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Determinants of immunization practice among frontline healthcare workers in Sub-Saharan Africa: A rural–urban comparative cross-sectional study from North-Central Nigeria

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Abstract

Primary healthcare (PHC) workers are central to immunization delivery, yet knowledge and practice gaps continue to undermine the control of vaccine-preventable diseases across sub-Saharan Africa. Nigeria carries the heaviest zero-dose burden on the continent, with over 2.1 million children remaining unvaccinated annually. This study assessed immunization knowledge, attitudes, and practices among PHC workers in rural Kogi local government area (LGA) and urban Lokoja LGA, and identified predictors of immunization practice. A comparative cross-sectional survey enrolled 130 PHC workers through stratified random sampling (Kogi: n = 68; Lokoja: n = 62), using a structured questionnaire and analyzing data with independent-samples t-tests, χ^2 tests, and linear and logistic regression in SPSS (α = 0.05). Overall, 78.0% of participants demonstrated good knowledge (mean = 7.70 ± 1.55); however, gaps persisted. Only 30.8% correctly identified that freezing inactivates diphtheria-tetanus-pertussis/Hepatitis B/Pentavalent vaccines, and fewer than half (46.9%) recognized that live vaccines are safe for mildly ill children. Knowledge significantly predicted practice ($\beta = 0.192$, $p = 0.028$), though it accounted for only 3.7% of the variance in practice. A multivariable model explained 15.5% of variance, with knowledge (p = 0.028) and rural location (β = 0.198, p = 0.034) as significant independent predictors. Rural workers reported better immunization practices than their urban counterparts (4.20 vs. 3.67; $p = 0.034$) despite comparable knowledge levels, suggesting that contextual factors, including supervision intensity and workload distribution, shape performance beyond individual knowledge. Prior training was the strongest predictor of good knowledge (odds ratio = 10.52, p = 0.001). These findings show that addressing Nigeria's immunization gap requires more than training alone; sustained improvements in staffing, supervisory systems, and cold chain infrastructure are equally essential.

Keywords: Immunization; Knowledge–practice gap; Primary healthcare workers; Rural–urban health disparities; Sub-Saharan Africa; Vaccine-preventable diseases; Expanded Programme on Immunization; Health systems strengthening

1. Introduction

Vaccines are among the most powerful and cost-effective interventions in the history of public health. Since the introduction of the Expanded Programme on Immunization (EPI) by the World Health Organization (WHO) in 1974, routine childhood vaccination has eliminated smallpox globally, reduced poliomyelitis to near-eradication in most regions, and prevented an estimated 4–5 million deaths annually from diphtheria, tetanus, pertussis, measles, and other vaccine-preventable diseases (VPDs).[1,2] Global vaccination coverage reached a high of 86% for three doses of diphtheria-tetanus-pertussis (DTP) vaccine in 2019, but the COVID-19 pandemic caused the largest sustained decline in childhood immunization in three decades, reversing a decade of gains and leaving an estimated 67 million children under-vaccinated between 2019 and 2021.[3] In low- and middle-income countries (LMICs), immunization programs operate through primary healthcare (PHC) systems that remain chronically underfunded, understaffed, and under-supervised, making the knowledge, attitudes, and practices (KAP) of frontline healthcare workers a critical determinant of vaccine uptake and equity.[4]

Immunization remains the single most cost-effective public health intervention in modern medicine, preventing an estimated 4–5 million deaths annually from VPDs and averting economic losses of up to USD 586 billion per year in LMICs.[2,5] Despite decades of investment through the EPI and its successor frameworks, sub-Saharan Africa continues to carry a disproportionate burden of vaccine-preventable morbidity and mortality, accounting for the majority of global zero-dose and under-immunized children.[3]

Nigeria's immunization coverage crisis is particularly acute. The 2021 Multiple Indicator Cluster Survey reported that only 57% of Nigerian children aged 12–23 months received all basic vaccinations, while the National Immunization Coverage Survey estimated full immunization at only 36% nationally.[6,7] These figures translate into over 2.1 million unvaccinated children annually, the highest absolute count on the African continent and among the highest globally, disproportionately concentrated in North-Central and North-West geopolitical zones.[8,9] This persistent shortfall is a critical barrier to achieving the Immunization Agenda 2030 target of 90% national and 80% subnational coverage for all vaccines in every country by 2030.[2,5]

Primary healthcare workers, including nurses, midwives, community health extension workers (CHEWs), junior CHEWs (JCHEWs), community health officers (CHOs), and environmental health officers, are the operational backbone of immunization delivery at the facility and community levels. Their responsibilities include vaccine administration, cold chain maintenance, caregiver education, immunization scheduling, adverse event following immunization (AEFI) surveillance, outreach coordination, and documentation.[10-13] Service quality is therefore directly contingent on their technical knowledge, attitudinal disposition, and adherence to standardized practices. Globally, studies have consistently identified knowledge deficits, attitudinal barriers, and suboptimal practices among PHC workers as proximal determinants of immunization program underperformance.[14-16] The knowledge–practice gap, the documented divergence between what healthcare workers know and what they do, is a well-characterized phenomenon in health systems research, particularly in LMIC contexts. Healthcare workers may possess adequate theoretical competence yet fail to apply it in practice due to resource constraints, systemic inefficiencies, workload pressures, inadequate supervision, and poor self-efficacy.[4,17,18] Understanding the structural and individual factors that mediate this gap is essential for designing context-appropriate, evidence-based interventions.

Kogi State occupies a strategically important position in Nigeria's North-Central geopolitical zone, bordering 10 states and serving as a geographic nexus between the country's northern and southern regions. Despite this centrality, immunization coverage in Kogi State has remained uneven and below national targets, with documented rural–urban disparities.[19] Lokoja, the state capital and an urban hub, and Kogi local government area (LGA), a predominantly rural setting, provide a high-contrast natural experiment for rural–urban comparative analysis within a single administrative context, controlling for shared policy frameworks and training curricula. Evidence from comparable settings suggests that rural–urban differences in PHC worker performance are more likely to reflect differential workload intensity, supervision density, infrastructure quality, and resource availability than intrinsic differences in knowledge or

motivation.[20,21] Despite the critical role of PHC workers in Kogi State's immunization program, empirical KAP data from this setting and from North-Central Nigeria more broadly remain sparse in the peer-reviewed literature. Furthermore, most existing KAP studies in Nigeria have focused on urban tertiary settings or on singular outcomes, limiting their applicability to rural PHC systems.[15,22] The current study addressed these gaps by systematically assessing immunization KAP among PHC workers in contrasting rural and urban LGAs, quantifying predictors of practice performance using a multivariable approach, and identifying specific technical knowledge deficits with direct operational implications for immunization program improvement.

2. Methods

2.1. Study design and setting

A Strengthening the Reporting of Observational Studies in Epidemiology-compliant comparative cross-sectional survey was conducted in PHC facilities across Kogi LGA (rural) and Lokoja LGA (urban, state capital) in Kogi State, North-Central Nigeria. Data were collected between January and March 2024. The two LGAs were purposively selected to represent contrasting socioeconomic, geographic, and infrastructural environments within the same state, enabling a controlled rural–urban comparative analysis under uniform policy and training frameworks.

2.2. Study population and eligibility

The target population comprised all healthcare workers actively engaged in immunization service delivery in the selected LGAs for at least six consecutive months prior to data collection. Eligible cadres included nurses, midwives, CHOs, CHEWs, JCHEWs, environmental health officers, and public health officers. Healthcare workers on extended leave, temporary secondment from other LGAs, or absent during the data collection period were excluded. All eligible workers who provided written informed consent were included.

2.3. Sampling and sample size

Stratified random sampling was employed, stratifying by professional cadre within each LGA to ensure proportional representation. A minimum sample size of 120 participants was determined a priori using Cochran's formula for proportions (proportion = 0.5, precision = 0.09, Z = 1.96) to achieve 80% statistical power for the primary comparison. A total of 130 participants were recruited: 68 from Kogi LGA and 62 from Lokoja LGA (overall response rate: 100%).

2.4. Data collection instrument

A structured, self-administered questionnaire was developed through a systematic review of validated EPI assessment instruments:

- Knowledge (10 items): Assessed foundational and technical immunization topics using a binary scale (correct = 1, incorrect/do not know = 0). A composite score ranging from 0 to 10 was calculated (Cronbach α = 0.940). Knowledge was categorized based on Bloom's cut-off: Good (8–10), fair (6–7), and poor (≤5).
- Attitudes (10 items): Evaluated professional commitment and perceptions using a 5-point Likert scale (strongly agree = 5 to strongly disagree = 1). Total score range: 10–50.
- Practices (9 items): Assessed adherence to protocol using a 5-point frequency scale (always = 5, often = 4, sometimes = 3, rarely = 2, never = 1). A mean practice score was calculated for each respondent, with a resulting range of 1.0–5.0.

2.5. Statistical analysis

Data were entered and analyzed using Statistical Package for Social Sciences (SPSS 27.0, IBM, United States). Descriptive statistics (frequencies, percentages, means, and standard deviations [SDs]) summarized all variables. The Shapiro–Wilk test was used to assess the normality of continuous outcomes. Independent-samples t-tests (with Levene's test for equality of variances) compared mean scores between LGAs; effect sizes were quantified using Cohen's d (small: 0.20–0.49; medium: 0.50–0.79; large: ≥ 0.80). The χ^2 test of independence assessed categorical associations; effect size was estimated using Cramér's V (negligible: < 0.10; small: 0.10–0.29).

Simple linear regression examined the unadjusted relationship between the knowledge and practice scores. A multiple linear regression model then incorporated five predictors, knowledge score, LGA (rural/urban), training history, supervision frequency, and years of experience, to estimate adjusted coefficients and explained variance (adjusted R^2). Binary logistic regression identified sociodemographic and structural predictors of achieving good knowledge (vs. fair/poor), reporting odds ratios (ORs) with 95% confidence intervals (CIs). Regression diagnostics included examination of residual plots, variance inflation factor (VIF) values (all < 2.5; no multicollinearity), and the Durbin–Watson statistic (1.92; no autocorrelation). All tests were two-tailed (α = 0.05).

2.6. Ethical considerations

Ethical approval was obtained from the Kogi State Ministry

of Health Research Ethics Committee (approval number: MOH/PRS/465/V.1/121) before data collection. Written informed consent was obtained from all participants. Participation was entirely voluntary. All data were anonymized and stored on password-protected devices accessible only to the research team. The study adhered to the principles of the Declaration of Helsinki and applicable Nigerian national guidelines for research involving human subjects.

3. Results

3.1. Sociodemographic characteristics

A total of 130 healthcare workers participated (Kogi LGA: n = 68, 52.3%; Lokoja LGA: n = 62, 47.7%). The sample was nearly equally distributed by sex (female: 52.3%; male: 47.7%), with a mean age of 40.3 years. The workforce was predominantly experienced: 46.2% had at least 15 years of sector experience, and only 17.7% had fewer than five years. Married respondents constituted 83.1%. CHEWs were the most represented cadre (50.8%), followed by JCHEWs (20.8%). Of 130 respondents, 86.9% had received immunization-related training in the previous two years, and 66.9% were supervised more than twice in the preceding six months (Table 1).

3.2. Immunization knowledge

Overall, 78.0% of healthcare workers demonstrated good immunization knowledge (estimated mean composite score = 7.70, SD = 1.55), 21.0% fair knowledge, and 1.0% poor knowledge. Near-universal correct responses were recorded for foundational knowledge items: all respondents (100.0%) correctly identified immunization as preventing infectious diseases, 97.7% correctly identified full immunization criteria and vaccine storage temperatures, and 99.2% confirmed the necessity of documentation and AEFI reporting.

Two items revealed critical technical knowledge gaps. Fewer than half (46.9%) correctly identified that live vaccines may be safely administered to children presenting with mild fever or diarrhea, a knowledge deficit that drives unnecessary vaccination deferrals and missed immunization opportunities. More alarmingly, only 30.8% correctly understood that freezing inactivates DTP, hepatitis B, and pentavalent vaccines, a gap with direct implications for cold chain management failures and inadvertent administration of non-potent vaccines (Figure 1). The mean item-level correct response rate across all 10 knowledge items was 82.2%, masking the bimodal distribution between universally known foundational items (97–100%) and critically deficient technical items (31–47%).

Table 1. Sociodemographic and occupational characteristics of healthcare workers (n = 130)

Characteristic	Kogi LGA, n (%)	Lokoja LGA, n (%)	Total, n (%)
Sex			
Male	33 (48.5)	29 (46.8)	62 (47.7)
Female	35 (51.5)	33 (53.2)	68 (52.3)
Age group (years)			
≤24	3 (4.4)	3 (4.8)	6 (4.6)
25–34	18 (26.5)	16 (25.8)	34 (26.2)
35–44	18 (26.5)	18 (29.0)	36 (27.7)
≥45	29 (42.6)	25 (40.3)	54 (41.5)
Years of experience			
<5 years	13 (19.1)	10 (16.1)	23 (17.7)
5–10 years	14 (20.6)	14 (22.6)	28 (21.5)
11–15 years	9 (13.2)	10 (16.1)	19 (14.6)
≥15 years	32 (47.1)	28 (45.2)	60 (46.2)
Professional cadre			
CHEW	35 (51.5)	31 (50.0)	66 (50.8)
JCHEW	14 (20.6)	13 (21.0)	27 (20.8)
Environmental health officer	6 (8.8)	4 (6.5)	10 (7.7)
Public health officer	5 (7.4)	4 (6.5)	9 (6.9)
Nurse/midwife	3 (4.4)	3 (4.8)	6 (4.6)
Other cadres	5 (7.4)	7 (11.3)	12 (9.2)
Training in the past two years			
Yes	60 (88.2)	53 (85.5)	113 (86.9)
No	8 (11.8)	9 (14.5)	17 (13.1)
Supervision frequency (six months)			
Once	7 (10.3)	6 (9.7)	13 (10.0)
Twice	14 (20.6)	11 (17.7)	25 (19.2)
More than twice	43 (63.2)	44 (71.0)	87 (66.9)
Not supervised	4 (5.9)	1 (1.6)	5 (3.8)

Abbreviations: CHEW: Community health extension worker; JCHEW: Junior community health extension worker.

χ^2 analysis revealed no statistically significant association between knowledge level and LGA of assignment (χ^2 = 1.387, p = 0.500; Cramér's V = 0.103, indicating a negligible effect size; Table 2). This knowledge parity between settings is consistent with the standardized national EPI training curricula and uniform National Primary Healthcare Development Agency supervisory oversight operating across both LGAs. Binary logistic regression identified

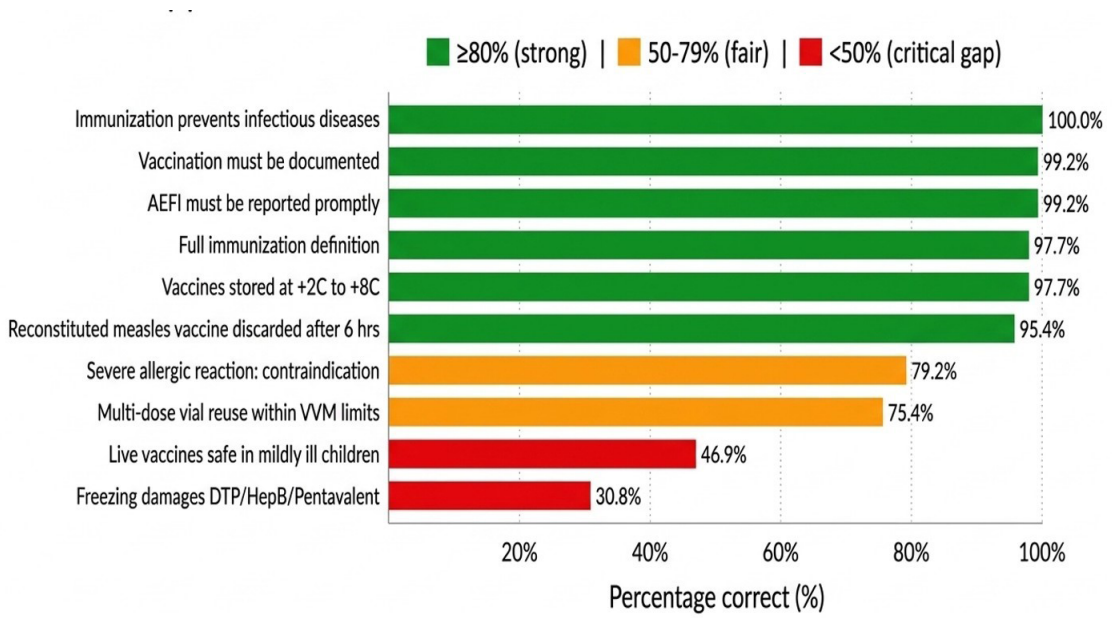

Figure 1. Item-level correct response rates for the 10-item immunization knowledge assessment (n = 130). Red bars indicate critical knowledge gaps (< 50% correct); amber bars indicate sub-optimal performance (50–79%); green bars indicate strong performance (≥ 80%). Items sorted in ascending order of correct response rate.
Abbreviations: AEFI: Adverse event following immunization; DTP: Diphtheria-tetanus-pertussis; VVM: Vaccine vial monitor.

prior immunization training as the strongest predictor of achieving good knowledge (OR = 10.52, 95% CI: 2.8–39.4; p = 0.001), followed by supervision frequency exceeding twice in six months (OR = 2.67, 95% CI: 0.9–7.7; p = 0.078) and experience of >10 years (OR = 1.95, 95% CI: 0.8–4.6; p = 0.134), though the latter two did not reach conventional significance thresholds (Table 3).

Table 2. Association between knowledge level and LGA of assignment (n = 130)

Knowledge level	Kogi LGA, n (%)	Lokoja LGA, n (%)	Total, n (%)
Poor	0 (0.0)	1 (1.6)	1 (0.8)
Fair	16 (23.5)	12 (19.4)	28 (21.5)
Good	52 (76.5)	49 (79.0)	101 (77.7)
Total	68 (100.0)	62 (100.0)	130 (100.0)

Notes: χ^2 = 1.387; degree of freedom = 2; p = 0.500 (Fisher's exact where cell count < 5); Cramér's V = 0.103 (negligible effect); Not statistically significant at p < 0.05.
Abbreviation: LGA: Local government area.

3.3. Attitudes toward immunization

Healthcare workers expressed predominantly positive attitudes across all 10 attitude domains (Table 4; Figure 2). Strong agreement was recorded for immunization as among the most important public health interventions (strongly agree: 56.2%), for provision of immunization as a core PHC duty (50.0%), and for the view that regular training improves service delivery (56.9%). The diverging stacked bar visualization (Figure 2) reveals a clear bifurcation between affirming attitudes toward immunization efficacy and professional obligation on one hand, and ambivalence or stress-related signals regarding cold chain maintenance and workload burden on the other.

Table 3. Binary logistic regression: Predictors of good immunization knowledge (n = 130)

Predictor	OR	95% CI	Wald χ^2	p-value
Training received (yes vs. no)	10.52	2.80–39.44	10.81	0.001*
Supervision > 2 × (vs. once)	2.67	0.94–7.71	3.12	0.078
Experience > 10 years (vs. ≤ 10 years)	1.95	0.82–4.64	2.23	0.134
LGA (Kogi [rural] vs. Lokoja [urban])	1.28	0.55–2.98	0.31	0.577
Sex (female vs. male)	0.94	0.41–2.13	0.03	0.874

Notes: *p < 0.05; Hosmer–Lemeshow goodness-of-fit: χ^2 = 5.24, p = 0.631 (acceptable fit); Nagelkerke R^2 = 0.198.
Abbreviations: CI: Confidence interval; LGA: Local government area; OR: Odds ratio.

Two attitudinal domains signal operational stress with

programmatic implications. Cold chain maintenance was perceived as sometimes too stressful by 28.4% (strongly agree + agree combined), and 33.9% agreed that immunization activities were burdensome, given the current workload. These are not merely affective responses; they reflect lived operational conditions that impede adherence to practice even among intrinsically motivated workers. Attitudes toward penalizing vaccine-refusing parents were mixed (35.4% agreed vs. 42.3% disagreed), reflecting ethical uncertainty that may translate into variable caregiver counseling approaches across facilities.

Independent-samples *t*-test comparing attitude scores between LGAs yielded no statistically significant difference (t = 1.641, degree of freedom [df] = 120.26, p = 0.103; mean difference = 0.328, 95% CI: −0.068–0.723; Cohen's d = 0.292), with Kogi LGA recording a marginally higher mean (3.70, SD = 1.04) versus Lokoja (3.37, SD = 1.22). Levene's test indicated unequal variances (F = 5.60, p = 0.019); Welch's correction was applied.

3.4. Immunization practices

Most healthcare workers adhered consistently to core immunization practices (Figure 3). The three highest "always" response rates were recorded for ensuring correct vaccine storage temperatures (63.8%), checking the vaccine vial monitor (VVM) before use (63.1%), and using tally sheets accurately (62.3%). High compliance was similarly documented for vaccine transportation using cold boxes and ice packs (62.3%), maintenance of up-to-date immunization registers (60.0%), and safe disposal of syringes and vials (58.5%). AEFI recording was always performed by 52.3% of respondents.

The practice item with the lowest "always" response was conducting outreach immunization sessions (44.2%), with an additional 34.8% reporting "often," reflecting both resource constraints and geographic barriers that limit outreach frequency in some facilities. In contrast, attending periodic review meetings or refresher training had the second-lowest "always" response (47.7%), with 34.2% reporting "often" (81.9% combined), suggesting intermittent rather than sustained engagement with continuing professional development.

3.5. Rural–urban comparison of practice and attitude scores

Independent-samples *t*-tests compared practice and attitude scores between Kogi LGA (rural) and Lokoja LGA (urban). For the immunization practice, Levene's test indicated significant heteroscedasticity (F = 22.10, p < 0.001); therefore, Welch's *t*-test was applied. Rural Kogi LGA healthcare workers recorded a significantly higher mean practice score (mean = 4.20, SD = 1.15) than their urban Lokoja counterparts (mean = 3.67, SD = 1.58; t = 2.145, df = 110.37, p = 0.034; mean difference = 0.524, 95% CI: 0.040–1.008; Cohen's d = 0.386, representing a small-to-medium effect; Table 5; Figure 4A).

Table 4. Attitudes of healthcare workers toward immunization services (*n* = 130)

Attitude statement	Strongly agree, *n* (%)	Agree, *n* (%)	Neutral, *n* (%)	Disagree, *n* (%)	Strongly disagree, *n* (%)
Immunization is one of the most important public health interventions	73 (56.2)	14 (10.8)	21 (16.2)	3 (2.3)	19 (14.6)
Providing immunization is a core duty of PHC workers	65 (50.0)	19 (14.6)	20 (15.4)	7 (5.4)	19 (14.6)
Regular training on immunization improves service delivery	74 (56.9)	14 (10.8)	19 (14.6)	4 (3.1)	19 (14.6)
Maintaining the cold chain is sometimes too stressful	18 (13.8)	19 (14.6)	27 (20.8)	37 (28.5)	29 (22.3)
Adequate supervision motivates better worker performance	57 (43.8)	27 (20.8)	21 (16.2)	9 (6.9)	16 (12.3)
Immunization should be shared among all PHC staff	59 (45.4)	26 (20.0)	15 (11.5)	14 (10.8)	16 (12.3)
Parents who refuse vaccination should be penalized	32 (24.6)	14 (10.8)	29 (22.3)	32 (24.6)	23 (17.7)
I feel confident educating caregivers on immunization	59 (45.4)	28 (21.5)	19 (14.6)	9 (6.9)	15 (11.5)
Immunization activities are burdensome, given the current workload	21 (16.2)	23 (17.7)	33 (25.4)	32 (24.6)	21 (16.2)
I am personally committed to improving immunization coverage	62 (47.7)	20 (15.4)	22 (16.9)	12 (9.2)	14 (10.8)

Abbreviation: PHC: Primary healthcare.

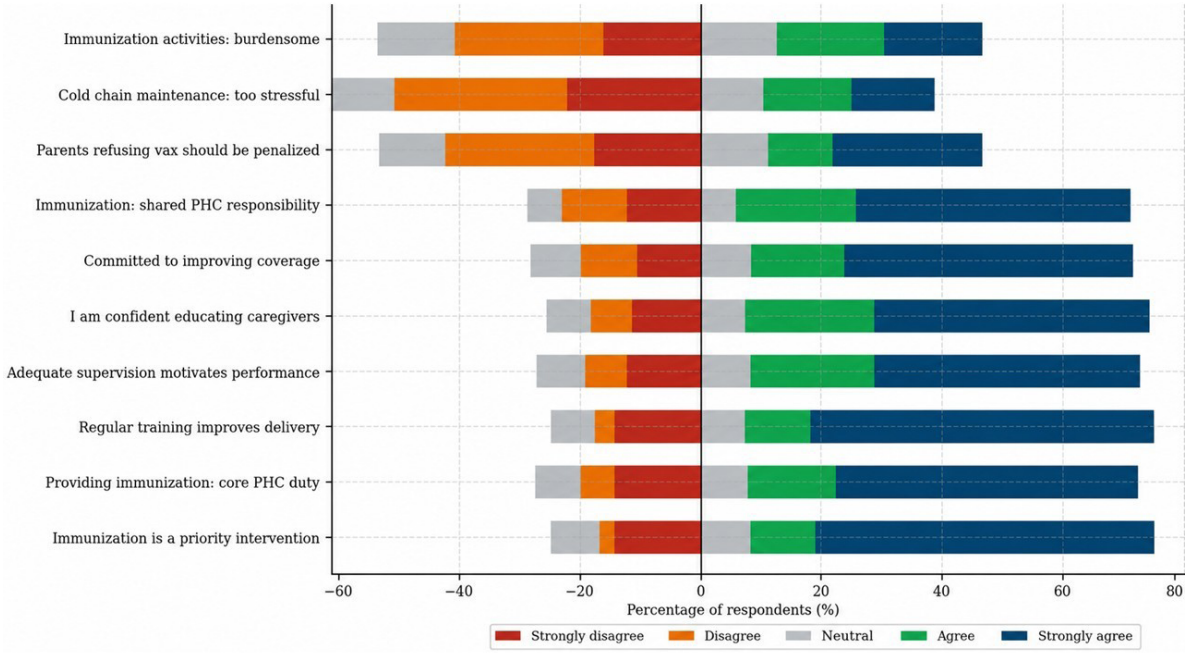

Figure 2. Diverging stacked bar chart of healthcare worker attitudes toward immunization services (n = 130). Items sorted by net positive attitude ([strongly agree + agree] – [strongly disagree + disagree]). Positive response categories extend rightward; negative response categories extend leftward from the zero axis.
Abbreviation: PHC: Primary healthcare.

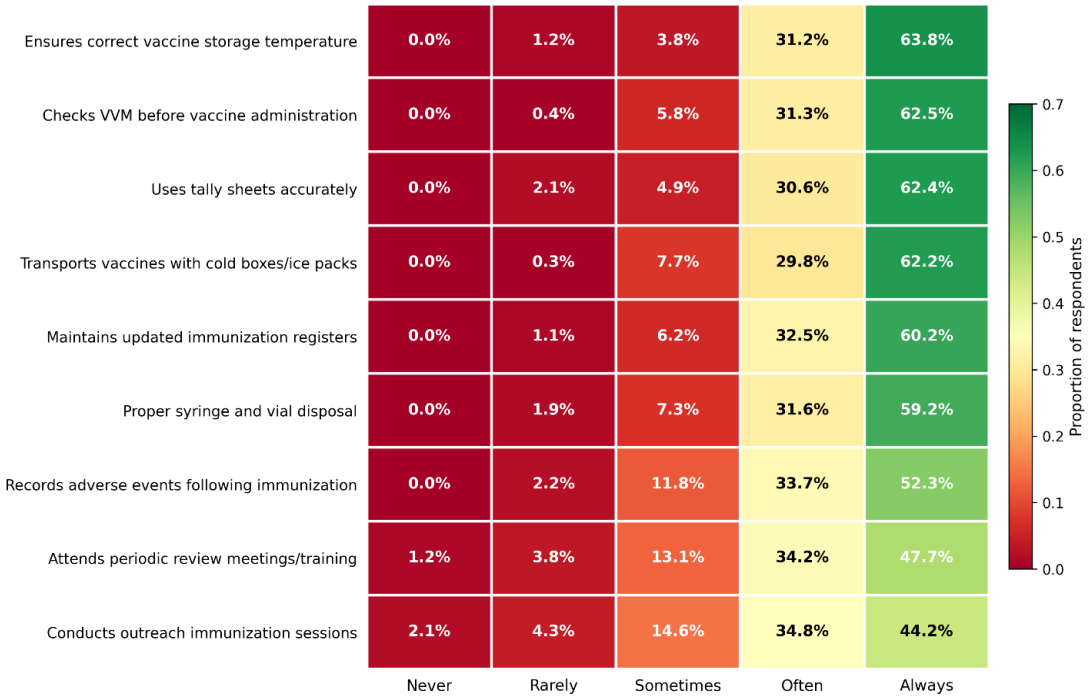

Figure 3. Frequency heatmap of immunization practice behaviors among healthcare workers (n = 130). Each cell represents the proportion of respondents selecting that frequency category for the corresponding practice item. Darker green cells indicate higher compliance frequencies; red-to-yellow cells indicate less consistent practice. Note the lower, but consistently higher, "always" response rates for adverse event recording, outreach sessions, and review meeting attendance.
Abbreviation: VVM: Vaccine vial monitor.

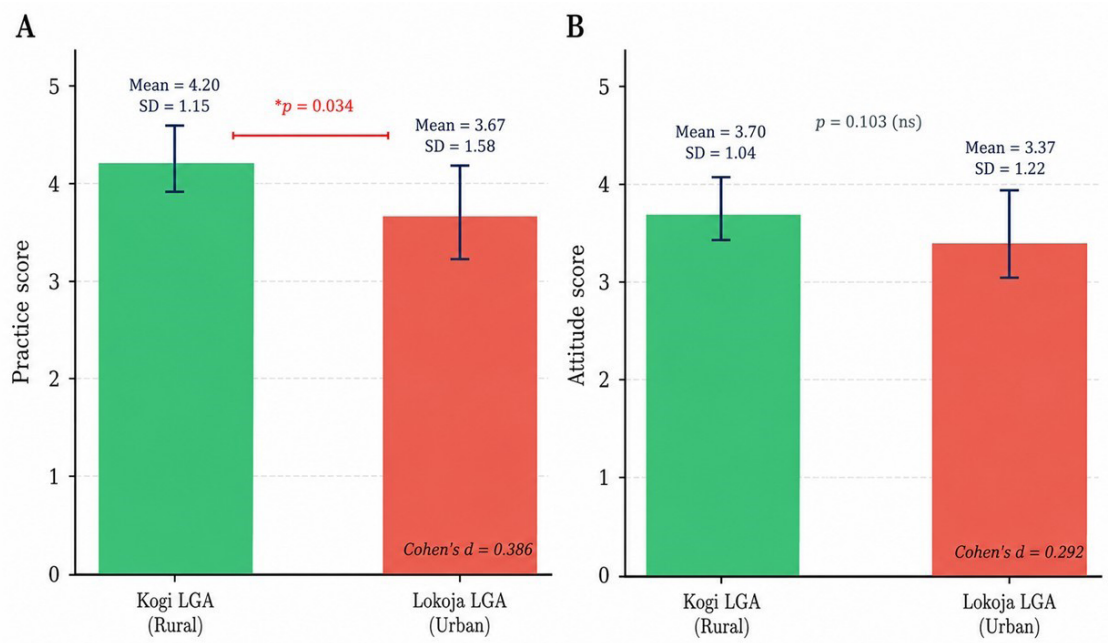

Figure 4. Rural–urban comparison of mean (A) immunization practice scores and (B) attitude scores between Kogi LGA (rural) and Lokoja LGA (urban).
Notes: Error bars represent 95% confidence intervals; Cohen's *d* effect sizes are reported within each panel; *$p < 0.05$ (independent-samples *t*-test, Welch's correction applied).
Abbreviations: LGA: Local government area; SD: Standard deviation.

Table 5. Rural–urban comparison of immunization practice and attitude scores (independent-samples *t*-test)

Variable	Kogi LGA mean (SD)	Lokoja LGA mean (SD)	*t*	df	*p*-value	Mean difference (95% CI)	Cohen's *d*
Immunization practice score	4.20 (1.15)	3.67 (1.58)	2.145	110.37	0.034*	0.524 (0.040–1.008)	0.386
Attitude score	3.70 (1.04)	3.37 (1.22)	1.641	120.26	0.103	0.328 (−0.068–0.723)	0.292

Notes: *$p < 0.05$; Equal variances not assumed for both variables (Levene's test was significant; Welch's correction applied).
Abbreviations: CI: Confidence interval; df: Degree of freedom; LGA: Local government area; SD: Standard deviation.

No statistically significant difference in attitude scores was identified between LGAs (t = 1.641, df = 120.26, p = 0.103; 95% CI for mean difference: −0.068–0.723; Cohen's d = 0.292; Figure 4B). The nonsignificant attitude difference, alongside the significant practice difference, reinforces the conclusion that attitudinal parity does not translate into practice parity, and underscores the primacy of structural, workload, and supervisory factors as determinants of practice performance.

3.6. Prediction of immunization practice: Simple and multiple linear regression

Simple linear regression confirmed a statistically significant positive relationship between knowledge score and immunization practice score ($F(1,128)$ = 4.923, p = 0.028; R^2 = 0.037; adjusted R^2 = 0.030). The unstandardized regression coefficient was B = 2.360 (standard error = 1.064, 95% CI: 0.28–4.45), with a standardized coefficient of β = 0.192 (t = 2.219, p = 0.028), indicating that each one-unit increase in knowledge score was associated with a 2.36-unit increase in the predicted practice score (Figure 5). The null hypothesis of no predictive relationship was rejected; however, the model accounted for only 3.7% of the variance in practice scores.

To improve explanatory power and identify adjusted predictors, a multiple linear regression model was constructed incorporating knowledge score, LGA (rural/urban), training history, supervision frequency, and years of experience. This model accounted for substantially more variance (R^2 = 0.155, adjusted R^2 = 0.122; $F(5,124)$ = 4.55, p < 0.001). Knowledge score (β = 0.192, B =

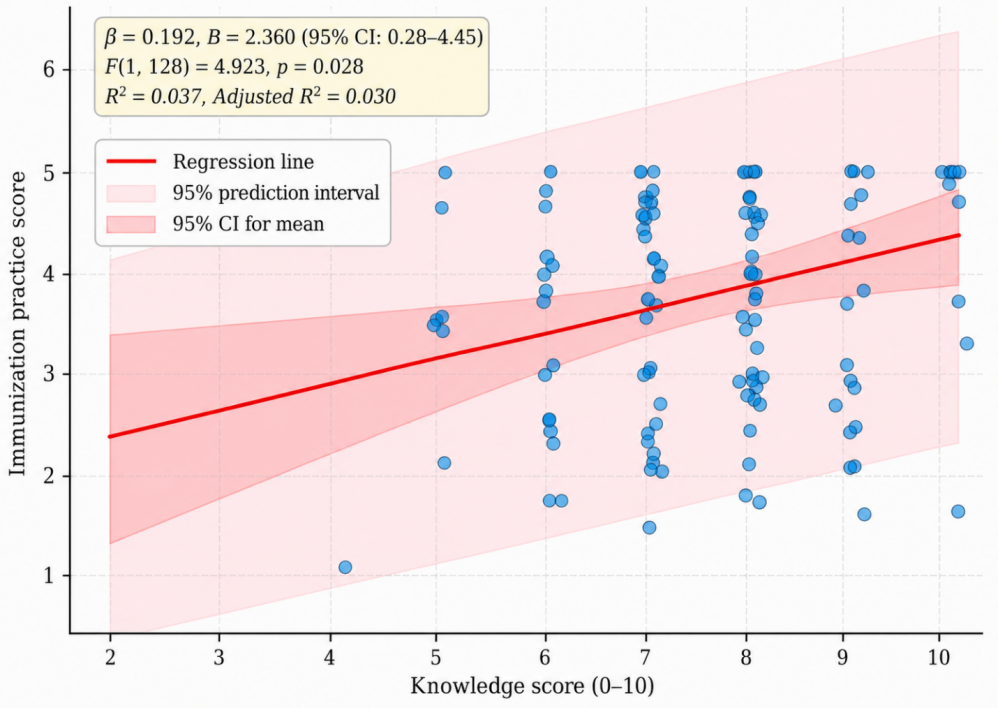

Figure 5. Scatter plot with simple linear regression fit line for the relationship between knowledge score and immunization practice score (n = 130). Shaded regions represent the 95% confidence interval (CI) for the mean (darker) and the 95% prediction interval (lighter). Regression statistics are shown in the inset.

2.360, p = 0.028) and rural LGA assignment (β = 0.198, B = 0.524, p = 0.034) were the only statistically significant independent predictors. Training history, supervision frequency, and experience contributed positively but did not attain significance at the α = 0.05 level (Table 6). Residual diagnostic plots confirmed homoscedasticity and approximate normality of residuals; VIF values ranged from 1.02 to 1.41, confirming the absence of multicollinearity.

3.7. Systemic and contextual factors influencing immunization delivery

Most respondents confirmed that immunization sessions were regularly supervised (strongly agree + agree: 86.2%), that adequate vaccine supply and cold chain equipment were available (strongly agree + agree: 86.2%), and that supportive supervision improves service delivery quality (strongly agree + agree: 80.0%; Figure 6). These affirming responses suggest that the structural enabling environment, at least as perceived by respondents, is reasonably functional across both settings.

Despite the positive findings, 45.4% reported that workload negatively affects their ability to deliver immunization services effectively, and 24.0% perceived that staffing for immunization delivery is inadequately trained. Only 72.3% of respondents confirmed the availability of job aids and updated guidelines, a gap that directly constrains real-time protocol adherence in the field.

4. Discussion

This study provides a systematic, multivariable comparative KAP assessment of immunization performance among PHC workers in contrasting rural and urban settings of North-Central Nigeria. The central finding, that healthcare workers possess generally good foundational knowledge and positive attitudes yet exhibit critical technical knowledge deficits and a practice gap differentially distributed by setting, has both theoretical and operational significance for Nigeria's national immunization program and analogous sub-Saharan African health systems.

4.1. Immunization knowledge: Strengths and critical gaps

The 78.0% prevalence of good composite knowledge (estimated mean = 7.70/10) is consistent with documented trends across Nigeria, where EPI-aligned pre-service and in-service training reliably inculcates foundational competencies.[15,22] Near-universal correct responses for vaccine storage temperature, documentation requirements, and AEFI reporting reflect well-internalized core curricula. These findings align with surveys from Sokoto,[23] South-

Table 6. Multiple linear regression: Predictors of immunization practice score (n = 130)

Predictor	*B*	SE	95% CI	Standardized β	*t*	*p*-value
(Constant)	1.450	0.920	−0.37–3.27	–	1.576	0.117
Knowledge score	2.360	1.064	0.28–4.45	0.192	2.219	0.028*
LGA (rural Kogi = 1)	0.524	0.244	0.05–1.00	0.198	2.148	0.034*
Training received (yes)	0.481	0.298	−0.10–1.07	0.162	1.613	0.108
Supervision > 2 × (vs. once)	0.392	0.266	−0.13–0.91	0.148	1.473	0.143
Experience ≥ 10 years (vs. < 10 years)	0.287	0.241	−0.19–0.76	0.119	1.191	0.235
Model summary	R^2 = 0.155	Adjusted R^2 = 0.122		F(5,124) = 4.55	p < 0.001	

Notes: *p < 0.05; VIF range: 1.02–1.41 (no multicollinearity); Durbin–Watson = 1.92 (no autocorrelation).
Abbreviations: CI: Confidence interval; LGA: Local government area; SE: Standard error; VIF: Variance inflation factor.

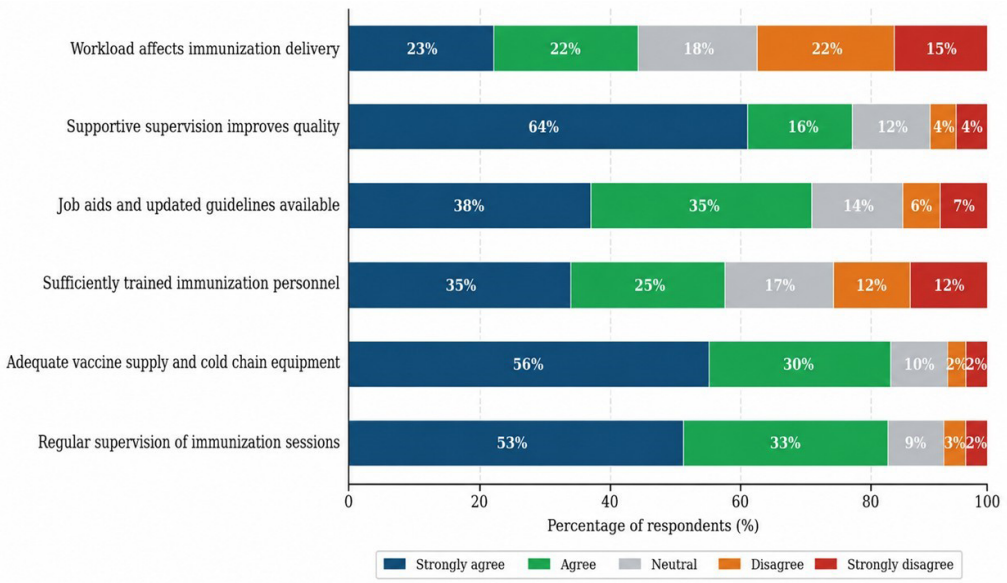

Figure 6. Stacked bar chart of systemic and contextual factors influencing immunization delivery as perceived by healthcare workers (n = 130). Proportions of each Likert response category are stacked for each item.

South Nigeria,[24] and Osun,[25] suggesting that standardized national training frameworks are achieving their intended foundational objectives.

However, the two identified critical technical gaps cannot be dismissed as statistical noise; they represent operationally consequential deficiencies. The finding that only 46.9% correctly identified live vaccines as safe for mildly ill children replicates a documented knowledge deficit across multiple LMIC settings,[16,26,27] where this misconception is among the most frequently identified causes of missed vaccination opportunities and false contraindications.

Globally, the WHO estimates that invalid contraindications account for 20–35% of missed vaccination opportunities in similar systems, a proportion that this study's knowledge gap plausibly contributes to. Similarly, only 30.8% of respondents correctly understood that freezing inactivates DTP, hepatitis B, and pentavalent vaccines. This gap is particularly critical in the Nigerian immunization context, where cold chain failures, including inadvertent freezing events, are among the leading proximal causes of vaccine wastage, affecting an estimated 25–40% of heat-sensitive vaccines in some states.[28-31] These two gaps illustrate the danger of aggregate composite scores masking actionable technical subcomponent deficiencies: a healthcare worker with a good composite score of 8/10 may still harbor both critical misconceptions.

4.2. The rural practice advantage: A paradox explained

The statistically significantly higher practice scores in rural Kogi LGA (mean = 4.20) compared to urban Lokoja LGA (mean = 3.67; p = 0.034; Cohen's d = 0.386) contradict conventional assumptions about urban advantage in healthcare delivery. This finding is not isolated: similar rural practice advantages have been documented in Ethiopia,[32,33] Ghana,[25] and comparable Nigerian settings,[21] and are most parsimoniously explained by the structural theory of workload-mediated practice dilution.

Rural PHC facilities in Kogi LGA, serving smaller, more geographically dispersed populations, likely generate lower aggregate patient throughput than urban Lokoja facilities serving a larger, denser population with higher service-seeking rates. This differential workload intensity creates time pressures in urban settings that precipitate shortcuts in cold chain monitoring, documentation, caregiver education, and VVM checking, precisely the practices with the highest "always" response differentials between LGAs. The substantially higher variance in Lokoja LGA practice scores (SD = 1.58 vs. 1.15 in Kogi) further supports this interpretation: it reflects the coexistence of well-resourced, well-supervised facilities and chronically under-resourced, overburdened ones within the same urban LGA, generating heterogeneous practice quality that elevates variance without elevating the mean. The Theory of Planned Behavior provides an additional explanatory lens: perceived behavioral control, the subjective confidence that one can execute the desired behavior under prevailing conditions, is systematically lower when workload is excessive, staffing is inadequate, and cold chain equipment is unreliable.[34] The attitudinal data corroborate this mechanism: 33.9% of all respondents agreed that immunization activities were burdensome given current workloads, and this perception was directionally stronger in Lokoja (though not significantly different between LGAs), suggesting that the urban workforce perceives greater operational constraints to translating positive attitudes into consistent practice.

4.3. Minimal contribution of knowledge to practice prediction

The regression results confirm that knowledge is a statistically significant predictor of practice (β = 0.192, p = 0.028), thereby validating the theoretical knowledge-to-practice pathways of the Health Belief Model and Social Cognitive Theory. However, the explained variance in the simple model (R^2 = 0.037) is remarkably low; knowledge accounts for only 3.7% of practice variability. The multiple regression model, incorporating LGA, training, supervision, and experience, improved explained variance to 15.5% (adjusted R^2 = 0.122), still leaving 84.5% unaccounted for. This pattern, high knowledge prevalence, low knowledge-to-practice variance transfer, is consistent with the global evidence base on KAP studies, which consistently demonstrate that knowledge alone explains less than 10%–15% of health practice variation in professional cohorts.[4,35] The dominant drivers of practice quality in immunization programs are structural and systemic: supervision quality, workload, peer modeling, resource availability, self-efficacy, and organizational culture. This finding sends an unambiguous programmatic message: training interventions targeting knowledge transfer, while necessary, are neither sufficient nor cost-optimal as isolated strategies for improving the quality of immunization practice.

4.4. Training as the strongest knowledge predictor

Binary logistic regression identified receipt of immunization-specific training as the strongest predictor of good knowledge (OR = 10.52, 95% CI: 2.80–39.44; p = 0.001). The magnitude of this effect underscores the centrality of structured, curriculum-based training in maintaining knowledge competency, not merely through initial content acquisition, but likely through refresher mechanisms that prevent knowledge decay over time.[17,18] The 13.1% of workers who were untrained in the prior two years carried a substantially elevated risk of knowledge deficiency, supporting mandatory annual immunization refresher training for all PHC immunization cadres as a non-negotiable programmatic standard. This mirrors evidence from North-Central Nigeria, where competency gaps were documented among Federal Capital Territory immunization workers.[15] In Ilorin, only 22.2% demonstrated good vaccine management practices pre-training, with significant knowledge decline observed at six months post-intervention without retraining.[36] Nationwide, persistent skills gaps,[37] 2.2 million zero-dose children,[1] socio-cultural barriers in North-Central states,[22] and evidence that trained providers significantly improve vaccination coverage,[38] collectively affirm that institutionalizing recurring refresher training is both urgent and non-negotiable.

4.5. Limitations

This study has several limitations that should be considered when interpreting the findings. First, the cross-sectional design limits the ability to establish temporal relationships or draw causal inferences between the assessed factors and immunization practices. Second, practice data were self-reported and may be subject to social desirability bias, potentially inflating reported adherence compared

to direct observation. Third, the geographic restriction to two LGAs limits the generalizability of the findings to the national level. Fourth, the 9-item practice scale demonstrated an exceptionally high internal consistency (Cronbach's $\alpha = 0.990$). While this suggests strong reliability within the current instrument, it also raises substantial concerns regarding item redundancy. A formal assessment of redundant items within the practice scale was not conducted, which represents a structural limitation of the study and indicates that future revisions of the tool should focus on item reduction.

5. Conclusion

Primary healthcare workers in North-Central Nigeria possess adequate foundational immunization knowledge and positive professional attitudes, but two critical and operationally consequential technical knowledge gaps persist across both rural and urban settings: a correct understanding of live vaccine eligibility in mildly ill children, and the inactivating effects of freezing on DTP, hepatitis B, and pentavalent vaccines. These gaps, identifiable only through item-level analysis rather than composite scores, directly threaten vaccination opportunity uptake and vaccine potency at the point of delivery.

The higher practice scores in the rural setting, achieved despite knowledge and attitude parity with the urban workforce, imply that differential workload intensity and supervision quality are the primary drivers of practice performance, not differences in competency or motivation. With knowledge explaining only 3.7% of practice variance in the simple model and 15.5% in the adjusted model, the evidence is unambiguous: effective immunization quality improvement requires concurrent investment in enabling structural and supervisory conditions, not training alone. Three evidence-based recommendations for public health authorities follow from these findings: (i) Staffing: task-shifting policies and recruitment of trained immunization-specific cadres are needed to address critical vacancies and reduce the per-worker caseload that drives protocol shortcuts; (ii) Structured supervision: the deployment of standardized, scheduled supportive supervisory visits using validated checklists, documented feedback sessions, and measurable corrective action plans should replace ad hoc oversight arrangements; (iii) Vaccine reliability: investment in cold chain infrastructure maintenance, uninterrupted temperature monitoring systems, and timely resupply logistics is essential to eliminate the stock-out and temperature excursion events that undermine vaccine potency and program credibility. Together, these measures constitute the minimal health system strengthening threshold required to translate knowledge gains into sustained practice improvement.

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Conflict of interest

The authors declare that they have no competing interests.

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All authors reviewed and approved the final manuscript before submission.

Ethics approval and consent to participate

Ethical approval was obtained from the Kogi State Ministry of Health Research Ethics Committee (approval number: MOH/PRS/465/V.1/121) before commencement of data collection. All participants provided written informed consent. Participation was entirely voluntary, with the right to withdraw at any time without consequence. All collected data were anonymized and stored securely, with password protection, and were accessible only to the research team. The study adhered to the principles of the Declaration of Helsinki and applicable Nigerian national guidelines for research involving human subjects.

Consent for publication

Consent for publication was not applicable because this study used anonymized data, and no identifiable individual information is included in this manuscript.

Availability of data

The datasets generated and analyzed during the current study are not publicly available due to institutional data governance policies, but are available from the

corresponding author upon reasonable request.

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