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RESEARCH ARTICLE

REVISED Preparedness for diphtheria epidemic among healthcare workers in Kano State, Nigeria

[version 3; peer review: 2 approved, 1 approved with reservations]

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Abstract

Background

Diphtheria remains a significant public health threat in Nigeria, highlighting the need for an adequately prepared healthcare workforce and health system. This study assessed healthcare workers' knowledge of diphtheria, infection prevention and control (IPC) practices, and preparedness for diphtheria outbreaks in Kano State, Nigeria. A descriptive cross-sectional study was conducted among 421 healthcare workers selected using a multistage sampling technique. Data were collected using a semi-structured interviewer-administered questionnaire, while facility preparedness was assessed using a structured checklist completed by designated facility focal persons in 24 selected health facilities. Descriptive statistics and logistic regression analyses were performed at a 5% significance level using SPSS version 28. Results showed that overall, 51.3% of healthcare workers had poor knowledge of diphtheria, while 53.4% demonstrated poor IPC practices. Healthcare workers in primary healthcare facilities had significantly lower odds of reporting good IPC practices than those in tertiary facilities (OR = 0.097, 95% CI: 0.041–0.232; p < 0.001). Overall, 70.8% of health facilities were

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classified as poorly prepared. Substantial gaps were identified in healthcare workers' knowledge, IPC practices, and facility-level preparedness. Strengthening healthcare worker training, improving adherence to IPC measures, and enhancing facility-level outbreak preparedness are essential to improve readiness and response to future diphtheria outbreaks.

Keywords
Diphtheria, healthcare workers, preparedness

This article is included in the European & Developing Countries Clinical Trials Partnership (EDCTP) gateway.

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REVISED **Amendments from Version 2**

Figure 1. A hypothetical conceptual framework showing the relationship between knowledge, IPC practices, and facility preparedness for diphtheria outbreak response was adjusted.

The manuscript has been proofread and the statistical outputs have been rechecked, with correction of all identified numerical and statistical inconsistencies across all tables.

Any further responses from the reviewers can be found at the end of the article

List of abbreviations

HCWs: Healthcare Workers
IPC: Infection Prevention and Control
IHR: International Health Regulations
IDSR: Integrated Disease Surveillance and Response
SPSS: Statistical Package for the Social Sciences

Background

Diseases transcend national borders, making global health security a shared responsibility. Recent outbreaks have highlighted the interconnected nature of health systems and demonstrated how infectious disease threats in one region can rapidly affect populations worldwide (CDC, 2023a). Emerging and re-emerging infectious diseases are among the leading threats to global health security, and one way to address this is by workforce development of frontline staff to identify, track and contain outbreaks at their source. The impact of infectious disease outbreaks is amplified when investments in global health security are inadequate. The goal of the Global Health Security Agenda is to improve the global capacity to prevent, identify, and address infectious disease threats. Nigeria is among the countries that have signed this framework. In 2019, Nigeria became a Global Health Security Agenda partner country committed to improving progress towards global health security agenda goals and international health regulations (CDC, 2023b).

Preparedness is a requirement for the 196 signatories to the International Health Regulations (IHR) (2005), the world's defense against significant threats to public health. Systems must be capable of preventing, defending against, controlling, and responding to the international spread of diseases, which can occur at unanticipated rates in an interconnected world (WHO, 2016). Epidemic preparedness refers to all the steps that need to be undertaken at the local, state, and federal levels, as well as in health facilities to be prepared and successfully address disease outbreaks. To prepare for an epidemic, routine surveillance systems must be developed to detect outbreaks, and healthcare workers must be organized and prepared to detect, investigate, and respond to epidemics (Fatiregun and Isere, 2017). To deal with the disease, it is important to prepare a culture of safe medical procedures that can limit and stop the spread of disease outbreaks. Without a culture of safe practices, healthcare facilities will be more vulnerable to communicable disease exposure and health disruption (Ughasoro et al., 2019).

In this study, preparedness for diphtheria outbreaks was conceptualized as the capacity of healthcare workers and health facilities to effectively prevent, detect, and respond to diphtheria outbreaks. Preparedness was assessed at facility level. Knowledge of diphtheria and infection prevention and control (IPC) practices were considered factors relevant to outbreak preparedness rather than components of preparedness itself. Adequate knowledge facilitates timely outbreak recognition and response, while good IPC practices reduce transmission risks and strengthen response capacity. Recent WHO guidance emphasizes that suspected diphtheria cases should be identified and treated promptly without waiting for laboratory confirmation. Recommended management includes administration of diphtheria antitoxin, appropriate antibiotic therapy, isolation of cases, and implementation of infection prevention and control (IPC) measures, including droplet precautions, hand hygiene, environmental cleaning, and WASH interventions. These measures are essential for reducing transmission, improving patient outcomes, and protecting healthcare workers during outbreaks (WHO, 2024a, 2024b).

A hypothetical conceptual framework for this study is presented in Figure 1. It shows the relationship between knowledge, IPC practices, and facility preparedness for diphtheria outbreak response.

Diphtheria, a vaccine-preventable disease and an epidemic-prone notifiable disease reported under the integrated disease surveillance and response system (IDSR), has historically been a major global health burden, although its incidence has declined substantially following the introduction of vaccination. However, Nigeria has recently experienced a resurgence, in the incidence of this contagious disease, causing epidemics that primarily affect children. Diphtheria is caused

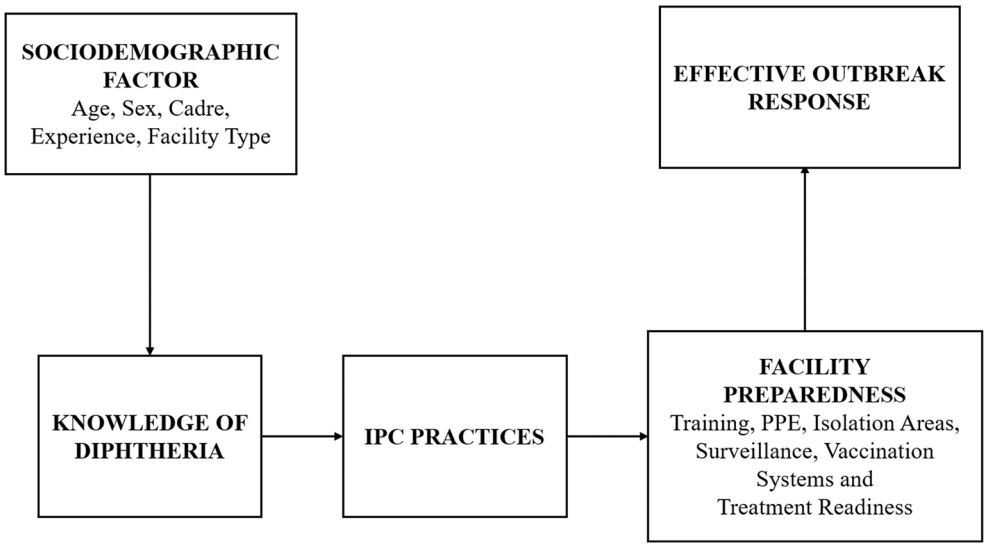

Figure 1. Conceptual framework showing the relationship between knowledge, IPC practices, and facility preparedness for diphtheria outbreak response.

primarily by toxigenic strains of *Corynebacterium diphtheriae*, and less commonly by toxigenic strains of *Corynebacterium ulcerans* and *Corynebacterium pseudotuberculosis.* Diphtheria commonly presents as tonsillitis, laryngitis, or pharyngitis with signs and symptoms such as fever, cough, running nose, sore throat, and red eyes, and is characterized by an adherent pseudo-membrane, a thick, grey coating made up of necrotic tissue and bacteria, which is the characteristics clinical feature of infection covering the tonsils, pharynx, and/or nose. In severe cases, complications such as myocarditis and neuritis may occur.

The resurgence of diphtheria outbreaks has been linked to suboptimal vaccine coverage. Healthcare workers are particularly vulnerable during diphtheria outbreaks because of their close contact with suspected and confirmed cases. Current recommendations for healthcare personnel include maintaining up-to-date diphtheria vaccination status, adherence to droplet and contact precautions, use of personal protective equipment, post-exposure prophylaxis where indicated, microbiological screening, symptom monitoring, and temporary work restrictions for infected personnel. Consequently, healthcare worker knowledge and IPC practices are critical determinants of outbreak preparedness (CDC, 2024).

As of epidemiological week 44 of 2023, a cumulative total of 10,863 confirmed diphtheria cases and 560 deaths had been reported across 130 local government areas in 20 Nigerian states, with a case fatality of 5.2%. The immunization coverage in northern Nigeria ranged from 5% to 48% in 2018, with Kano state among the affected states reporting low coverage levels (Eze et al., 2021). Kano State, located in northwestern Nigeria, is currently one of the states most affected by the ongoing diphtheria outbreak, and has recorded the highest number of cases and deaths.

Recent epidemiological analyses have further highlighted the magnitude of the Kano outbreak. An analysis of 18,320 confirmed diphtheria cases published in EBioMedicine documented substantial morbidity and mortality and identified persistent immunity gaps and delayed healthcare seeking as important contributors to transmission. Similarly, a study published on Infectious Disease Modelling study examined the transmission dynamics of diphtheria in Kano and demonstrated the importance of rapid case detection, vaccination, and outbreak control measures in reducing transmission (Abbas et al., 2025; Kamadjeu et al., 2025). These findings emphasize the need for a well-prepared healthcare workforce capable of early case recognition, timely reporting, and effective case management. Skilled healthcare personnel are indispensable for successful infectious disease outbreak response. Therefore, this study aimed to assess healthcare workers' knowledge of diphtheria, infection prevention and control practices, and preparedness for diphtheria outbreaks in Kano State, Nigeria.

Methodology

Study design and setting

A descriptive cross-sectional study was conducted between September and December 2023 among healthcare workers in Kano State, northwestern Nigeria, one of the states most affected by the recent resurgence of diphtheria. Kano State

has an estimated population of approximately 13.1 million people and comprises 44 Local Government Areas (LGAs) distributed across three senatorial districts. Public health services are delivered through primary, secondary, and tertiary healthcare facilities and coordinated by the Kano State Ministry of Health.

Preparedness was conceptualized as the capacity of healthcare workers and health facilities to effectively prevent, detect, and respond to diphtheria outbreaks. In this study, preparedness was assessed at the facility levels. Healthcare workers' knowledge of diphtheria and infection prevention and control (IPC) practices were assessed as factors relevant to outbreak preparedness rather than as components of the facility preparedness scores.

Study population

The study population comprised nurses and Community Health Extension Workers (CHEWs) employed in registered public primary, secondary, and tertiary healthcare facilities in Kano State. These cadre were selected because they constituted the principal frontline healthcare workers involved in patient assessment, surveillance health education and initial outbreak response in facilities. Eligible participants were nurses and CHEWs employed in registered public health facilities who were present during data collection and provided written informed consent. Administrative staff, volunteers, interns, and healthcare workers absent during the survey period were excluded.

Sample size

The sample size was calculated using the single population proportion formula for descriptive cross-sectional studies, assuming a prevalence of good IPC practices of 56%, a 95% confidence level, and a 5% margin of error. After adjustment for a 10% anticipated non-response rate, the minimum sample size was increased to 421.

The minimum sample size was calculated using the single population proportion formula for descriptive cross-sectional studies:

$$n = \frac{Z^2 pq}{d^2}$$

where:

- $Z = 1.96$ corresponding to a 95% confidence level;
- p = The sample size was calculated using a prevalence of 56% ($p = 0.56$), representing the proportion of healthcare workers with good infection prevention and control practices reported in a previous study among healthcare workers in Nigeria (Amali & Van Wyk, 2023).
- $q = 1 - p = 0.44$;
- $d = 0.05$ margin of error.

The calculated sample size was 379 participants. After adjustment for a 10% anticipated non-response rate, the minimum required sample size was 421 participants. To allow for possible incomplete responses and to increase the number of available observations, 430 questionnaires were distributed.

Sampling

A multistage sampling technique was used. Kano State was stratified into its three senatorial districts, from which one LGA was selected per district. One LGA in Kano Central containing a tertiary healthcare facility was purposively selected, while the remaining LGAs were selected by simple random sampling. Subsequently, health facilities were selected through simple random sampling, except for the tertiary facility, which was included purposively. A total of 24 health facilities were selected: 18 primary, 5 secondary and 1 tertiary health facility. Eight facilities were selected from each senatorial district. Kano North and Kano South each contributed six primary and two secondary facilities, while Kano Central contributed six primary, one secondary and one tertiary facility. These 24 facilities were the same as those included in the facility assessment. All the 24 facilities were approached and participated in the study.

On the individual level, a total of 430 participants were approached across all the participating facilities, of which 428 participated. Of the 430 healthcare workers approached, 428 participated, seven records were excluded because of missing data leaving 421 complete records for analysis. Therefore, the analyses in this study were based on the 421 complete records across the 24 participating facilities.

Proportionate allocation was used to distribute the sample across senatorial districts, and eligible healthcare workers were recruited within selected facilities until the required sample size was achieved. Facility preparedness was assessed in 24 health facilities selected through purposive sampling of the only available and accessible tertiary facility in the study area and simple random sampling of other categories of eligible facilities within the selected LGAs.

Data collection

Data were collected using a semi-structured interviewer-administered questionnaire adapted from the World Health Organization (WHO) Diphtheria Surveillance Standards, WHO Diphtheria Fact Sheet, Nigeria Integrated Disease Surveillance and Response (IDSR) Guidelines, and the WHO Infection Prevention and Control Assessment Framework. The questionnaire assessed socio-demographic characteristics, knowledge of diphtheria, IPC practices, and preparedness for diphtheria outbreaks. Eight trained research assistants collected data under the supervision of the principal investigator. The questionnaire was developed in English and administered through face-to-face interviews. Research assistants were fluent in both English and Hausa and conducted interviews in the participant's preferred language. Where necessary, questions were verbally explained in Hausa to facilitate comprehension. A structured facility preparedness checklist, adapted from WHO and NCDC guidelines, was completed by the designated focal person in each facility. Information was obtained through self-report and verified, where possible, by review of available records and facility resources. The checklist assessed the availability of preparedness guidelines, surveillance tools, personal protective equipment, laboratory capacity, isolation facilities, essential supplies, and staff training.

Measurement of variables

Scoring and classification: Responses were scored and aggregated to generate composite scores for knowledge, IPC practices, facility preparedness (Haguminshuti et al., 2022; WHO, 2015).

Knowledge of Diphtheria: Knowledge was assessed using 45 items covering disease transmission, symptoms, prevention, surveillance, outbreak recognition, and treatment. The median score (28/45) was used as the cut-off point for classification, consistent with previous studies (Haguminshuti et al., 2022). Respondents scoring 0–28 were classified as having poor knowledge, while those scoring 29–45 were classified as having good knowledge.

Infection Prevention and Control Practices: IPC practices were assessed using 19 items. The median score (14/19) was used as the cut-off point for classification (Haguminshuti et al., 2022). Respondents scoring 0–14 were classified as having lower IPC scores, while those scoring 15–19 were classified as having higher IPC scores, which we regarded as poor and good practices respectively.

Facility Preparedness: Facility preparedness was assessed using a 33-item checklist covering emergency preparedness and response, staff training, vaccination services, surveillance systems, infection prevention and control measures, and treatment readiness. Each correct response was scored 1, with a total of 33 scores obtainable. Preparedness was categorized into three levels based on tertiles of: first as poor (0–11), second as moderate (12–22), and third as good (23–33), these checklist were informed by WHO facility readiness principles (WHO, 2015).

Instrument validation and pretesting

The study instruments were reviewed by experts in epidemiology, public health, and disease surveillance to establish content validity. Pretesting was conducted among healthcare workers in Bebeji LGA, which was not included in the main study, using approximately 10% of the calculated sample size. Feedback from the pretest informed revisions to improve clarity, wording, and administration procedures. The internal consistency of the knowledge assessment items was evaluated using Cronbach's alpha coefficient. The knowledge and infection prevention scale had Cronbach's alpha coefficients of 0.8410 and 0.7701 respectively, indicating acceptable reliability.

Statistical analysis

Data were analysed using IBM SPSS Statistics version 28. Descriptive statistics were used to summarize respondents' socio-demographic characteristics and study variables using frequencies, percentages, means, and standard deviations, as appropriate. Associations between independent variables and knowledge of diphtheria and infection prevention and control (IPC) practices were assessed using Pearson's chi-square test. Variables with p-values <0.20 in the bivariate analysis and those considered epidemiologically relevant based on previous literature were entered into separate multivariable binary logistic regression models. Knowledge and IPC practice outcomes were coded as binary variables (good = 1, poor = 0). Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported, and statistical significance was set at $p < 0.05$. Facility preparedness was summarised descriptively using frequencies and percentages. Categories with sparse observations were combined where necessary to improve model stability.

Ethical approval statement and consent to participate

Ethical approval was obtained from the Health Research Ethics Committee of the Kano State Ministry of Health, Kano State, Nigeria on the 19th of May 2023.The approval number is NHREC/17/03/2018 and the reference number is SHREC/2023/3985. The study commenced in September 2023 where written informed consent was obtained from all the participants. Participants were informed about the choice to participate or withdraw from the study at any time with no consequences.

A written informed consent was obtained from all participants, and this document was approved by the ethics committee before the study was implemented.

Results

The mean age of the healthcare workers was 34 ± 9.2 years, indicating that most participants were in their early to mid-adulthood. Females constituted slightly more than half of the respondents (54.2%), while males accounted for 45.8%. The majority of participants were Muslims (80.5%) and of Hausa ethnicity (58.9%), reflecting the predominant religious and ethnic composition of Kano State. Regarding educational attainment, 47.7% of respondents held a certificate or diploma, 8.3% had an undergraduate degree, and 44.0% had a graduate or postgraduate qualification. Most respondents were married (72.5%), while 27.5% were not married. Nurses constituted 53.9% of the study population, whereas 46.1% were Community Health Extension Workers (CHEWs). Respondents were fairly distributed across the three senatorial districts, with 31.4%, 33.0%, and 35.6% drawn from Kano South, Kano North, and Kano Central, respectively. In terms of facility level, 47.0% worked in primary healthcare facilities, 25.9% in secondary healthcare facilities, and 27.1% in tertiary healthcare facilities (Table 1).

Table 1. Socio-demographic characteristics of the respondents.

Socio-demographics	Frequency
Age group (years)	
≤ 25	83 (19.7)
26–30	113 (26.8)
31–35	77 (18.3)
36–40	62 (14.7)
41+	86 (20.5)
Mean age ± SD (years)	34± 9.2
Sex	
Female	228 (54.2)
Male	193 (45.8)
Highest level of education	
Certificate/diploma	201 (47.7)
Undergraduate	35 (8.3)
Graduate/postgraduate	185 (44.0)
Religion	
Islam	339 (80.5)
Christianity	82 (19.5)
Ethnicity	
Fulani	75 (17.8)
Hausa	248 (58.9)
Igbo	55 (13.1)
Yoruba	35 (8.3)
Others	8 (1.9)
Marital status	
Not married	116 (27.5)
Married	305 (72.5)

Table 1. *Continued*

Socio-demographics	Frequency
Cadre	
Community health worker	194 (46.1)
Nurse	227 (53.9)
Facility level	
Primary	198 (47.0)
Secondary	109 (25.9)
Tertiary	114 (27.1)
Senatorial district	
Kano South	132 (31.4)
Kano North	139 (33.0)
Kano Central	150 (35.6)

Overall knowledge grading of respondents

For the overall knowledge score, slightly above half of the respondents 51.3% have poor knowledge as compared with 48.7% of the respondents who had good knowledge (Figure 2).

Respondents' association between socio-demographic characteristics and knowledge of diphtheria

The distribution of knowledge of diphtheria according to respondents' background characteristics is presented in Table 2. Knowledge was significantly associated with age group ($\chi^2 = 15.323$, $p = 0.004$), highest educational level ($\chi^2 = 8.001$, $p = 0.018$), religion ($\chi^2 = 7.431$, $p = 0.006$), ethnicity (fisher's exact test, $p = 0.017$), No significant associations were found between knowledge and sex ($p = 0.560$), marital status ($p = 0.157$), cadre ($p = 0.144$), facility level ($p = 0.118$) or senatorial district ($p = 0.247$). Higher proportions of good knowledge were observed among respondents with graduate/postgraduate education (56.2%), Christians (62.2%), and respondents of other ethnicities (75.0%) (Table 2).

Respondents' association between socio-demographic characteristics and infection prevention control practices

The distribution of IPC practices according to respondents' background characteristics is presented in Table 3. Good IPC practice was significantly associated with highest educational level ($\chi^2 = 12.395$, $p = 0.002$), cadre ($\chi^2 = 15.862$, $p = 0.001$), healthcare facility level ($\chi^2 = 108.454$, $p = 0.001$), and senatorial district ($\chi^2 = 66.408$, $p = 0.001$). Higher proportions of good IPC practice were observed among respondents with graduate/postgraduate education (56.2%),

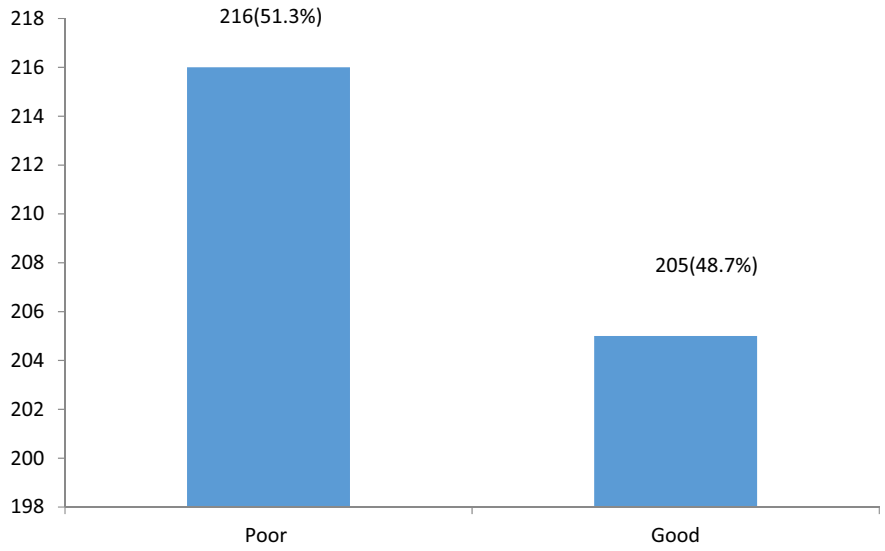

Figure 2. The level of Knowledge among respondents.

Table 2. Association between Socio-demographic characteristics and knowledge of diphtheria among Healthcare Workers.

Parameters	Knowledge			
	Poor (%)	Good (%)	χ^2	p-value
Age group (years)			15.323	**0.004***
≤ 25	57 (68.7)	26 (31.3)		
26–30	50 (44.2)	63 (55.8)		
31–35	42 (54.5)	35 (45.5)		
36–40	26 (41.9)	36 (58.1)		
> 40	41 (47.7)	45 (52.3)		
Sex			0.340	0.560
Female	114 (50.0)	114 (50.0)		
Male	102 (52.8)	91 (47.2)		
Highest level of education			8.001	**0.018***
Certificate/diploma	113 (56.2)	88 (43.8)		
Undergraduate	22 (62.9)	13 (37.1)		
Graduate/postgraduate	81 (43.8)	104 (56.2)		
Religion			7.431	**0.006***
Islam	185 (54.6)	154 (45.4)		
Christianity	31 (37.8)	51 (62.2)		
Ethnicity			11.805[f]	**0.017***
Fulani	38 (50.7)	37 (49.3)		
Hausa	141 (56.9)	107 (43.1)		
Igbo	19 (34.5)	36 (65.5)		
Yoruba	16 (45.7)	19 (54.3)		
Others	2 (25.0)	6 (75.0)		
Marital status			2.003	**0.157[f]**
Not married	66 (56.9)	50 (43.1)		
Married	150 (49.2)	155 (50.8)		
Cadre			2.133	0.144
Community health worker	107 (55.2)	87 (44.8)		
Nurse	109 (48.0)	118 (52.0)		
Facility level			4.278	0.118
Primary	91 (46.0)	107 (54.0)		
Secondary	61 (56.0)	48 (44.0)		
Tertiary	64 (56.1)	50 (43.9)		
Senatorial district			2.796	0.247
Kano South	62 (47.0)	70 (53.0)		
Kano North	79 (56.8)	60 (43.2)		
Kano Central	75 (50.0)	75 (50.0)		

[f]Fishers exact test.

nurses (55.5%), those working in tertiary healthcare facilities (81.6%), and respondents from Kano Central Senatorial District (72.0%). No significant associations were found between IPC practice and age group (p = 0.218), sex (p = 0.341), ethnicity (p = 0.404), or marital status (p = 0.425) (Table 3).

Table 3. Association between socio-demographic characteristics and infection prevention control practice among healthcare workers.

Variables	Practice		χ^2	p-value
	Poor (%)	Good (%)		
Age group (years)			5.762	0.218
≤ 25	47 (56.6)	36 (43.4)		
26–30	67 (59.3)	46 (40.7)		
31–35	40 (51.9)	37 (48.1)		
36–40	34 (54.8)	28 (45.2)		
> 40	37 (43.0)	49 (57.0)		
Sex			0.905	0.341
Female	117 (51.3)	111 (48.7)		
Male	108 (56.0)	85 (44.0)		
Highest level of education			12.395	**0.002***
Certificate/diploma	123 (61.2)	78 (38.8)		
Undergraduate	21 (60.0)	14 (40.0)		
Graduate/postgraduate	81 (43.8)	104 (56.2)		
Ethnicity			3.907[f]	0.421
Fulani	41 (54.7)	34 (45.3)		
Hausa	134 (54.0)	114 (46.0)		
Igbo	32 (58.2)	23 (41.8)		
Yoruba	16 (45.7)	19 (54.3)		
Others	2 (25.0)	6 (75.0)		
Marital status			0.710	0.437
Not married	55 (50.0)	55 (50.0)		
Married	170 (54.7)	141 (45.3)		
Cadre			15.862	**0.001**
Community health worker	124 (63.9)	70 (36.1)		
Nurse	101 (44.5)	126 (55.5)		
Facility level			108.454	**0.001**
Primary	155 (78.3)	43 (21.7)		
Secondary	49 (45.0)	60 (55.0)		
Tertiary	21 (18.4)	93 (81.6)		
Senatorial district			66.408	**0.001**
Kano South	99 (75.0)	33 (25.0)		
Kano North	84 (60.4)	55 (39.6)		
Kano Central	42 (28.0)	108 (72.0)		

[f]Fishers exact test.

Respondents' socio-demographic predictors of knowledge of diphtheria

In the multivariable logistic regression analysis, only religion remained independently associated with knowledge of diphtheria. Muslim healthcare workers had lower odds to have good knowledge than Christians (AOR = 0.528, 95% CI: 0.322–0.868; p = 0.012), while age, educational level, ethnicity, and marital status were not significant predictors (Table 4).

Respondents' predictors of infection prevention control practices

Table 5 presents the multivariable logistic regression analysis of factors associated with good IPC practice. After adjusting for potential confounders, only healthcare facility level remained independently associated with IPC practice.

Table 4. **Socio-demographic predictors of knowledge of diphtheria among study participants.**

Variables	β	AOR	95% CI	p-value
Age group (years)				
≤ 25	−0.561	0.570	0.280–1.161	0.121
26–30	0.334	1.397	0.757–2.579	0.285
31–35	−0.143	0.867	0.457–1.645	0.662
36–40	0.278	1.320	0.669–2.606	0.424
> 40	RC			
Highest level of education				
Certificate/diploma	0.445	1.561	0.715–3.408	0.264
Undergraduate	0.673	1.960	0.887–4.332	0.096
Graduate/postgraduate	RC			
Religion				
Islam	−0.638	0.528	0.322–0.868	**0.012**
Christianity	RC			
Ethnicity				
Fulani	−0.052	0.949	0.408–2.206	0.903
Hausa	−0.280	0.756	0.357–1.602	0.465
Igbo	0.493	1.637	0.668–4.010	0.281
Others	1.030	2.802	0.474–16.548	0.256
Yoruba	RC			
Marital status				
Not married	0.133	1.142	0.734–1.778	0.556
Married	RC			

RC = Reference category.

Table 5. **Predictors of Infection prevention control practice of diphtheria among study respondents.**

Variables	β	AOR	95% CI	p-value
Highest level of education				
Certificate/diploma	0.894	2.445	0.982–6.090	0.055
Undergraduate	0.762	2.142	0.905–5.072	0.083
Graduate/postgraduate	RC			
Cadre				
Community health worker	−0.276	0.759	0.452–1.274	0.297
Nurse	RC			
Facility level				
Primary	−2.333	0.097	0.041–0.232	**0.001**
Secondary	−0.902	0.406	0.176–0.936	0.034
Tertiary	RC			
Senatorial district				
Kano South	−0.689	0.502	0.234–1.076	0.076
Kano North	−0.419	0.658	0.318–1.362	0.260
Kano Central	RC			

RC = Reference category.

Table 6. Assessment checklist for evaluating the state of preparedness of facility for diphtheria respondents.

	Yes (%)	No (%)
Emergency Response Plan		
The facility has a comprehensive emergency response plan specific to diphtheria	13 (54.2)	11 (45.8)
The plan is routinely reviewed and revised is as necessary	14 (58.3)	10 (41.7)
The roles and responsibilities of staff are clearly stated within the plan	15 (62.5)	9 (37.5)
There is a designated individual responsible for overseeing the response efforts	16 (66.7)	8 (33.3)
Training and Education		
All healthcare personnel have received training on the protocols associated with diphtheria response	7 (29.2)	17 (70.8)
Staff members are knowledgeable about the symptoms and signs of diphtheria	23 (95.8)	1 (4.2)
Staff have been adequately trained in the proper utilization of personal protective equipment (PPE)	23 (95.8)	1 (4.2)
There is an ongoing program for staff training and refresher courses on diphtheria	10 (41.7)	14 (58.3)
Vaccination and Immunization		
The vaccination coverage target is met in the facility for the pentavalent vaccine against diphtheria	11 (45.8)	13 (54.2)
There are systems in place for maintaining accurate records of the vaccination status of children	13 (54.2)	11 (45.8)
The facility has protocols in place for administering booster vaccinations as necessary for diphtheria	12 (50.0)	12 (50.0)
There are initiatives to promote community-wide vaccination for diphtheria	18 (75.0)	6 (25.0)
Surveillance and Reporting		
The facility possess a robust system for monitoring diphtheria cases within the community	14 (58.3)	10 (41.7)
There is a streamlined process for promptly reporting suspected cases to local health authorities	23 (95.8)	1 (4.2)
The facility is linked to a regional or national disease surveillance network	24 (100.0)	0 (0.0)
Diagnostic capacity		
The facility has access to rapid diagnostic tests designed for diphtheria	5 (20.8)	19 (79.2)
There is a dedicated laboratory responsible for confirming diphtheria cases	4 (16.7)	20 (83.3)
Laboratory personnel are adequately trained in diphtheria diagnostic procedures	3 (12.5)	21 (87.5)
Infection control		
There is a designated isolation area for diphtheria cases	7 (29.2)	17 (70.8)
Hand hygiene stations readily available throughout the facility	15 (62.5)	9 (37.5)
The facility has an ample supply of personal protective equipment (PPE) for healthcare staff	22 (91.7)	2 (8.3)
Stringent hand hygiene and infection control measures are in place	22 (91.7)	2 (8.3)
There are written infection prevention and control measures for diphtheria cases	19 (79.2)	5 (20.8)
Medication and treatment		
There is a readily accessible stockpile of diphtheria antitoxin and antibiotics within the facility	12 (50.0)	12 (50.0)
There is an established process for promptly administering antitoxin and antibiotics to confirmed cases	9 (37.5)	15 (62.5)
Healthcare personnel have been trained in the correct administration of these medications	8 (33.3)	16 (66.7)
The facility has established protocol for monitoring patients receiving diphtheria treatment	18 (75.0)	6 (25.0)

Table 6. *Continued*

	Yes (%)	No (%)
Communication and coordination		
There is a predefined communication plan for disseminating information to the public, staff, and patients during an outbreak	18 (75.0)	6 (25.0)
There is designated spokesperson or communication team responsible for diphtheria response communications	19 (79.2)	5 (20.8)
The facility engages in collaborative efforts with local health authorities and neighbouring healthcare facilities during an outbreak	24 (100.0)	0 (0.0)
Recovery and Evaluation		
There is a well-structured plan for post-outbreak recovery, including comprehensive disinfection of affected areas	15 (62.5)	9 (37.5)
There are established mechanisms in place for evaluating the facility's response and identifying areas necessitating improvement	19 (79.2)	5 (20.8)
There are protocols established for returning the facility to standard operations following an outbreak	21 (87.5)	3 (12.5)

Compared with respondents working in tertiary healthcare facilities, those in primary healthcare facilities had lower odds of having good IPC practice (AOR = 0.097, 95% CI: 0.041–0.232, p = 0.001), while those in secondary healthcare facilities had lower odds of having good IPC practice (AOR = 0.406, 95% CI: 0.176–0.936, p = 0.034). Educational level, cadre, and senatorial district were not independently associated with IPC practice (p > 0.05) (Table 5).

Assessment of the state of preparedness of the healthcare facilities

Facility preparedness for diphtheria was assessed across nine domains: emergency response plan, training and education, vaccination and immunization, surveillance and reporting, diagnostic capacity, infection control, and medication and treatment, communication and coordination, recovery and evaluation. Among the assessed facilities, preparedness was poor, with 70.8% of facilities classified as poorly prepared, 20.8% as moderately prepared, and only 8.3% as well prepared. While most facilities reported strong surveillance and reporting systems and adequate availability of personal protective equipment, important gaps were identified in staff training, availability of isolation areas, vaccination systems, and prompt treatment of suspected or clinically diagnosed cases (Table 6).

Discussion

This study assessed healthcare workers' knowledge of diphtheria, infection prevention and control (IPC) practices, and preparedness for diphtheria outbreaks in Kano State, Nigeria. The findings revealed important gaps in knowledge and IPC practices. In addition, facility preparedness was generally poor, particularly in areas related to staff training, isolation capacity, diagnostic capacity, vaccination systems, and treatment readiness. These findings are important in the context of the recent diphtheria resurgence in Kano State and suggest that significant weaknesses remain in the health system's capacity to effectively prevent, detect, and respond to future outbreaks (Abbas et al., 2025; Kamadjeu et al., 2025).

The study found that slightly more than half of the respondents had poor knowledge of diphtheria. This finding raises concerns because healthcare workers are often the first point of contact for patients and play a critical role in disease recognition, notification, case management, and implementation of control measures (WHO, 2024a; CDC, 2024).

The observed knowledge gaps may partly reflect the epidemiology of diphtheria in Nigeria. For many years, the disease received limited attention compared with other priority infectious diseases, resulting in fewer training opportunities and lower familiarity among healthcare workers. However, the recent resurgence of diphtheria in Kano and other northern states has demonstrated the need for renewed attention to disease-specific training. Recent analyses of the Kano outbreak highlighted the contribution of delayed case recognition, immunity gaps, and late healthcare seeking to ongoing transmission (Abbas et al., 2025). In such settings, inadequate knowledge among frontline healthcare workers may delay diagnosis and reporting, thereby reducing opportunities for early outbreak containment. Similar findings have been reported in studies examining preparedness for infectious disease outbreaks among healthcare workers in resource-constrained settings (Okoeguale et al., 2021; Ughasoro et al., 2019).

For healthcare workers, disparities in knowledge may reflect unequal access to in-service training, differences in professional cadre, years of experience, and opportunities for participation in outbreak preparedness activities. Previous studies have shown that healthcare worker preparedness is influenced by prior training, disaster response experience, and

access to capacity-building programmes (Nayahangan et al., 2021; Balut et al., 2022). Targeted continuing professional development programmes, periodic simulation exercises, supportive supervision, and dissemination of updated clinical and public health guidelines may help address these gaps and strengthen preparedness for infectious disease outbreaks. Furthermore, simulation-based training has been demonstrated to improve healthcare workers' knowledge, skills, confidence, and preparedness in outbreak response settings (Kabi et al., 2021; Elendu et al., 2024). Ensuring equitable access to training across facility types and healthcare worker categories is particularly important in resource-constrained settings where preparedness depends heavily on frontline health personnel.

Regular in-service training, dissemination of updated clinical guidelines, and simulation exercises may therefore help address these gaps and improve outbreak response capacity (WHO, 2024a).

Another important finding was the generally poor level of IPC practices among healthcare workers. Effective IPC remains one of the most important strategies for preventing healthcare-associated transmission during outbreaks. Current WHO recommendations emphasize rapid isolation of suspected cases, adherence to droplet precautions, appropriate use of personal protective equipment, hand hygiene, environmental cleaning, and other IPC measures as key components of diphtheria control (WHO, 2024a, 2024b). Poor compliance with these practices may increase the risk of transmission within healthcare facilities and expose healthcare workers to preventable occupational infections.

Several contextual factors may contribute to poor IPC practices, although these were not directly assessed in the study, challenges such as inadequate training, irregular supportive supervision, heavy workloads, and limited access to IPC resources have been reported in similar healthcare settings (Haguminshuti et al., 2022; Ughasoro et al., 2019). The finding is particularly relevant because healthcare workers are at increased risk of exposure during outbreaks. CDC guidance for healthcare personnel emphasizes vaccination, post-exposure management, appropriate use of personal protective equipment, and strict adherence to infection prevention measures to reduce occupational transmission (CDC, 2024). Strengthening IPC programmes through regular training, supervision, audits, and sustained availability of IPC supplies may therefore improve preparedness for future outbreaks (WHO, 2024b; CDC, 2024).

A notable finding of this study was the substantially poorer IPC performance among healthcare workers in primary healthcare facilities compared with those in tertiary facilities. Respondents working in primary healthcare facilities were significantly less likely to demonstrate good IPC practices. This disparity is likely to reflect differences in infrastructure, access to continuing professional education, availability of IPC materials, staffing levels, and supervisory support across levels of care. Similar inequalities between primary and higher-level facilities have been reported in studies assessing outbreak preparedness and infection prevention practices in resource-constrained settings (Fatiregun & Isere, 2017; Ughasoro et al., 2019).

The vulnerability of primary healthcare facilities has important implications for outbreak control. Primary healthcare facilities are often the first point of contact for patients with febrile illnesses and respiratory symptoms. Consequently, deficiencies in IPC practices at this level may contribute to delayed recognition of cases, inadequate infection control, and continued community transmission before referral occurs. Strengthening primary healthcare services should therefore be a priority for outbreak preparedness efforts. This includes ensuring adequate supplies of personal protective equipment, improving access to training, strengthening supervision, and integrating outbreak preparedness activities into routine service delivery (Mearns et al., 2025).

The assessment of facility preparedness revealed that most facilities were inadequately prepared to respond to diphtheria outbreaks. The most prominent deficiencies were related to staff training, availability of designated isolation areas, vaccination monitoring systems, and treatment readiness. Although many facilities reported having surveillance and reporting structures in place, substantial weaknesses remained in other critical components of preparedness.

The limited availability of designated isolation areas is particularly concerning because prompt isolation of suspected cases is a cornerstone of diphtheria outbreak control (WHO, 2024a, 2024b). Similarly, the absence of regular staff training programmes may reduce healthcare workers' ability to identify cases early and implement appropriate response measures. The findings relating to treatment readiness are equally important. A considerable proportion of facilities lacked adequate arrangements for the prompt administration of diphtheria antitoxin and antibiotics, despite WHO recommendations that treatment should be initiated as early as possible because delays are associated with increased morbidity and mortality (WHO, 2024a). Similar concerns regarding health facility readiness and outbreak response capacity have been reported in previous studies conducted in Nigeria (Ughasoro et al., 2019).

Weaknesses in vaccination monitoring systems observed in this study may also have implications for outbreak prevention. The recent Kano outbreak demonstrated the consequences of immunity gaps within affected populations (Abbas et al., 2025; Kamadjeu et al., 2025). Healthcare facilities play an important role in maintaining vaccination records, identifying missed children, and supporting routine immunization activities. Strengthening these systems may contribute not only to improved outbreak response but also to long-term prevention of future outbreaks (Eze et al., 2021; Abbas et al., 2025).

Taken together, these findings indicate that preparedness for diphtheria outbreaks extends beyond individual healthcare worker knowledge. Effective preparedness requires a combination of competent healthcare workers, strong IPC systems, adequate treatment capacity, functional surveillance mechanisms, reliable vaccination services, and supportive institutional structures (WHO, 2016, 2024a, 2024b; CDC, 2024). Weaknesses in any of these areas may compromise outbreak response efforts.

Overall, the findings reveal important gaps in diphtheria outbreak readiness among healthcare workers and facilities in Kano State. More than half of healthcare workers had poor knowledge and IPC practice scores, while 17 of 24 assessed facilities were poorly prepared. Strengthening frontline training, IPC, isolation, diagnostic and treatment capacity should therefore be prioritized. Addressing the deficiencies identified in this study will require coordinated investments in workforce development, primary healthcare strengthening, IPC programmes, surveillance systems, and facility readiness.

Strengths and limitations

A major strength of this study is that it assessed preparedness at facility levels across multiple tiers of the health system in one of the states most affected by the recent diphtheria outbreak in Nigeria. This provides a more comprehensive understanding of preparedness than studies focusing solely on individual healthcare workers. However, several limitations should be considered when interpreting the findings. The cross-sectional design does not permit causal inference. Knowledge and IPC practices were assessed using self-reported measures and may therefore be subject to recall and social desirability bias. In addition, the study included only nurses and community health extension workers in public health facilities and may not fully represent other categories of healthcare workers or private-sector facilities in Kano State. Healthcare workers were clustered within 24 health facilities, responses from individuals within the same facility may not have been statistically independent. The purposive selection of the only available tertiary facility limited the feasibility of further statistical analysis and reduced the generalizability of the findings across the study area.

Recommendations

1. Institutionalize simulation exercises and outbreak preparedness drills at all levels of healthcare delivery to improve healthcare workers' practical skills, confidence, and readiness to respond to diphtheria outbreaks.

2. Strengthen healthcare worker training on diphtheria preparedness and response through regular in-service training, continuing professional development programmes, and dissemination of updated national and WHO guidelines.

3. Enhance infection prevention and control (IPC) programmes, particularly in primary healthcare facilities, through regular supportive supervision, IPC audits, mentorship, and sustained availability of personal protective equipment and other IPC supplies.

4. Strengthen primary healthcare facilities, which demonstrated poorer IPC practices, by improving access to training opportunities, supervisory support, staffing, and essential outbreak response resources.

5. Conduct periodic preparedness assessments at both healthcare worker and facility levels to monitor progress, identify gaps, and guide targeted interventions for outbreak preparedness and response.

6. Improve facility preparedness for diphtheria outbreaks by establishing designated isolation areas, ensuring availability of diphtheria treatment supplies, strengthening vaccination monitoring systems, and maintaining functional outbreak response plans.

Data availability statement

Underlying data

Zenodo: Preparedness for diphtheria epidemic among healthcare workers in Kano State, Nigeria. Zenodo; 2025, https://doi.org/10.5281/zenodo.17887775 (Ayodele, 2025).

This project contains the following underlying data:

- Preparedness Diphtheria.sav

Data are available under the terms Creative Commons Attribution 4.0 International (CC BY 4.0).

Extended data

Zenodo: Preparedness for diphtheria epidemic among healthcare workers in Kano State, Nigeria. Zenodo; 2025, https://doi.org/10.5281/zenodo.17887775 (Ayodele, 2025).

This project contains the following underlying data:

- Consent form and Questionnaire.docx
- Ethical approval document.pdf

Data are available under the terms Creative Commons Attribution 4.0 International (CC BY 4.0).

Software availability statement

All software used to analyse data in this article are open access. The Statistical Package for Social Sciences (SPSS) version 28 was used for the analysis.

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Open Peer Review

Current Peer Review Status: ✔ ✔ ?

Version 3

Reviewer Report 17 September 2026

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✔ **Ukamaka Gladys Okafor**
Euclid University, Bangui, Central African Republic

The authors have comprehensively responded to the previous concerns I raised. The methods are clear and can be replicated.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public Health, Policy and regulation,

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 2

Reviewer Report 13 August 2026

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✔ **Ukamaka Gladys Okafor**
[1] Euclid University, Bangui, Central African Republic
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Dear Authors

Your extensive revisions to the manuscript are commendable, and I am pleased with its current state.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public Health, Policy and regulation,

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 13 August 2026

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David Broderick
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I thank the authors for addressing my concerns, the article should now be indexed.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Microbiology, Epidemiology, Microbiomes

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 24 July 2026

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Thang Nguyen
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Thank you for the substantial revision. The manuscript is clearer, and several previous concerns have been addressed. However, a number of important issues remain that affect the

reproducibility and interpretation of the study.

1. Individual preparedness remains insufficiently reported.

The Abstract, Discussion, and Conclusions state that healthcare workers demonstrated good or relatively high self-reported individual preparedness. However, the Methods do not define the individual-preparedness instrument, number of items, scoring procedure, possible score range, classification threshold, or reliability, and the Results contain no corresponding table or numerical estimate. Please either report this outcome fully, including the score distribution and numerator/denominator for each category, or remove all claims regarding good individual preparedness. Item-level findings discussed in the Discussion, such as recognition of the case definition and outbreak threshold, should also be presented in the Results. In addition, the conceptual framework should be described as hypothetical because the proposed pathways from knowledge to IPC practice and preparedness were not tested in the reported analyses.

2. The sampling structure and clustering require further attention.

Participants were nested within facilities and districts, yet the logistic regression models do not appear to account for within-facility correlation. Moreover, the tertiary-care participants appear to have been recruited from a single purposively selected tertiary facility. Consequently, the strong association between facility level and IPC practice may partly represent a single-facility effect rather than a general difference between levels of care. Please specify the number and type of facilities contributing healthcare-worker participants, clarify whether these were the same 24 facilities included in the facility assessment, and report the numbers approached, refusing participation, and excluded because of missing data. Cluster-robust or multilevel analyses should be considered where methodologically feasible. Otherwise, the inference should be substantially tempered and this limitation explicitly acknowledged. Generalizability should also be restricted to the sampled nurses and community health extension workers in selected public facilities and LGAs, rather than all healthcare workers in Kano State.

3. The outcome classifications require clearer justification.

The use of the sample median to classify knowledge and IPC practice almost inevitably divides respondents into approximately equal groups. Therefore, the terms “poor” and “good” imply a criterion-referenced standard that has not been demonstrated. Please report the underlying continuous score distributions and either use neutral terms such as “lower” and “higher” scores or provide a validated external basis for the selected thresholds. Item scoring, treatment of missing responses, and any reverse-coded items should also be specified. Facility preparedness is described as a 33-item measure, whereas Table 6 presents only 22 items. The complete checklist and scoring guide should be provided, and the authors should clarify whether the 0–11, 12–22, and 23–33 categories are prespecified absolute score bands, tertiles, or percentile-based cut-offs.

4. Several numerical and statistical inconsistencies remain.

Please undertake another complete verification against the statistical output. In particular:

- In Table 4, a coefficient of −0.638 corresponds to an AOR of approximately 0.528, not 0.428; the reported confidence interval of 0.322–0.868 is also consistent with an estimate of approximately 0.53.
- The displayed collapsed marital-status counts in Table 2 do not appear to support $\chi^2 = 6.779$ and $p = 0.028$. Please recalculate the test and specify whether Pearson’s chi-square or Fisher’s exact test was used.
- In Table 3, the certificate/diploma counts sum to 202, although Table 1 reports 201 participants in this category.
- The p-value for Kano South is missing from Table 5.
- In Table 6, 14/24 is 58.3%, not 56.3%; 15/24 is 62.5%, not 62.6%; and 5/24 is 20.8%, not 8.2%.

- The 216 respondents shown in Figure 2 represent 51.3% of 421, rather than 51.0%.

Adjusted results should consistently be labelled as AORs, and interpretations should refer to "lower odds" rather than "less likelihood," particularly because these are common cross-sectional outcomes.

5. Reproducibility and presentation still need improvement.

The author response states that facility-level clustering was acknowledged, but this limitation is not included in the Strengths and Limitations section. The data availability statement still does not identify a codebook, complete scoring guide, or analysis syntax; these materials should be deposited to permit reproducibility. A completed STROBE checklist would also be helpful. The software statement should be corrected because the statement that all software was open access conflicts with the subsequent statement that SPSS was licensed; "SPSS version 20iiii" and the unnecessary serial number should also be removed. In Table 6, treatment readiness should refer to prompt treatment of suspected or clinically diagnosed cases rather than waiting for confirmation, in accordance with the clinical guidance cited elsewhere in the manuscript. A final technical language edit remains necessary, including correction of expressions such as "internal health regulations," "staffs," the duplicate funder statement, and residual grammatical errors in the Abstract and tables.

The study addresses an important public-health problem and the revision represents meaningful progress. Nevertheless, the unresolved outcome-definition, sampling, clustering, scoring, and numerical issues remain sufficiently important that I retain the status **Approved with Reservations**.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: PharmacoTherapy and Pharmaceutical Care

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 28 Aug 2026

Feyisara Ayodele

1. Thank you for the comment. We have removed unsupported claims regarding individual preparedness and revised the manuscript accordingly. We have also ensured that item-level findings are reported in the Results and clarified that the pathways in the conceptual framework are hypothetical and were not tested in this study.
2. Thank you for the comment. We have clarified the participating facilities, recruitment and exclusion numbers, and their relationship with the 24 assessed facilities. Given the facility structure and single tertiary-facility recruitment, we have tempered the interpretation of facility-level associations, explicitly acknowledged the potential clustering and single-facility effect as limitations, and restricted generalizability to the sampled nurses and CHEWs in selected public facilities and LGAs.
3. Thank you for the comment. We have clarified the scoring procedures and handling of missing and reverse-coded items and provided the complete checklist and scoring guide. We have also clarified the basis of the preparedness categories and revised the terminology

for knowledge and IPC practice to avoid implying validated criterion-based thresholds.
4. Thank you for the careful review. We have rechecked the statistical outputs and corrected all identified numerical and statistical inconsistencies across all tables.
5. Thank you for the comments. We have addressed all the issues raised, including adding the clustering limitation and scoring guide, correcting the software statement, revising Table 6, and proofreading the manuscript to correct terminology, duplication, and grammatical errors.

Competing Interests: No competing interests were disclosed.

Version 1

Reviewer Report 29 May 2026

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The manuscript addresses an important and timely public health topic: preparedness for diphtheria outbreaks among healthcare workers in Kano State, Nigeria. The study uses a descriptive cross-sectional survey of nurses and community health extension workers and reports substantial gaps in diphtheria knowledge, infection prevention and control practices, and facility-level preparedness. The topic has clear academic and policy merit, particularly given the recent diphtheria resurgence in Nigeria and the critical role of frontline healthcare workers in outbreak detection, IPC, treatment initiation, vaccination counseling, and referral.
Overall, the study has potential value, but I have significant reservations about the current version. The main findings are relevant, but the manuscript requires substantial revision of the methods, statistical reporting, interpretation, and discussion before the work can be considered scientifically sound and reproducible.

Major points that must be addressed

1. **Clarify the conceptual framework and align the title, aims, results, and conclusions.** The title focuses on “preparedness,” but the manuscript presents knowledge, IPC practice, individual preparedness, and facility preparedness as separate or overlapping constructs. The authors should clearly define “preparedness” and explain whether knowledge and IPC practice are components of preparedness or independent outcomes. A brief conceptual framework would help. The abstract and conclusion should then align with this framework.
2. **The methods section is too brief to allow replication.**

The authors should provide sufficient detail for another researcher to reproduce the study. Methods should include: the study setting and the number and type of facilities sampled; the sampling frame; detailed steps of the two-stage or multistage sampling procedure; sample size calculation and assumptions; inclusion and exclusion criteria; recruitment procedure; response rate; dates of data collection; interviewer training; whether the questionnaire was developed, adapted, or adopted; the language and translation process; pilot testing; validity and reliability assessment; and handling of missing data.

3. **Scoring systems must be fully described.**
The manuscript reports "poor" versus "good" knowledge, "poor" versus "good" IPC practice, and "poor/moderate/good" facility preparedness, but the scoring rules are insufficiently described. The authors should specify the number of items in each domain, the scoring for each item, the total possible score, the cut-offs used to classify poor/good or poor/moderate/good, and the justification for these cut-offs. Without this information, the main outcomes cannot be replicated or interpreted with confidence.
4. **Facility preparedness assessment needs clearer reporting.** Table 6 appears to use a facility-level denominator of 24, but the manuscript does not clearly describe how the facilities were selected, who completed the checklist, whether the checklist was based on direct self-report, or how the overall facility preparedness category was derived. This is especially important because the conclusion highlights poor facility preparedness as a major finding.
5. **Statistical analysis and interpretation require revision.** Chi-square tests and logistic regression are generally appropriate for the stated outcomes, but the analysis plan is under-described. The authors should specify outcome coding, reference categories, variables included in each model, the rationale for model selection, how sparse categories were handled, and whether clustering by facility or district was considered. Some cells are small, for example, the "others" ethnicity and divorced/separated/widowed marital status categories, so the authors should consider Fisher's exact test or collapsing categories where appropriate.
The authors should also clearly distinguish between bivariate associations and multivariable predictors. For example, the manuscript reports several bivariate associations, but many variables are not statistically significant in the multivariable models. Non-significant variables should not be described as "predictors." The wording in the abstract and conclusion should be revised accordingly.
6. **Check and correct numerical and table inconsistencies.** Several numerical or reporting issues need attention. For example, the text reports female respondents as 54.7%, whereas Table 1 gives 228/421 = 54.2%. The mean age is written as 34(9.2%) years, but the standard deviation should not be expressed as a percentage. In Table 2, the percentage for Igbo respondents with good knowledge appears inconsistent with the denominator. Some p-values appear missing, such as for marital status in Table 2 and Kano South in Table 5. These should be corrected.
7. **Update and strengthen the literature review.**
The introduction is relevant but should cite more current, disease-specific literature and guidelines. The authors should incorporate recent guidance on diphtheria clinical management, IPC/WASH measures, and healthcare personnel exposure management. WHO lists 2024 materials on clinical management, IPC/WASH, and diphtheria antitoxin safety, and its diphtheria page also summarizes vaccination, antibiotics, antitoxin, and early treatment principles. CDC's 2024 healthcare personnel guidance includes recommendations on post-exposure prophylaxis, work exclusion, cultures, monitoring, vaccination, and

droplet/contact precautions. The authors should also add recent Kano/Nigeria outbreak literature, such as the 2025 EBioMedicine analysis of 18,320 Kano cases and the 2025 Infectious Disease Modelling paper on transmission dynamics in Kano.

8. **Improve the discussion.**
The discussion currently repeats many descriptive results rather than interpreting them. The authors should restructure it around the main findings: knowledge gaps, IPC practice gaps, primary facility vulnerabilities, and poor facility preparedness. They should compare their findings with disease-specific diphtheria literature and outbreak preparedness literature, explain plausible reasons for the findings, and discuss implications for training, availability of PPE, isolation capacity, antitoxin/antibiotic readiness, surveillance, vaccination systems, and primary healthcare strengthening.
9. **Revise the conclusion so that it is directly supported by the results.**
The conclusions that HCWs had poor knowledge and poor IPC practice, and that facility preparedness was poor, are generally supported. However, the conclusion should not list variables as “key predictors” unless they were statistically significant in the multivariable models. The statement about political instability and logistic factors should be removed unless these were measured and presented in the results. The statement that 78.1% of respondents demonstrated good preparedness should be supported by a clearly presented table or analysis in the results section.
10. **Language and presentation need professional editing.**
The manuscript contains grammar, punctuation, and terminology problems that affect clarity. Examples include “this review aims” despite the study being original research, “staffs”, “not loose guards”, and the phrase “low vaccine coverage of diphtheria antitoxin,” which is inaccurate because antitoxin is a treatment, not a vaccine. The manuscript should undergo language editing and careful technical review.

Minor comments
The authors should report the study according to the STROBE checklist for cross-sectional studies. They should also ensure consistency in the software description, as the methods mention SPSS version 21, whereas the software availability statement mentions SPSS version 20 and Stata version 12.1. If Stata was used, the analyses performed in Stata should be specified; if not, Stata should be removed. The data availability statement is useful, but reproducibility would be improved by providing a codebook, scoring guide, and analysis syntax.

Overall assessment
This manuscript addresses an important topic and the cross-sectional design is acceptable for assessing knowledge, IPC practice, and preparedness at a specific time point. However, the current manuscript is not sufficiently detailed for replication, and some statistical interpretations and conclusions require correction. I recommend approval with reservations, conditional on substantial revision of the methods, scoring procedures, statistical reporting, discussion, and conclusions.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: PharmacoTherapy and Pharmaceutical Care

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 26 Jun 2026

Feyisara Ayodele

1. Thank you for this observation. We have added a conceptual framework and revised the manuscript to clearly define preparedness and distinguish knowledge and IPC practices as determinants of preparedness.

2. Thank you for this observation. We have revised the Methods section to provide sufficient detail on the study design, sampling, data collection, questionnaire development, and statistical analysis to improve transparency and reproducibility.

3. Thank you for this observation. We have revised the Methods section to clearly describe the scoring procedures, including the scoring criteria, classification thresholds, and justification for the selected cut-off points.

4. Thank you for this observation. We have revised the Methods section to clearly describe the facility preparedness assessment, including facility selection, checklist administration, data sources, and the derivation of facility preparedness scores.

5. Thank you for this comment. We have revised the Statistical Analysis section to clarify the analytical approach, handling of sparse data, and interpretation of multivariable results and acknowledged facility-level clustering as a study limitation.

6. Thank you for this observation. We have reviewed and corrected all tables, percentages, descriptive statistics, and p-values and cross-checked them against the text to ensure accuracy and consistency throughout the manuscript.

7. Thank you for this valuable suggestion. We have updated the introduction with recent WHO and CDC guidance and current evidence from the Nigerian diphtheria outbreak to provide a stronger, disease-specific rationale for the study.

8. Thank you for this comment. We have revised the Discussion to emphasize interpretation, comparison with relevant literature, and the implications for policy and practice.

9. Thank you for this observation. We have revised the Conclusion to ensure it reflects only the study findings, removing unsupported statements and restricting conclusions to variables that remained significant after multivariable analysis.

10. Thank you for this observation. The manuscript has been thoroughly edited to improve grammar, clarity, consistency, and scientific terminology, and the identified language issues have been corrected throughout.

Competing Interests: The authors declare that they have no competing interests.

Reviewer Report 29 May 2026

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David Broderick
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This paper represents an important aspect of epidemic preparedness- in assessing baseline knowledge prior to an existing epidemic.
The methodology of the paper seems sound, however there are aspects of the manuscript which could be expanded further to better highlight the key elements of the study and explain some of the authors choices. I have made a detailed list below:

1. The authors use several demographic variables in their reporting in particular (marriage status, religion and ethnic group) but don't introduce what these groups are and why they might need to be considered and important. This is relevant as the results are presented with this lens in mind, but I'm unsure differences within these groups would be common knowledge amongst the readership

2. Similarly while the results are split by demographics, there is currently insufficient discussion of the meaning as to why these knowledge disparities may exist- and more importantly- what can be done about them.

3. Figure 1 should be represented as a plain 2D figure as 3D can be difficult to interpret and mislead readers

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Microbiology, Epidemiology, Microbiomes

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 26 Jun 2026

Feyisara Ayodele

1. Thank you for this observation. We have revised the manuscript to clarify the relevance of marital status, religion, and ethnicity by explaining their potential influence on health knowledge, risk perception, healthcare utilisation, and public health behaviours. We also added brief descriptions of these variables to improve understanding for readers unfamiliar with the Nigerian context. 2. Thank you for this valuable observation. We have revised the Discussion to explain the observed socio-demographic differences using relevant literature and highlighted their public health implications, including targeted health education, risk communication, and healthcare worker training. 3. Thank you for this suggestion. Figure 1 has been revised to a two-dimensional format to improve clarity, readability, and interpretation of the results.

Competing Interests: The authors declare that they have no competing interests.

Reviewer Report 12 May 2026

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The paper's title focuses on preparedness, and the abstract and body of the manuscript include this knowledge. Are the authors assuming that knowledge is part of preparedness?
2. The last sentence in the introduction section described the study as a review, but the study is original research.
3. Authors are advised to subject the manuscript to a language check, including punctuation.
4. The method section was too brief and vague, and did not explain the study design and procedure for sampling and data collection, including the source of the survey tool, whether it was developed, adapted, or adopted. How and where did you recruit the participants
5. The discussion section was visibly a repetition of results, including figures. The conclusion also contains some results figures. The discussion is expected to analyze the findings, compare them with the literature review, explain how they relate to current practice, and discuss the policy implications.

Thank you

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public Health, Policy and regulation,

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 26 Jun 2026

Feyisara Ayodele

1. Thank you for this valuable observation. We have revised the manuscript to clarify that preparedness is a multidimensional construct comprising knowledge, infection prevention and control (IPC) practices, and individual and facility readiness for diphtheria outbreak response. Knowledge is presented as a foundational determinant of preparedness rather than a standalone outcome.
We have also added a conceptual framework and revised the Introduction and Methods sections to clearly distinguish and explain the relationships between knowledge, IPC practices, and preparedness

2. Thank you for identifying this oversight. We have corrected the final paragraph of the Introduction to accurately reflect the study design and objectives.

The revised sentence now states: *"This study aimed to assess the knowledge, infection prevention and control practices, and preparedness of healthcare workers for diphtheria outbreak response in Kano State, Nigeria."*

3. Thank you for this valuable suggestion. The manuscript has been thoroughly edited and proofread to improve grammar, punctuation, clarity, and overall readability, ensuring consistency with the journal's language requirements.

4. Thank you for this important observation. We have substantially revised the Methods section to provide a clearer and more comprehensive description of the study design, setting, participant selection, sampling and recruitment procedures, data collection methods, survey instrument development, validity and reliability assessment, and statistical analysis, thereby improving the transparency, reproducibility, and clarity of the study.

5. Thank you for this valuable comment. We have revised the Discussion to emphasize interpretation, comparison with relevant literature, and the implications for practice and policy, rather than repeating the results. The conclusion has also been revised to remove numerical findings and provide a concise summary of the study's key implications and recommendations.

Competing Interests: The authors declare that they have no competing interests.