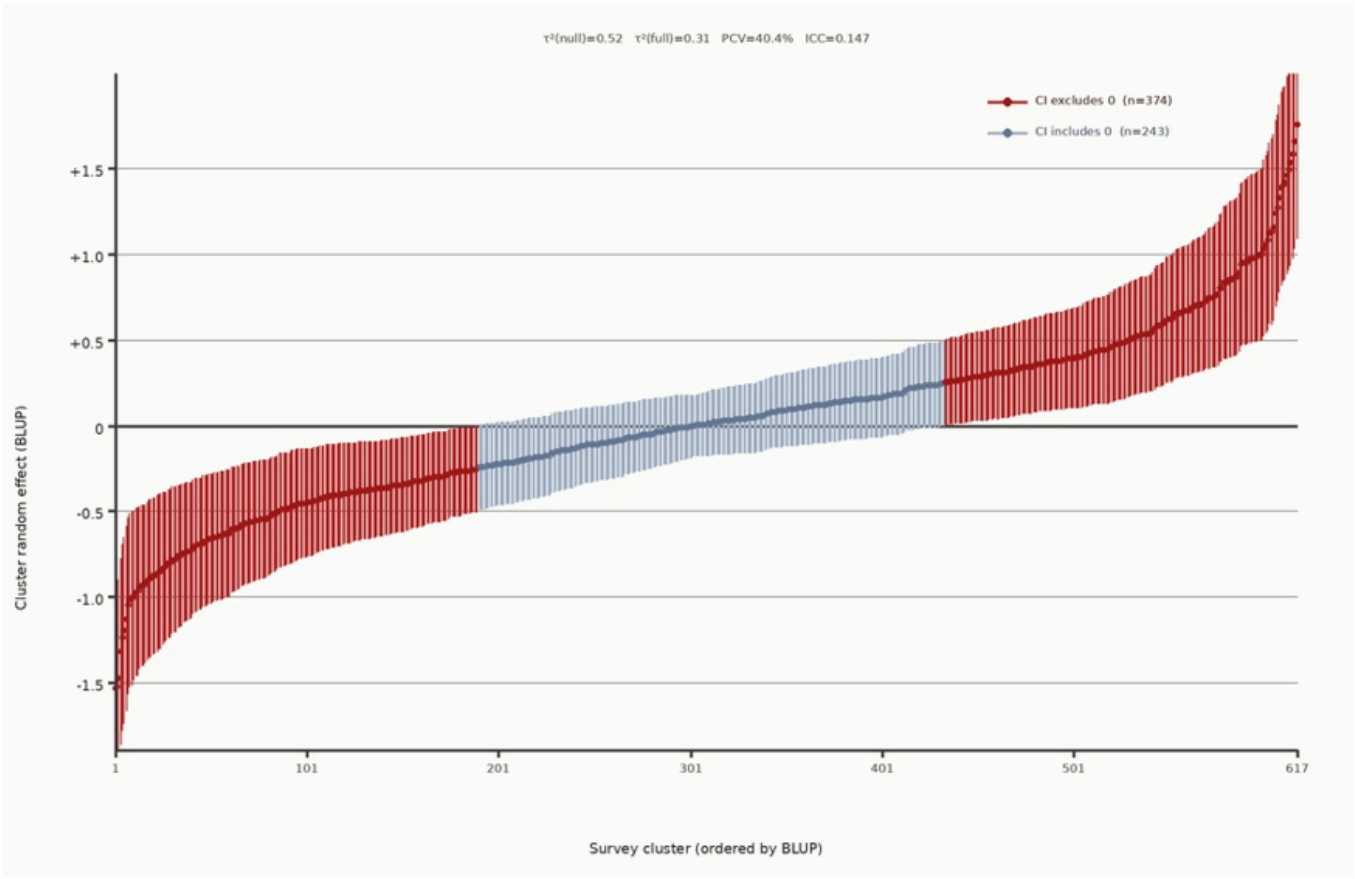


Figure 2

Caterpillar plot of cluster-level random effects (best linear unbiased predictors, BLUPs) from the full multilevel logistic regression model, ordered by magnitude with 95% confidence intervals. Each point represents one primary sampling unit cluster (n = 617). Clusters whose confidence intervals exclude zero (shown in red) exhibit systematic departure from the population mean caretaker-reported ARI symptom risk after adjustment for all covariates. The dashed horizontal line indicates zero random effect (population mean).

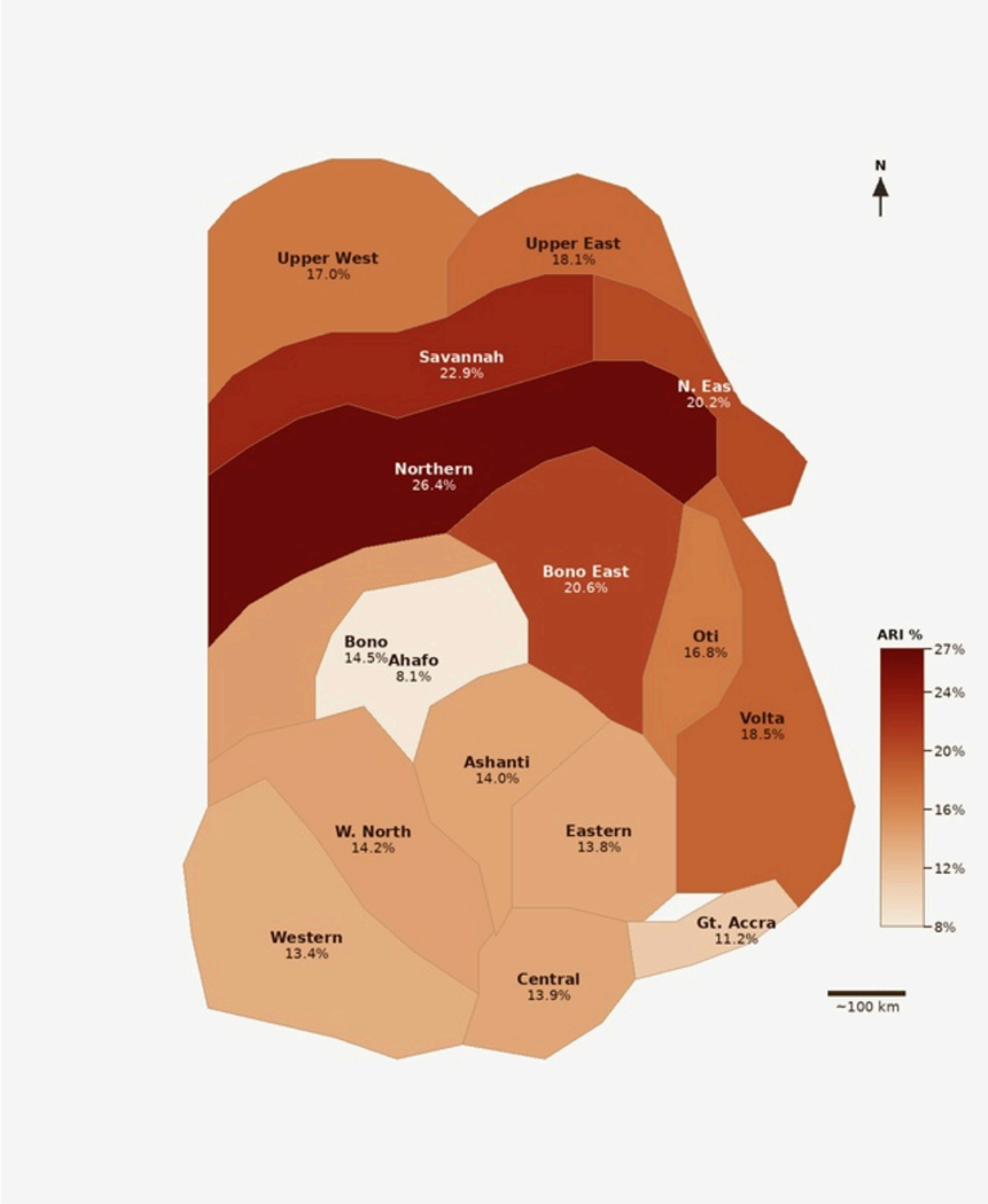


Figure 3

Choropleth map of weighted caretaker-reported acute respiratory infection (ARI) symptom prevalence (%) among children under five years, by administrative region, Ghana Demographic and Health Survey 2022 (n = 9,024). Prevalence estimates are survey-weighted. Regional boundaries are based on Ghana Statistical Service 2018 administrative shapefiles. Colour gradient ranges from lowest prevalence (Ahafo Region) to highest prevalence (Northern Region). Generated using the tmap package in R version 4.3.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryTable1.docx
- Supplementarytable2.docx
- SupplementaryTable3.docx
- SupplementaryFigureS1DAG.tiff