



(RESEARCH ARTICLE)



KNOWLEDGE OF CHILDHOOD AND ADULT IMMUNISATION AMONG CAREGIVERS OF CHILDREN UNDER FIVE IN RURAL AND URBAN COMMUNITIES OF THE EASTERN REGION, GHANA: A COMPARATIVE CROSS-SECTIONAL STUDY

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ABSTRACT

Caregivers' knowledge of the immunisation schedule shapes whether children are presented for each dose and whether adults seek recommended vaccines, yet rural–urban differences in this knowledge have not been examined across childhood and adult vaccination within one design in Ghana. This study assessed and compared knowledge of immunisation among caregivers of children under five years in rural and urban communities of the Eastern Region. A comparative cross-sectional survey enrolled 1,400 caregivers, 700 in each arm, by multistage sampling of two rural and two urban districts. Knowledge was measured with 14 binary items (score 0–14). Arms were compared using Welch's t test, Cohen's d, chi-square and trend tests, a proportional-odds model and item-level risk differences, with false-discovery-rate and design-effect corrections. Mean knowledge was 6.78 (SD 2.59) in rural and 7.87 (SD 2.41) in urban respondents, a difference of 1.09 points (95% CI 0.83–1.35; $d = 0.44$). Poor knowledge was recorded for 61.0% of rural and 43.4% of urban respondents, and urban residence was associated with higher odds of a better knowledge category (proportional-odds OR 2.02; 95% CI 1.65–2.49). Urban respondents answered all 14 items correctly more often, by 4.9 to 11.3 percentage points; 13 differences were significant, all of which survived false-discovery-rate correction and 10 of which survived design-effect correction. The largest gaps concerned adult and maternal vaccination, and the weakest knowledge in both arms concerned operational facts: that routine vaccines are free (38.1% rural, 44.1% urban), that a mild illness does not preclude vaccination, and where and when a child should be vaccinated. Within each arm, knowledge level was not associated with willingness to vaccinate or with receipt of the third pentavalent dose, and stratification by knowledge left the rural–urban gap in willingness unchanged (OR 3.01 before and after). Knowledge of immunisation was modest in both settings and consistently lower in rural communities. Health education should prioritise operational information on cost, timing, eligibility and place of vaccination, particularly in rural communities, alongside measures that address access and confidence.

Keywords: Immunisation knowledge; Childhood vaccination; Adult vaccination; Rural–urban disparities; Caregivers; Health education; Eastern Region; Ghana

1 INTRODUCTION

Vaccination is among the most effective public health interventions available. Modelling of the first 50 years of the Expanded Programme on Immunization (EPI) estimated that vaccination averted about 154 million deaths, most of them among children under five years [1]. Gains have nonetheless stalled, and more than 14 million infants worldwide received no dose of routine vaccine in 2024 [2]. In sub-Saharan Africa, coverage remains uneven between and within countries, and dropout between early and later doses leaves many children only partly protected [3,4].

In Ghana, coverage is high by regional standards but unequal. The 2022 Ghana Demographic and Health Survey reported full vaccination in 77% of urban and 66% of rural children aged 12–23 months [5], and analyses of the same survey show steep gradients by maternal education, wealth and region [6,7]. In the Eastern and Oti Regions, coverage of later doses and their determinants differ markedly between districts [8]. Adult vaccination receives less attention: uptake of tetanus-diphtheria boosters and influenza vaccines is low, and acceptance of COVID-19 vaccines has varied between rural and urban settlements, including in the Eastern Region [9–11].

Caregivers' knowledge is one of the conditions through which these inequalities arise. The 5As taxonomy identifies awareness, together with access, affordability, acceptance and activation, as a distinct determinant of uptake [12], and the Health Belief Model places knowledge of disease risk and vaccine benefit upstream of the perceptions that shape intention [13,14]. Completing the schedule requires more than knowing that vaccines exist: the caregiver must know when each dose is due, where it is offered, that it is free and that a mild illness is no reason to wait. In rural Ghana, caregivers with favourable attitudes still had incomplete knowledge of later doses and suboptimal coverage [15], and in an urban sub-metro of Accra, specific gaps in understanding persisted despite good access to services [16].

Most Ghanaian studies of immunisation knowledge have been confined to one district, one setting or one vaccine, and childhood and adult vaccination have usually been studied separately [9,16,17]. Multi-country decomposition has shown that rural–urban gaps in childhood immunisation reflect differences in maternal education, media exposure and service contact [18], but the content of caregivers' knowledge, and whether rural and urban deficits lie in the same places, has not been compared directly in Ghana. It is also unclear whether knowledge, as usually measured, is related to the willingness and uptake that programmes seek to improve. This study therefore assessed and compared knowledge of childhood and adult immunisation among caregivers of children under five years in rural and urban communities of the Eastern Region of Ghana, and examined whether knowledge was associated with willingness to vaccinate and with childhood vaccine uptake in each setting.

2 MATERIAL AND METHODS

2.1 Study design

A comparative cross-sectional design was used, in which two groups defined in advance by place of residence, rural and urban, were surveyed during the same period with the same instrument. This article reports the first objective of a larger study of willingness to vaccinate and vaccine uptake in the Eastern Region, and it is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [19].

2.2 Study setting

The Eastern Region lies in south-eastern Ghana, covers about 19,323 km² and comprises 33 administrative districts, municipalities and metropolitan assemblies, most of them predominantly rural. Its capital is Koforidua. The population is mainly Akan, chiefly Akyem and Kwahu, with Krobo, Dangme, Ewe and Guan communities; farming, trading, small-scale mining and fishing are the main occupations. Routine immunisation is delivered under the EPI by the Eastern Regional Health Directorate of the Ghana Health Service through hospitals, polyclinics, health centres and Community-based Health Planning and Services (CHPS) compounds, using static and outreach sessions [20,21].

2.3 Study population and eligibility

The study population comprised mothers and couples with a child under five years who were resident in the selected communities. Caregivers were chosen because they decide whether and when children are presented for vaccination and are themselves eligible for adult vaccines. Respondents were eligible if they were aged 18 years or older, had a child under five years, had lived in the Eastern Region for at least one year before data collection and gave written informed consent. Caregivers who were too ill to be interviewed, who had a hearing or speech impairment that prevented interview, or who declined consent were excluded.

2.4 Sample size and sampling

The sample size was calculated with the formula for comparing two independent proportions, $n = (Z_{\alpha} + Z_{\beta})^2 [P_1(1 - P_1) + P_2(1 - P_2)] / (P_1 - P_2)^2$, using full vaccination among urban ($P_1 = 0.77$) and rural ($P_2 = 0.66$) children in the 2022 Ghana Demographic and Health Survey [5]. After a design effect of 1.5 for clustered selection and an allowance of 10% for non-response, the minimum sample was 669 caregivers per arm; 700 caregivers were enrolled in each arm, 1,400 in total.

Respondents were selected by four-stage sampling. The 33 districts of the region were stratified as rural or urban, and two districts were selected from each stratum by simple random sampling. Sub-districts were then selected at random within each district, and communities were selected at random within each sub-district in proportion to population. Households with a child under five years were selected systematically from community registers using a sampling interval with a random start, and where more than one eligible caregiver lived in a household, one was chosen by ballot. The sample in each arm was allocated across districts in proportion to the size of their eligible populations.

2.5 Data collection and measures

Data were collected with a semi-structured, interviewer-administered questionnaire in the language the respondent preferred. Interviews were conducted in private by enumerators not employed at the local facilities. The questionnaire covered socio-demographic characteristics, access to vaccination services, knowledge of vaccination, attitude towards vaccination, willingness to vaccinate and vaccination uptake. Childhood vaccination was abstracted from the child health record card where available and otherwise from the facility register or caregiver report [22,23]. The instrument was pre-tested on 201 caregivers in an Eastern Region district not included in the study, and ambiguous or non-discriminating items were revised before the main survey.

Knowledge was assessed with 14 items on immunisation (K1–K14; Table 3). These covered awareness and purpose of vaccination, diseases prevented, the timing of the first vaccination and of the first measles-rubella (MR) dose, the number of pentavalent doses, the age by which the schedule should be completed, where vaccination is offered, whether routine vaccines are free, possible reactions, whether a child with a mild illness can be vaccinated, adults' need for vaccines, vaccines available to adults and the tetanus-containing vaccine given in pregnancy. Each correct response scored 1 and any other response 0, giving a total score of 0–14, which was classified as poor, moderate or good knowledge using the cut-offs prespecified in the study protocol. For descriptive interpretation, the items were grouped by content into four domains: awareness and disease prevention (K1, K2, K3, K10), schedule and timing (K4–K7), service access and eligibility (K8, K9, K11), and adult and maternal vaccination (K12–K14). The domains are a conceptual grouping and were not derived psychometrically.

Place of residence (rural or urban) was assigned from the administrative classification of the district of enrolment. Willingness to vaccinate was recorded as a binary study indicator, and childhood uptake was represented by receipt of the third dose of pentavalent vaccine (Penta 3).

2.6 Statistical analysis

Data were checked, coded and analysed in SPSS version 27 and Stata version 17, and supplementary computations were made in Python 3 (SciPy and statsmodels). Characteristics of the two arms were compared using Pearson's chi-square test, with Cramér's V or the odds ratio (OR) as the effect size. Mean knowledge scores were compared using Welch's t-test, and the difference was expressed as the mean difference with its 95% confidence interval (CI), Cohen's d with its 95% CI and the probability of superiority, which is the probability that a randomly chosen urban respondent scores higher than a randomly chosen rural respondent. The distribution of knowledge levels was compared using the chi-square test, the Cochran–Armitage test for trend [24] and a proportional-odds logistic model with residence as the only predictor [25].

For each knowledge item, the urban–rural risk difference (RD) in percentage points with a Wald 95% CI and the OR with a Woolf 95% CI were estimated. Because 14 items were tested, the false discovery rate was controlled using the Benjamini–Hochberg procedure [26]. Because respondents were selected in clusters, a first-order design-effect correction was applied as a sensitivity analysis by dividing each test statistic by the planning design effect of 1.5 [27]. Internal consistency was estimated with Cronbach's α , which is equivalent to the Kuder–Richardson formula 20 for binary items [28,29], and the implied mean inter-item correlation was derived from α .

The association between knowledge level and the two behavioural outcomes, willingness to vaccinate and Penta 3 uptake, was examined separately within each arm using the chi-square and Cochran–Armitage tests and crude ORs comparing moderate or good with poor knowledge. Mantel–Haenszel ORs pooled across arms, with Woolf's test of homogeneity, were used to examine whether residence confounded the association. Multivariable logistic regression models fitted within each arm estimated the OR per level of knowledge, adjusted for sex, age group, education, income band, health insurance, travel time, attitude level and campaign exposure, with willingness also entered in the uptake models. Following Rothman [30], the number of comparisons is reported in full, and statistical significance was set at $p < 0.05$.

3 RESULTS

3.1 Characteristics of respondents

All 1,400 caregivers, 700 in each arm, were included in the analysis (Table 1). Most were female (70.7% rural, 70.4% urban; $p = 0.907$), and the arms did not differ in the age distribution of the index child ($p = 0.492$). Rural respondents were older, more often married and had markedly less schooling: 37.1% had only primary education compared with 17.9% of urban respondents, and 3.9% compared with 17.8% had tertiary education ($V = 0.306$). Educational attainment was not stated by 20.0% of rural and 6.7% of urban respondents. The largest differences were in occupation, income and access. Farming was the main occupation of 46.0% of rural respondents, 45.4% of rural households earned under GH¢ 500 a month, and 43.6% of rural respondents lived more than 5 km from a vaccination point, compared with 8.4% of urban respondents ($V = 0.485$). Urban respondents were more often insured under the National Health Insurance Scheme (77.6% vs 55.9%; OR 2.73) and more often reported that services were open when needed (82.6% vs 68.6%; OR 2.17), and the child health record card was seen for 74.1% of urban and 56.1% of rural children.

Table 1: Socio-demographic and service-access characteristics of respondents by place of residence

Characteristic	Rural (n = 700) n (%)	Urban (n = 700) n (%)	Test statistic	p-value	Effect size
Sex			$\chi^2(1) = 0.01$	0.907	OR 0.99 (0.78–1.24)
Female	495 (70.7)	493 (70.4)			
Male	205 (29.3)	207 (29.6)			
Age group (years)			$\chi^2(3) = 20.14$	<0.001	V = 0.120
18–24	116 (16.6)	113 (16.1)			
25–34	263 (37.6)	335 (47.9)			

35–44	244 (34.9)	207 (29.6)			
≥45	77 (11.0)	45 (6.4)			
Marital status			$\chi^2(4)$ 24.65	= <0.001	V = 0.133
Married	474 (67.7)	406 (58.0)			
Never married	69 (9.9)	125 (17.9)			
Cohabiting	73 (10.4)	83 (11.9)			
Separated/divorced	56 (8.0)	47 (6.7)			
Widowed	28 (4.0)	39 (5.6)			
Education ^a			$\chi^2(3)$ 113.28	= <0.001	V = 0.306
Primary	208 (37.1)	117 (17.9)			
JHS/Middle	228 (40.7)	223 (34.2)			
SHS/Secondary	102 (18.2)	197 (30.2)			
Tertiary	22 (3.9)	116 (17.8)			
Religion ^b			$\chi^2(3)$ 48.88	= <0.001	V = 0.191
Christian	500 (75.2)	529 (78.0)			
Muslim	87 (13.1)	127 (18.7)			
Traditional	73 (11.0)	14 (2.1)			
Other	5 (0.8)	8 (1.2)			
Occupation			$\chi^2(6)$ 330.09	= <0.001	V = 0.486
Farmer	322 (46.0)	42 (6.0)			
Trader	179 (25.6)	232 (33.1)			
Artisan	66 (9.4)	123 (17.6)			
Salaried	44 (6.3)	183 (26.1)			
Unemployed	63 (9.0)	81 (11.6)			
Student/other	26 (3.7)	39 (5.6)			
Monthly household income (GH¢)			$\chi^2(4)$ 174.04	= <0.001	V = 0.353
<500	318 (45.4)	115 (16.4)			
500–999	192 (27.4)	196 (28.0)			
1,000–1,999	127 (18.1)	208 (29.7)			
2,000–2,999	48 (6.9)	117 (16.7)			
≥3,000	15 (2.1)	64 (9.1)			
Insured under NHIS	391 (55.9)	543 (77.6)	$\chi^2(1)$ 74.32	= <0.001	OR 2.73 (2.17–3.45)
Distance to vaccination point			$\chi^2(4)$ 329.50	= <0.001	V = 0.485
<1 km	53 (7.6)	228 (32.6)			
1–2 km	138 (19.7)	266 (38.0)			

3–5 km	204 (29.1)	147 (21.0)			
6–10 km	201 (28.7)	50 (7.1)			
>10 km	104 (14.9)	9 (1.3)			
Travel time ≥60 minutes ^c	267 (38.1)	63 (9.0)	$\chi^2(4)$ 312.27	= <0.001	V = 0.472
Services open when needed	480 (68.6)	578 (82.6)	$\chi^2(1)$ 37.16	= <0.001	OR 2.17 (1.69–2.79)
Child health record			$\chi^2(2)$ 52.91	= <0.001	V = 0.194
Card seen	393 (56.1)	519 (74.1)			
Reported, not seen	175 (25.0)	118 (16.9)			
No card	132 (18.9)	63 (9.0)			

Note. OR, odds ratio (urban vs rural) with 95% confidence interval; V, Cramér's V; NHIS, National Health Insurance Scheme; JHS, junior high school; SHS, senior high school; GH¢, Ghana cedi. a Percentages among respondents who stated their education (rural n = 560; urban n = 653); not stated by 140 (20.0%) rural and 47 (6.7%) urban respondents. b Percentages among respondents who stated a religion (rural n = 665; urban n = 678). c Test statistic and effect size refer to the five-category travel-time variable (<15, 15–29, 30–59, 60–119 and ≥120 minutes).

3.2 Overall knowledge of immunisation

The mean knowledge score was 7.32 (SD 2.56) on the 14-point scale: 6.78 (SD 2.59; 95% CI 6.59–6.97) in the rural arm and 7.87 (SD 2.41; 95% CI 7.69–8.05) in the urban arm (Table 2). The mean difference of 1.09 points (95% CI 0.83–1.35; Welch t = 8.15; p < 0.001) corresponded to a relative difference of 16.1% and a Cohen's d of 0.44 (95% CI 0.33–0.54), a small-to-moderate effect. The probability that a randomly selected urban respondent scored higher than a randomly selected rural respondent was 0.62. Respondents answered on average 48.4% of the items correctly in the rural arm and 56.2% in the urban arm, so that the typical caregiver in either setting answered only about half of the items correctly.

More than half of all respondents (52.2%) had poor knowledge, 36.5% had moderate knowledge and 11.3% had good knowledge. Poor knowledge was recorded for 61.0% of rural and 43.4% of urban respondents, and good knowledge for 8.0% and 14.6%, respectively ($\chi^2(2) = 45.69$; p < 0.001; V = 0.181; Figure 1). The shift across categories was monotonic (Cochran–Armitage z = 6.61; p < 0.001), and urban residence was associated with twice the odds of being in a higher knowledge category (proportional-odds OR 2.02; 95% CI 1.65–2.49). The ORs at the two cut-points were almost identical (2.04 for moderate or good versus poor, and 1.96 for good versus poor or moderate), which supports the proportional-odds assumption. All differences remained significant after correction for the design effect (Table 2).

Table 2: Knowledge of immunisation score and level by place of residence

Indicator	Rural (n = 700)	Urban (n = 700)	Difference or effect (95% CI)	Test statistic	p-value
Knowledge score (0–14)					
Mean (SD)	6.78 (2.59)	7.87 (2.41)	MD 1.09 (0.83–1.35)	t(1391) = 8.15	<0.001
95% CI of mean	6.59–6.97	7.69–8.05			
Median (IQR)	7.0 (5.0–9.0)	8.0 (6.0–10.0)			
Range	1–13	1–14			
Mean items correct, %	48.4	56.2	+7.8 pp		
Cohen's d			0.44 (0.33–0.54)		
Probability of superiority			0.62		
Design-effect-adjusted comparison				t = 6.66	<0.001

Knowledge level, n (%)			V = 0.181	$\chi^2(2)$ 45.69	=	<0.001
Poor	427 (61.0)	304 (43.4)				
Moderate	217 (31.0)	294 (42.0)				
Good	56 (8.0)	102 (14.6)				
Linear trend (Cochran–Armitage)				z = 6.61		<0.001
Proportional-odds model, urban vs rural			OR 2.02 (1.65–2.49)			<0.001
Moderate or good vs poor	273 (39.0)	396 (56.6)	OR 2.04 (1.65–2.52)	$\chi^2(1)$ 43.31	=	<0.001
Good vs poor or moderate	56 (8.0)	102 (14.6)	OR 1.96 (1.39–2.77)	$\chi^2(1)$ 15.10	=	<0.001
Design-effect-adjusted trenda				z = 5.40		<0.001
Internal consistency						
Cronbach's α (KR-20)b	0.529	0.456	Overall 0.518			
Implied mean inter-item correlation	0.074	0.056	Overall 0.071			

Note. MD, mean difference (urban minus rural); t, Welch's t test; pp, percentage points; OR, odds ratio for urban relative to rural residence; V, Cramér's V; SD, standard deviation; IQR, interquartile range; CI, confidence interval. a Test statistic divided by the square root of the planning design effect (1.5). b For binary items, Cronbach's α is equivalent to the Kuder–Richardson formula 20.

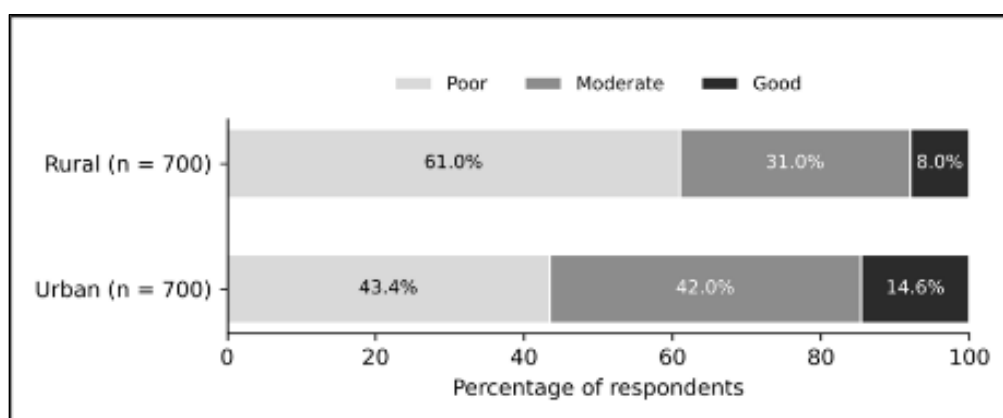


Figure 1: Distribution of knowledge levels among rural and urban respondents

Note. $\chi^2(2) = 45.69$, $p < 0.001$; proportional-odds OR for urban residence 2.02 (95% CI 1.65–2.49).

3.3 Item-level and domain-level knowledge

Urban respondents answered every one of the 14 items correctly more often than rural respondents, by margins of 4.9 to 11.3 percentage points (Table 3; Figure 2). Thirteen differences were statistically significant; the exception was the age at which a child should receive the first vaccination (K4: 41.6% vs 46.4%; RD 4.9 percentage points, 95% CI –0.3 to 10.1; $p = 0.067$). All 13 significant differences survived the Benjamini–Hochberg correction (largest $q = 0.024$). Under the design-effect correction, ten items remained significant, whereas the differences for the number of pentavalent doses (K6), free provision of vaccines (K9) and vaccination during mild illness (K11) became borderline ($p = 0.056$ – 0.063).

The largest rural–urban differences concerned adult and maternal vaccination. Knowledge that adults need vaccines (K12) differed by 11.3 percentage points (46.0% vs 57.3%; OR 1.57, 95% CI 1.27–1.94), and knowledge of the tetanus-containing vaccine given in pregnancy (K14) by 9.1 points. Knowledge of the diseases that childhood vaccines prevent (K3) differed by 10.0 points. At the domain level, mean correct responses in the rural and urban arms were 56.6% and 64.8% for awareness and disease prevention, 48.3% and 55.2% for schedule and timing, 39.2% and 45.8% for service access and eligibility, and 46.9% and 56.5% for adult and maternal vaccination.

The ranking of items was almost the same in the two arms. In both, the weakest knowledge concerned the operational facts on which completion of the schedule depends. Only 38.1% of rural and 44.1% of urban respondents knew that routine childhood vaccines are free at public facilities (K9), 39.0% and 45.1% knew that a child with a mild illness can still be vaccinated (K11), 40.4% and 48.1% knew where a child can be vaccinated in the community (K8), and 41.6% and 46.4% knew the age for the first vaccination (K4). By contrast, general awareness of immunisation (K1) and knowledge of possible reactions after vaccination (K10) were the most frequently correct items in both arms.

Table 3: Correct responses to knowledge items by place of residence, grouped by knowledge domain

Knowledge item	Rural n (%)	Urban n (%)	RD, pp (95% CI)	OR (95% CI)	p	q ^a	DEFF p ^b
Awareness and disease prevention (domain mean)	56.6%	64.8%	+8.2				
K1. Aware of immunisation or vaccination	426 (60.9)	471 (67.3)	6.4 (1.4 to 11.4)	1.32 (1.06–1.65)	0.012	0.017	0.041
K2. Main purpose of vaccination	351 (50.1)	402 (57.4)	7.3 (2.1 to 12.5)	1.34 (1.09–1.66)	0.006	0.010	0.026
K3. Diseases that childhood vaccines protect against	400 (57.1)	470 (67.1)	10.0 (4.9 to 15.1)	1.53 (1.23–1.90)	<0.001	<0.001	0.002
K10. Possible reactions after vaccination	407 (58.1)	470 (67.1)	9.0 (4.0 to 14.0)	1.47 (1.18–1.83)	<0.001	0.002	0.004
Schedule and timing (domain mean)	48.3%	55.2%	+6.9				
K4. Age for a child's first vaccination	291 (41.6)	325 (46.4)	4.9 (-0.3 to 10.1)	1.22 (0.99–1.50)	0.067	0.067	0.135
K5. Age for the first measles-rubella dose	310 (44.3)	370 (52.9)	8.6 (3.4 to 13.8)	1.41 (1.14–1.74)	0.001	0.003	0.009
K6. Recommended number of pentavalent doses	393 (56.1)	436 (62.3)	6.1 (1.0 to 11.3)	1.29 (1.04–1.60)	0.019	0.023	0.056
K7. Age by which routine vaccines should be completed	358 (51.1)	415 (59.3)	8.1 (3.0 to 13.3)	1.39 (1.13–1.72)	0.002	0.004	0.012
Service access and eligibility (domain mean)	39.2%	45.8%	+6.6				
K8. Where a child can be vaccinated in the community	283 (40.4)	337 (48.1)	7.7 (2.5 to 12.9)	1.37 (1.11–1.69)	0.004	0.006	0.018
K9. Routine childhood vaccines are free at public facilities	267 (38.1)	309 (44.1)	6.0 (0.9 to 11.1)	1.28 (1.04–1.59)	0.023	0.024	0.063
K11. A child with a mild illness can still be vaccinated	273 (39.0)	316 (45.1)	6.1 (1.0 to 11.3)	1.29 (1.04–1.59)	0.020	0.023	0.057
Adult and maternal vaccination (domain mean)	46.9%	56.5%	+9.6				

K12. Adults need to receive vaccines	322 (46.0)	401 (57.3)	11.3 (6.1 to 16.5)	1.57 (1.27–1.94)	<0.001	<0.001	<0.001
K13. Vaccines that adults may receive	381 (54.4)	440 (62.9)	8.4 (3.3 to 13.6)	1.42 (1.14–1.75)	0.001	0.003	0.009
K14. Vaccine given in pregnancy to protect the newborn against tetanus	282 (40.3)	346 (49.4)	9.1 (4.0 to 14.3)	1.45 (1.17–1.79)	<0.001	0.002	0.005

Note. RD, risk difference (urban minus rural) in percentage points (pp) with Wald 95% CI; OR, odds ratio for urban relative to rural residence with Woolf 95% CI; p, Pearson's chi-square test. Domain rows give the mean percentage of correct responses across the items in that domain. a Benjamini–Hochberg false-discovery-rate-adjusted p-value across the 14 items. b p-value after dividing the chi-square statistic by the planning design effect of 1.5.

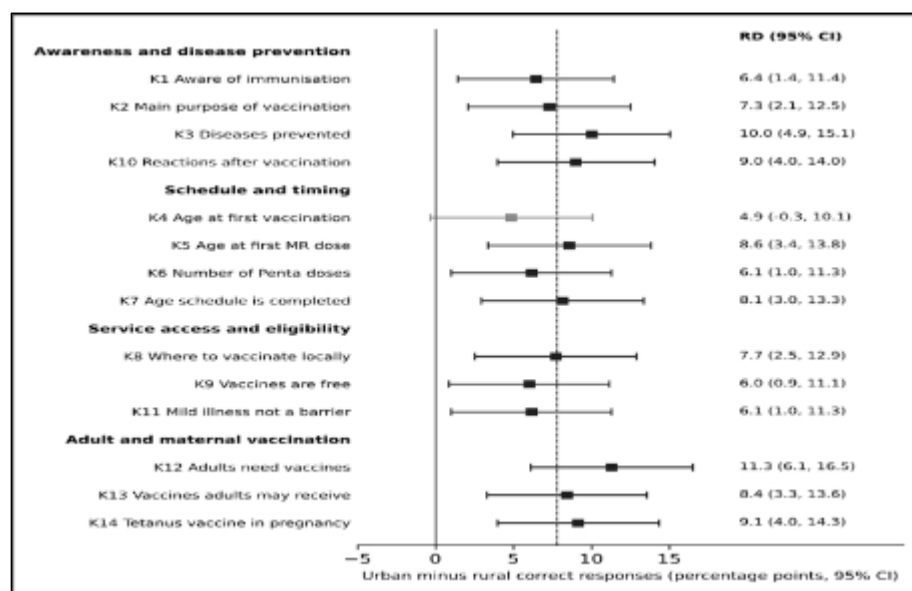


Figure 2: Urban–rural differences in correct responses to the 14 knowledge items, grouped by domain

Note. Squares show risk differences (urban minus rural) in percentage points with 95% confidence intervals; grey denotes a non-significant difference. The dashed line marks the mean difference across items (7.8 percentage points). MR, measles-rubella; Penta, pentavalent vaccine.

3.4 Reliability of the knowledge score

Cronbach's α for the 14 items was 0.518 overall, 0.529 in the rural arm and 0.456 in the urban arm (Table 2), which correspond to mean inter-item correlations of 0.07 and 0.06. The items therefore captured largely distinct pieces of information rather than a single underlying trait, and a reflective scale with this inter-item correlation would need about 30 items to reach an α of 0.70. The item-level results are therefore the more secure basis for inference, and the composite score is best read as a count of correctly known facts.

3.5 Knowledge, willingness to vaccinate and uptake

Willingness to vaccinate was reported by 47.0% of rural and 72.7% of urban respondents, and Penta 3 was received by 74.3% and 77.6% of index children, respectively. Within each arm, neither outcome varied with knowledge level (Table 4). In the rural arm, willingness was 48.2%, 46.5% and 39.3% among respondents with poor, moderate and good knowledge (trend $p = 0.254$), and in the urban arm it was 71.4%, 73.8% and 73.5% (trend $p = 0.557$). Penta 3 uptake showed no gradient in either arm (trend $p = 0.829$ rural; 0.389 urban). The adjusted ORs per level of knowledge were close to 1 and non-significant for willingness (rural 0.89; urban 1.10), for Penta 3 uptake (rural 1.00; urban 1.09) and for adult COVID-19 vaccine uptake (rural 0.81, 95% CI 0.62–1.07; urban 0.86, 95% CI 0.68–1.07).

When the two arms were pooled, the crude OR for willingness among respondents with moderate or good rather than poor knowledge was 1.19 (95% CI 0.96–1.47). Stratified by residence, it fell to 0.98 (Mantel–Haenszel 95% CI 0.79–1.23), with no evidence of heterogeneity between the arms ($p = 0.286$). The small crude association therefore reflected the concentration of both higher knowledge and higher willingness in urban communities. Conversely, the urban–rural

OR for willingness was 3.01 (95% CI 2.40–3.76) before and 3.01 (95% CI 2.40–3.78) after stratification by knowledge level. Differences in knowledge thus accounted for none of the rural–urban gap in willingness.

Table 4: Willingness to vaccinate and third-dose pentavalent uptake by knowledge level within each arm

Knowledge level	Rural n	Rural willing, %	Rural Penta 3, %	Urban n	Urban willing, %	Urban Penta 3, %
Poor	427	48.2	73.3	304	71.4	74.7
Moderate	217	46.5	77.4	294	73.8	81.3
Good	56	39.3	69.6	102	73.5	75.5
All levels	700	47.0	74.3	700	72.7	77.6
$\chi^2(2); p$		1.62; 0.445	1.96; 0.375		0.48; 0.785	4.06; 0.131
Trend test, p		0.254	0.829		0.557	0.389
Crude OR, moderate/good vs poor		0.88 (0.65–1.19)	1.14 (0.80–1.62)		1.13 (0.81–1.57)	1.34 (0.94–1.91)
Adjusted OR per knowledge level ^a		0.89 (0.69–1.16)	1.00 (0.74–1.36)		1.10 (0.86–1.41)	1.09 (0.83–1.43)
Adjusted p		0.399	0.980		0.451	0.536

Note. Penta 3, third dose of pentavalent vaccine received by the index child; OR, odds ratio (95% confidence interval). Trend test, Cochran–Armitage. Pooled across arms, the Mantel–Haenszel OR for moderate or good versus poor knowledge was 0.98 (0.79–1.23) for willingness (homogeneity $p = 0.286$) and 1.23 (0.96–1.59) for Penta 3 uptake (homogeneity $p = 0.532$). The urban–rural OR for willingness was 3.01 (2.40–3.76) unadjusted and 3.01 (2.40–3.78) after Mantel–Haenszel stratification by knowledge level. ^a Within-arm logistic regression adjusted for sex, age group, education, income band, NHIS insurance, travel time, attitude level and campaign exposure; uptake models were additionally adjusted for willingness to vaccinate.

4 DISCUSSION

This comparative survey of 1,400 caregivers in the Eastern Region found that knowledge of immunisation was modest in both settings and consistently lower in rural communities. The typical caregiver answered about half of 14 basic questions correctly, more than half were classified as having poor knowledge, and urban residence was associated with a one-point higher score and twice the odds of a higher knowledge category. The urban advantage appeared on every item, was robust to correction for multiple testing and largely robust to the design effect, and was greatest for adult and maternal vaccination. Within each setting, however, knowledge was not associated with willingness to vaccinate or with childhood uptake, and it explained none of the rural–urban gap in willingness.

The magnitude of the rural–urban difference deserves careful interpretation. A difference of 1.09 points corresponds to roughly one additional item answered correctly, and a d of 0.44 means that the two distributions overlap substantially; a randomly chosen urban caregiver outscored a rural one only 62% of the time. The importance of the finding lies in its consistency rather than its size: the direction was identical on all 14 items, and the item ranking was nearly the same in the two arms. Rural and urban caregivers therefore share a common pattern of knowledge, with rural caregivers lower at every point, rather than having different kinds of deficit. This pattern is consistent with a compositional explanation. Educational attainment differed more between the arms than any characteristic other than occupation, income and access, and national analyses have documented a pronounced maternal education gradient in immunisation outcomes in Ghana [6,7]. Urban caregivers also had more contact with the health system, being more often insured, closer to services and in possession of the child health record. In Health Belief Model terms, such contacts act as cues to action and as occasions for learning [13], and multi-country decomposition attributes much of the rural–urban immunisation gap to these compositional factors [18].

The structure of knowledge is as informative as its level. Awareness that vaccination exists and that it prevents disease was the most secure knowledge in both arms, whereas the operational knowledge on which completion of the schedule depends was the least secure: fewer than half of caregivers in either setting knew that routine vaccines are free, that a mild illness is not a reason for postponement, where vaccination is offered locally and when the first dose is due. This profile mirrors earlier Ghanaian evidence. In rural Ghana, caregivers with positive attitudes had high general awareness but limited knowledge of later doses and incomplete coverage [15], and in the Okaikoi sub-metro of Accra, favourable attitudes coexisted with specific gaps in understanding of vaccine purpose and schedule in a well-served urban population [16]. The present study shows the same gaps in both settings of one region, which indicates that deficits in operational knowledge are not simply a product of rural isolation.

The low proportion of caregivers aware that routine vaccines are free is of particular concern. The 5As taxonomy treats affordability as a determinant separate from awareness and acceptance [12], and a caregiver who believes that vaccination attracts a charge faces a perceived financial barrier whatever the actual price. Similarly, the belief that a mild illness contraindicates vaccination is a recognised source of missed opportunities. Both misconceptions bear directly on the attrition seen in the parent study, in which dropout between the first and second MR doses was 61.7% in rural and 55.1% in urban communities, and on the dropout between early and later doses reported across sub-Saharan Africa [3,31]. The larger gap in knowledge of adult and maternal vaccination is consistent with the lower COVID-19 vaccine uptake among rural respondents in the same survey (37.0% vs 48.7%) and with Ghanaian evidence of rural–urban differences in adult vaccine acceptance [10,11]. Adult vaccination is promoted mainly through campaigns and media that reach urban residents more readily.

The absence of a within-arm association between knowledge and either willingness or uptake is an important finding. The urban arm had both more knowledge and more willingness, which produced a weak crude association when the arms were pooled, but this association disappeared once residence was taken into account, and stratifying by knowledge left the rural–urban OR for willingness unchanged at 3.01. The rural–urban difference in willingness therefore operated through factors other than the knowledge measured here. This is consistent with behavioural theory, in which knowledge is a distal determinant that acts through confidence, perceived constraints and the conversion of intention into action [14,32,33], and with the observation from rural Ghana that coverage can be suboptimal even where knowledge and attitudes are favourable [15]. Two qualifications apply. First, the low reliability of the knowledge score attenuates associations: corrected for an α of 0.518, the rural–urban d of 0.44 would correspond to about 0.61, and true associations with behaviour may likewise be understated. Second, the cross-sectional design cannot exclude reverse effects, since caregivers who have already completed a child's schedule may know more about it without that knowledge having caused vaccination.

The psychometric properties of the knowledge measure carry a methodological lesson. With a mean inter-item correlation of 0.07, the 14 items behaved as largely independent facts rather than as indicators of a single trait. This is common in knowledge, attitude and practice instruments, whose summed scores presume a unidimensionality that should be examined rather than assumed [34]. For such instruments, knowledge is better treated as a formative index, and inference is more secure at the item level, as reported in Table 3, than through a composite score with arbitrary categories.

4.1 Strengths and limitations

The study used probability sampling across four districts, a large sample with equal numbers in each arm, a single instrument applied concurrently in both settings and a knowledge measure that covered both childhood and adult vaccination. Effect sizes, CIs, a trend test, an ordinal model, false-discovery-rate control and a design-effect sensitivity analysis were reported, so that the practical size of each difference can be judged alongside its statistical significance.

Several limitations should be noted. First, the design was cross-sectional, so temporal and causal relationships cannot be established. Second, residence was assigned from the administrative classification of the district, and such districts are internally heterogeneous. Third, the primary analyses did not model clustering explicitly; the design-effect correction is a first-order approximation, and the true design effect may differ by item. Fourth, educational attainment was not recorded for 13.4% of respondents, more often in the rural arm, and the rural–urban comparison of knowledge was not adjusted for education or other socio-economic characteristics, so the extent to which the gap is compositional could not be quantified. Fifth, knowledge was assessed by interview and may be affected by social desirability, although interviews were private and conducted by enumerators unconnected to local services. Sixth, the low internal consistency of the knowledge score limits the interpretation of the composite and of its association with behaviour. Finally, the study was confined to one region, and the findings apply most directly to districts with similar settlement patterns and service configurations.

4.2 Implications for practice and research

The findings suggest that health education on immunisation in the Eastern Region should move beyond general messages about the value of vaccines towards the operational information on which each later contact depends: that vaccines are free, that minor illness is not a contraindication, when each dose is due and where it can be obtained. This information should be delivered at every contact, including child welfare clinics, antenatal care and outreach, and reinforced on the child health record. In rural communities, channels that respondents in the parent study rated as reaching them more effectively, notably community information centres, durbars and community health volunteers, are the logical vehicles. Because knowledge did not explain the rural–urban gap in willingness, improvement in knowledge alone is unlikely to close it, and education should be combined with measures that address distance, opening hours and confidence in vaccines. Future studies should use validated, multidimensional knowledge instruments, adjust rural–urban comparisons for socio-economic composition using multilevel models, and examine prospectively whether gains in operational knowledge reduce dropout.

5 CONCLUSION

Knowledge of immunisation among caregivers of children under five in the Eastern Region of Ghana was modest, and it was consistently lower in rural than in urban communities across all aspects measured, most of all for adult and maternal vaccination. In both settings, the weakest knowledge concerned the practical facts on which completion of the schedule depends: cost, timing, eligibility during minor illness and place of vaccination. Knowledge was not associated with willingness to vaccinate or with childhood uptake within either setting and did not account for the rural–urban gap in willingness. Health education that gives priority to operational information, particularly in rural communities, should be pursued alongside measures that reduce access barriers and strengthen confidence in vaccines.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

Statement of ethical approval

Ethical approval was obtained from the Research Ethics Committee of the University of Port Harcourt. Before entry into each selected community, permission was obtained from the chief and community leadership, to whom the purpose, procedures and duration of the study were explained. The study was conducted in accordance with the principles of respect for persons, beneficence and justice, and identification numbers were used in place of names to protect confidentiality.

Statement of informed consent

Written informed consent was obtained from every respondent before data collection, after the purpose of the study, the voluntary nature of participation, the right to withdraw at any time without penalty, and the absence of risk and of direct personal benefit had been explained in the language the respondent understood. Respondents were assured that refusal or withdrawal would not affect their access to health services.

Authors' contributions

RKE conceptualised the study, developed the research methodology, coordinated the research process, contributed to data interpretation, and led the preparation and revision of the manuscript. **MOY** contributed to the study design, methodology, data collection, interpretation of findings, and critical revision of the manuscript. **SMS** contributed to developing the research methodology, literature review, data collection, interpretation of findings, and manuscript revision. **JBN** contributed to the study design, methodological development, data collection, interpretation of results, and critical review of the manuscript. **JKA** contributed to the research methodology, data collection, data interpretation, and manuscript review. **RTM** contributed to the literature review, methodological refinement, interpretation of findings, and critical revision of the manuscript. **BA** contributed to the study design, research methodology, data analysis, interpretation of findings, and critical review of the manuscript. **BA** contributed to data collection, field coordination, data validation, interpretation of findings, and manuscript revision. **AA** contributed to the research methodology, data management, interpretation of results, and critical review of the manuscript. **PEOA** contributed to the literature review, research methodology, interpretation of findings, and substantive revision of the manuscript. **OV** contributed to field coordination, data collection, data validation, interpretation of findings, and manuscript review. **EAO** contributed to the study design, methodological review, interpretation of findings, and critical revision of the manuscript. **DS** contributed to the study design, methodological review, interpretation of findings, and critical revision of the manuscript. **BAA** and **BO** contributed to the conceptual development of the study, methodological review, interpretation of findings, and critical revision of the manuscript. All authors reviewed the manuscript, provided intellectual input, approved the final version for submission, and agreed to be accountable for the accuracy and integrity of their respective contributions to the work.

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