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Knowledge–Practice Gap, Attitudes, and Determinants of Dengue Management Practices Among Physicians in Sudan: A Cross-Sectional Study, 2026

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Research Article

Keywords: Dengue fever, Physicians, Knowledge, attitudes and practices, Clinical practice, Guideline adherence, Health system readiness, Sudan, Cross-sectional study

Posted Date: July 28th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10163047/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Dengue fever is an emerging public health threat in Sudan, where recurrent outbreaks occur within a fragile and conflict-affected health system. Physicians play a central role in dengue diagnosis, management, and outbreak response. However, limited evidence exists regarding whether dengue-related knowledge translates into appropriate clinical practice. This study assessed dengue-related knowledge, attitudes, practices, and clinical readiness among physicians in Sudan and examined determinants of high dengue management practice.

Methods

An online cross-sectional survey was conducted among physicians practicing in Sudan between February and April 2026. A structured questionnaire adapted from a validated dengue knowledge, attitude, and practice (KAP) instrument was used to collect data on dengue disease knowledge, vector knowledge, attitudes, clinical practices, WHO guideline familiarity, resource availability, and healthcare-system readiness. Knowledge and practice scores were classified using Bloom's cut-off criteria. Multivariable logistic regression was performed to identify factors independently associated with high dengue management practice.

Results

A total of 633 physicians participated. Only 3.8% demonstrated high disease knowledge, while 48.8% had low disease knowledge. High vector knowledge was observed in 28.8% of participants, whereas 40.0% achieved high practice scores. Important knowledge gaps were identified regarding dengue etiology, vector behavior, diagnostic testing, and breeding sites. Only 36.2% of physicians reported familiarity with WHO dengue guidelines, and 57.7% reported inadequate resources for dengue management. Correlation analysis demonstrated weak relationships between disease knowledge and practice ($r = 0.077$) and between vector knowledge and practice ($r = 0.026$), suggesting a knowledge–practice gap. In multivariable analysis, familiarity with WHO dengue guidelines (AOR = 2.66, 95% CI: 1.82–3.89), belief in the usefulness of WHO guidelines (AOR = 4.06, 95% CI: 1.94–8.51), and higher attitude scores (AOR = 1.07, 95% CI: 1.03–1.11) were independently associated with high practice, whereas disease knowledge was not.

Conclusions

A substantial knowledge–practice gap exists among physicians managing dengue in Sudan. Clinical practice was influenced more strongly by guideline familiarity, perceived guideline usefulness, and

attitudes than by disease knowledge alone. Strengthening physician preparedness through practical training, implementation of WHO dengue guidelines, and improved health-system readiness may enhance dengue management in conflict-affected settings.

1. Introduction

Dengue fever (DF) is one of the fastest-growing mosquito-borne viral infections worldwide and remains a major public health threat in tropical and subtropical regions [1, 2]. It is caused by four antigenically distinct dengue virus serotypes and is transmitted primarily by female Aedes aegypti and Aedes albopictus mosquitoes [3]. The burden of dengue has increased substantially in recent decades, driven by urbanization, climate change, population mobility, and the expanding geographic distribution of competent mosquito vectors [2, 4]. An estimated 3.9–4.0 billion people live in areas at risk of dengue transmission, and approximately 100–400 million infections occur annually, of which nearly 96 million manifest clinically [1, 2, 4]. Beyond its substantial morbidity and mortality, dengue places considerable pressure on healthcare systems through increased healthcare utilization, repeated outbreaks, and substantial economic costs, highlighting the need for effective prevention, early diagnosis, and standardized clinical management [5].

Dengue has a broad clinical spectrum, ranging from asymptomatic infection and uncomplicated febrile illness to severe dengue with plasma leakage, bleeding, shock, organ impairment, and death [3, 6]. Because there is no specific antiviral treatment, effective management depends on early recognition, identification of warning signs, appropriate fluid therapy, avoidance of harmful medications such as aspirin and non-steroidal anti-inflammatory drugs, laboratory monitoring, and timely referral of severe cases [6, 7]. Physicians therefore play a critical role in dengue diagnosis, treatment, surveillance, outbreak reporting, and patient counseling on prevention measures. Recent evidence further emphasizes that healthcare professionals are central to the successful implementation of integrated dengue prevention and control strategies, serving as trusted sources of health information and facilitating the translation of evidence-based recommendations into routine clinical practice [5].

In Africa, dengue is likely under-recognized and under-reported because of overlapping febrile illnesses, weak surveillance systems, limited diagnostic capacity, and insufficient awareness among healthcare providers [8]. Sudan has experienced recurrent dengue outbreaks across multiple states, with evidence suggesting geographic expansion of dengue transmission. A previous report from Sudan documented 8,673 suspected cases and 2,796 confirmed cases between July 2022 and April 2023, with cases reported across 84 localities in 12 states and a national case fatality rate of 0.52% [9]. More evidence indicates that dengue has been documented in 11 of Sudan’s 18 states, with an estimated seroprevalence of approximately 30% [10]. This growing burden has occurred alongside the ongoing armed conflict, which has further weakened healthcare infrastructure, disrupted vector-control activities, displaced healthcare workers and communities, and reduced access to laboratory services, clinical training, and essential medical supplies [11]. These challenges underscore the importance of

strengthening physician preparedness and ensuring consistent implementation of evidence-based dengue management in fragile and conflict-affected health systems [12].

Several studies have assessed knowledge, attitudes, and practices (KAP) related to dengue among healthcare professionals and communities in different settings. Studies from Ethiopia, Pakistan, and Sudan have generally shown moderate-to-good dengue-related knowledge and positive attitudes among healthcare workers, but also persistent gaps in training, vector knowledge, diagnostic practices, guideline familiarity, and resource availability [13–16]. Recent Sudanese evidence from Port Sudan also suggests that physicians practicing during the war may have positive attitudes and acceptable practices, but still experience important knowledge gaps related to severe dengue recognition, less common symptoms, and vector-control measures [16]. Similarly, recent studies among healthcare professionals have demonstrated that although knowledge and attitudes are often adequate, deficiencies in formal training, institutional preparedness, availability of clinical resources, and implementation of recommended practices remain common, suggesting that knowledge alone is insufficient to ensure optimal dengue management [17]. Furthermore, a recent national study from Indonesia emphasized that identifying KAP gaps is essential for developing integrated dengue management programs that combine physician education, guideline dissemination, vaccination strategies, and vector control interventions [5].

A key limitation of many previous KAP studies is that they focus on categorizing knowledge, attitudes, and practices without examining whether knowledge translates into clinical behavior. In practice, physicians' dengue management may be shaped not only by theoretical knowledge, but also by attitudes, familiarity with clinical guidelines, previous exposure to dengue cases, access to diagnostic tools, resource availability, and institutional preparedness [18, 19]. As a result, some knowledge–practice gap may occur when physicians know about dengue but do not consistently apply appropriate diagnostic, management, or preventive practices. This concept aligns with implementation science, which recognizes that successful adoption of evidence-based clinical guidelines depends on multiple interacting factors, including provider behavior, organizational support, availability of resources, implementation strategies, and healthcare system readiness, rather than knowledge alone [12].

This knowledge–practice gap is particularly important in Sudan, where recurrent outbreaks are occurring in a fragile and conflict-affected health system. Physicians are expected to diagnose and manage dengue despite limited laboratory capacity, disrupted referral pathways, inconsistent access to guidelines, and shortages of training and resources. However, limited evidence is available on whether dengue disease knowledge, vector knowledge, attitudes, World Health Organization (WHO) guideline familiarity, previous case exposure, or resource availability are the main determinants of good dengue management practice among physicians in Sudan. Understanding these determinants is essential for designing targeted interventions that strengthen physician preparedness, improve implementation of WHO recommendations, and enhance health-system resilience during dengue outbreaks [6, 16].

Therefore, this study aimed to assess dengue-related knowledge, attitudes, practices, and clinical readiness among physicians in Sudan and to examine the knowledge–practice gap. Specifically, it

sought to identify factors associated with high dengue management practice, with particular attention to disease knowledge, vector knowledge, attitudes, WHO guideline familiarity, previous dengue case exposure, and resource availability. By moving beyond conventional KAP assessment to investigate the determinants of evidence-based clinical practice, this study seeks to generate evidence that can inform physician training, guideline implementation, and dengue preparedness in Sudan and other resource-constrained and conflict-affected settings.

2. Materials and methods

2.1. Study design and setting

A nationwide online cross-sectional survey was conducted among physicians practicing in Sudan between February and April 2026. The study aimed to assess dengue-related knowledge, attitudes, clinical practices, and readiness, and to identify determinants of high dengue management practice.

Sudan has experienced recurrent dengue outbreaks across multiple states in recent years [9, 11]. Adding to that, the ongoing armed conflict has severely disrupted healthcare services, disease surveillance, referral pathways, vector-control activities, healthcare worker distribution, and access to clinical training and essential medical resources [20, 21]. During this period, probability-based physician sampling was difficult due to physician displacement, disrupted health facilities, and the lack of an up-to-date national registry of actively practicing physicians [20]. Consequently, data were collected through an online survey distributed via professional physician networks, an approach that has been successfully employed in previous nationwide studies involving Sudanese physicians during the conflict period [20].

2.2. Study population and eligibility criteria

The source population comprised all physicians actively practicing in Sudan during the study period. The study population consisted of physicians who received the online survey invitation through professional networks and voluntarily completed the questionnaire.

Eligible participants included licensed physicians practicing in Sudan, including house officers, general practitioners, registrars/residents, specialists, and consultants working in governmental, private, university, primary healthcare, and referral healthcare settings. Physicians were eligible if they were actively involved in clinical practice during the study period and provided electronic informed consent.

Physicians practicing outside Sudan, those not actively involved in clinical work, non-physician healthcare workers, and respondents who did not provide informed consent or submitted incomplete questionnaires lacking essential study variables were excluded from the final analysis.

2.3. Sample size calculation

The sample size was calculated using the single population proportion formula for an unknown population [22]: $n = Z^2 \times p \times (1 - p) / d^2$

where *Z* represented the standard normal value corresponding to a 95% confidence level (1.96), *p* represented the expected proportion of adequate dengue-related knowledge or practice, assumed to be 0.5 to maximize variability, and *d* represented the margin of error, set at 0.05.

The minimum required sample size was 384 participants. To improve precision and compensation for potential non-response and the limitations of convenience sampling, additional responses were sought. A total of 633 complete responses were included in the final analysis, exceeding the minimum required sample size.

2.4. Sampling and recruitment procedures

A convenience sampling approach was used. The questionnaire link was distributed through professional WhatsApp, Facebook, Telegram, and physician networking groups commonly used by Sudanese physicians for clinical discussions, examination preparation, academic exchange, and professional communication.

This recruitment strategy was selected because the absence of an updated centralized physician database limited the feasibility of probability-based sampling. Similar online recruitment strategies have been used in recent Sudanese physician and community surveys conducted during the conflict period [15, 20].

The questionnaire was administered through Google Forms. To reduce duplicate submissions, the survey was configured to allow only one response per participant where possible. Participation was voluntary, and electronic informed consent was obtained before accessing the questionnaire.

2.5. Questionnaire development and data collection instrument

Data were collected using a structured, self-administered questionnaire developed based on the Knowledge, Attitude, and Practice (KAP) framework described by Yusuf and Ibrahim [13], the WHO dengue guidelines, and relevant literature. The questionnaire was adapted to the Sudanese physician context and expanded to assess WHO guideline familiarity, clinical management practices, resource availability, and health-system readiness. The complete English version of the questionnaire is provided as Supplementary File 1.The questionnaire consisted of five sections: sociodemographic characteristics, dengue disease knowledge, dengue vector knowledge, attitudes toward dengue prevention and control, and dengue-related clinical practice and readiness. Additional items were incorporated to assess WHO dengue guideline familiarity, perceived usefulness of WHO guidelines, previous dengue case exposure, diagnostic testing practices, resource availability, laboratory capacity, medication availability, training opportunities, and healthcare-system readiness.

Data collection was conducted online between February and April 2026. The questionnaire was distributed in English, as medical education and clinical training among physicians in Sudan are predominantly conducted in English.

2.6. Validity and reliability assessment

Because the questionnaire was adapted and expanded from a previously published instrument, psychometric evaluation was performed before final analysis.

Content validity was supported through adaptation of items from a previously validated dengue KAP questionnaire and review of questionnaire content to ensure relevance to the Sudanese physician context.

Construct validity was assessed using exploratory factor analysis (EFA). Sampling adequacy was evaluated using the Kaiser–Meyer–Olkin (KMO) statistic, while Bartlett's test of sphericity was used to determine the suitability of the correlation matrix for factor analysis.

The attitude domain demonstrated acceptable sampling adequacy (KMO = 0.761), while the practice/readiness domain showed moderate adequacy (KMO = 0.679). Bartlett's test of sphericity was statistically significant for both domains ($p < 0.001$), supporting the suitability of the data for factor analysis.

Exploratory factor analysis identified three components within the attitude domain, explaining approximately 51.9% of the total variance, and two components within the practice/readiness domain, explaining approximately 43.2% of the variance.

Internal consistency was assessed using Cronbach's alpha. Reliability coefficients were 0.625 for the attitude domain and 0.610 for the practice/readiness domain, indicating acceptable internal consistency for exploratory population-based research.

Given that the questionnaire assessed multiple constructs, including disease knowledge, vector knowledge, attitudes, clinical practices, guideline familiarity, and health-system readiness—domain-level and item-level analyses were prioritized over interpretation of a single overall score.

2.7. Study variables and measurements

The primary outcome variable was high dengue management practice. Practice was assessed using items related to diagnostic testing, use of complete blood count monitoring, paracetamol prescribing, avoidance of inappropriate medications, patient counseling on mosquito-bite prevention, and clinical management readiness. Participants with practice scores of 80% or higher were classified as having high practice, while those with low or moderate practice scores were classified as not having high practice.

Main explanatory variables included dengue disease knowledge score, dengue vector knowledge score, attitude score, WHO dengue guideline familiarity, perceived usefulness of WHO guidelines, previous exposure to dengue cases, and resource availability. Sociodemographic and professional variables

included age, sex, marital status, nationality, professional level, work sector, healthcare facility type, years of medical practice, and geographical location.

Correct knowledge responses were assigned a score of 1, while incorrect responses were assigned a score of 0. Knowledge scores were calculated separately for disease knowledge and vector knowledge and converted into percentage scores. Attitudes toward dengue prevention and control were measured using ten Likert-scale statements scored from 1 to 5, with higher scores indicating more favorable attitudes. Practice scores were calculated as percentage scores based on appropriate dengue-related clinical practice responses.

2.8. Scoring and classification

Knowledge and practice scores were classified using Bloom's cutoff criteria, consistent with the methodology used in previous dengue KAP studies [13]. Scores below 60% were classified as low, scores from 60% to 79% as moderate, and scores of 80% or higher as high.

Attitude scores were categorized as favorable for scores of 39–50, neutral for scores of 33–38, and unfavorable for scores below 32, consistent with prior dengue KAP scoring approaches [13]. For regression analyses, high dengue management practice was defined as a practice score of 80% or higher. Low and moderate practice categories were combined as the reference group.

2.9. Statistical analysis

Data were exported from Google Forms, cleaned, coded, and analyzed using IBM SPSS Statistics version 28. Descriptive statistics were used to summarize participant characteristics and questionnaire responses. Categorical variables were presented as frequencies and percentages. Item-level analyses were conducted to identify specific knowledge, practice, and readiness gaps.

Correlation analysis was performed to assess relationships between disease knowledge, vector knowledge, attitude scores, and practice scores. Pearson correlation coefficients were used for continuous scores.

Multivariable binary logistic regression was performed to identify factors independently associated with high dengue management practice. Candidate variables entered into the model included WHO guideline familiarity, perceived usefulness of WHO guidelines, attitude score, disease knowledge score, vector knowledge score, adequate resource availability, previous dengue case exposure, age, and sex. Adjusted odds ratios with 95% confidence intervals were reported.

Because WHO guideline familiarity emerged as a major determinant of high practice, a supplementary multivariable logistic regression model was conducted to identify factors associated with WHO guideline familiarity. Candidate predictors included previous dengue case exposure, resource availability, professional level, disease knowledge score, vector knowledge score, and attitude score. Statistical significance was defined as a two-sided p-value < 0.05.

3. Results

3.1. Sociodemographic characteristics

A total of 633 physicians completed the survey and were included in the final analysis. Most participants were younger than 30 years (85.0%), female (67.8%), and single (82.9%). General practitioners represented the largest professional group (43.6%), followed by house officers (34.3%) and registrars/residents (18.0%). The majority worked in governmental health facilities (85.8%), with primary hospitals being the most common workplace setting (60.3%). Regarding professional experience, 44.7% had less than 1 year of clinical experience, while 46.1% had between 1 and 5 years of practice. Geographically, most participants resided in the central region of Sudan (69.4%), whereas the eastern and western regions accounted for only 2.8% and 2.4% of respondents, respectively (Table 1).

Table 1. Sociodemographic characteristics of participants

Characteristic	Category	N	%
Age	<30 years	538	85.0
	≥30 years	95	15.0
Sex	Male	204	32.2
	Female	429	67.8
Marital status	Single	525	82.9
	Married	108	17.1
Nationality	Sudanese	622	98.3
	Non-Sudanese	11	1.7
Level of work	House officer	217	34.3
	General practitioner	276	43.6
	Registrar/Resident	114	18.0
	Specialist	23	3.6
	Consultant	3	0.5
Work sector	Governmental	543	85.8
	Private	90	14.2
Facility type	Health center	101	16.0
	Primary hospital	382	60.3
	Referral hospital	150	23.7
Experience	<1 year	283	44.7
	1–5 years	292	46.1
	5–10 years	43	6.8
	>10 years	15	2.4
Residence	Northern	133	21.0
	Southern	28	4.4
	Central	439	69.4
	Western	15	2.4
	Eastern	18	2.8

3.2. Distribution of disease knowledge, vector knowledge, and dengue management practice scores among physicians

Substantial gaps were observed between physicians' dengue-related knowledge and reported clinical practice. Based on Bloom's classification, nearly half of the participants demonstrated low disease knowledge (48.8%), whereas only 3.8% achieved high disease-knowledge scores. In contrast, 40.0% of physicians demonstrated high practice scores. Similarly, vector knowledge remained limited, with 43.1% classified as having low knowledge and only 28.8% demonstrating high vector-knowledge scores (Table 2).

Table 2. Distribution of disease knowledge, vector knowledge, and dengue management practice scores among physicians according to Bloom's classification

Domain	Low n (%)	Moderate n (%)	High n (%)
Disease knowledge	309 (48.8)	300 (47.4)	24 (3.8)
Vector knowledge	273 (43.1)	178 (28.1)	182 (28.8)
Practice	166 (26.2)	214 (33.8)	253 (40.0)

3.3. Attitudes toward dengue prevention among physicians

Attitudes toward dengue prevention and control were predominantly neutral: 49.3% of physicians were neutral, 39.2% favorable, and 11.5% unfavorable (Table 3).

Table 3: Classification of attitude toward dengue prevention among physicians

Attitude level	N	%
Favorable	248	39.2
Neutral	312	49.3
Unfavorable	73	11.5

3.4. Item-level knowledge and readiness gaps toward dengue among physicians

Although general awareness of dengue was high, important knowledge gaps were observed. Most physicians had heard about dengue outbreaks in Sudan (92.1%) and believed that dengue could be prevented (92.3%). Most also correctly identified intravenous fluid hydration as part of dengue management (86.1%), while 68.1% identified paracetamol as an appropriate treatment.

However, several key gaps were identified. Only 39.8% correctly identified dengue as a viral disease, 37.4% recognized daytime mosquito biting, 33.0% identified retro-orbital pain as a symptom, 25.6%

selected ELISA as a confirmatory test, 23.9% were aware of dengue vaccine availability, and only 13.9% correctly identified stagnant clean water as a breeding site for the dengue vector (Table 4).

Table 4. Key knowledge gaps toward dengue among physicians

Item	Correct/positive response
Dengue can be prevented	92.3%
Heard about the dengue outbreak in Sudan	92.1%
Correctly identified IV fluid hydration	86.1%
Correctly identified paracetamol	68.1%
Correctly identified dengue as a viral disease	39.8%
Correctly identified daytime mosquito biting	37.4%
Correctly identified retro-orbital pain	33.0%
Correctly identified ELISA confirmation	25.6%
Aware of dengue vaccine availability	23.9%
Correctly identified stagnant clean water breeding	13.9%

3.5. Clinical practice and readiness indicators toward dengue among physicians

Clinical readiness gaps were substantial. Only 229 physicians (36.2%) reported familiarity with WHO dengue guidelines, while 404 (63.8%) were not familiar with them. More than half of the participants reported inadequate resources for dengue management (365, 57.7%). Reported resource gaps included insufficient training (471, 74.4%), lack of medications (407, 64.3%), lack of laboratory tools (368, 58.1%), and lack of instruments (253, 40.0%) (Table 5).

Table 5. Clinical practice and readiness indicators toward dengue among physicians

Indicator	N	%
Familiar with WHO dengue guideline	229	36.2
Not familiar with WHO dengue guideline	404	63.8
Adequate resources available	268	42.3
Inadequate resources available	365	57.7
Lack sufficient training	471	74.4
Lack medications	407	64.3
Lack laboratory tools	368	58.1
Lack instruments	253	40.0
Always perform dengue test if suspected	263	41.5
Always prescribe paracetamol	417	65.9
Always advise patients to avoid mosquito bites	402	63.5
Always use CBC monitoring	356	56.2

3.6. Correlation between KAP domains and practice toward dengue among physicians

Correlation analysis showed weak relationships between knowledge domains and practice. Disease knowledge had a very weak correlation with practice score (r = 0.077), while vector knowledge had a negligible correlation (r = 0.026). Attitude showed a stronger, although still modest, positive correlation with practice (r = 0.200). These findings suggest a knowledge–practice gap, where higher knowledge alone did not necessarily translate into better dengue-related practice (Table 6).

Table 6. Correlation between KAP domains and practice score toward dengue among physicians

Variable	Correlation with practice score	Interpretation
Disease knowledge score	0.077	Very weak
Vector knowledge score	0.026	Negligible
Attitude score	0.200	Weak but meaningful

3.7. Predictors of high practice toward dengue among physicians

In multivariable logistic regression, WHO guideline familiarity was independently associated with high practice. Physicians' familiar with WHO dengue guidelines had higher odds of high practice compared with those unfamiliar with the guidelines (AOR = 2.66, 95% CI: 1.82–3.89, p < 0.001). Belief that WHO guidelines help in dengue management was also strongly associated with high practice (AOR = 4.06, 95% CI: 1.94–8.51, p < 0.001).

Attitude score was independently associated with high practice; each one-point increase in attitude score was associated with a 7% increase in the odds of high practice (AOR = 1.07, 95% CI: 1.03–1.11, p = 0.002). Vector knowledge showed a borderline association with high practice (AOR = 1.01, 95% CI: 1.00–1.02, p = 0.055). In contrast, disease knowledge was not associated with high practice (AOR = 1.00, 95% CI: 0.99–1.01, p = 0.943) (Table 7).

Table 7. Multivariable logistic regression for high practice toward dengue among physicians

Predictor	Adjusted OR	95% CI	p-value
WHO guideline familiarity	2.66	1.82–3.89	<0.001
Belief that WHO guideline helps	4.06	1.94–8.51	<0.001
Attitude score	1.07	1.03–1.11	0.002
Vector knowledge score	1.01	1.00–1.02	0.055
Disease knowledge score	1.00	0.99–1.01	0.943
Adequate resources	1.17	0.82–1.68	0.390
Previous dengue case exposure	1.44	0.88–2.35	0.146
Age ≥30 years	1.28	0.71–2.31	0.411
Male sex	1.22	0.84–1.77	0.300

3.8. Predictors of WHO guideline familiarity toward dengue among physicians

Because WHO guideline familiarity was a major predictor of high practice, a supplementary analysis was conducted to identify factors associated with guideline familiarity. Only 36.0% of physicians were familiar with WHO dengue guidelines. In adjusted analysis, physicians who had seen dengue cases had substantially higher odds of guideline familiarity (AOR = 4.43, 95% CI: 2.75–7.16, p < 0.001). Adequate resource availability was also associated with guideline familiarity (AOR = 2.84, 95% CI: 1.99–4.06, p < 0.001). Senior physicians had lower odds of guideline familiarity compared with house officers (AOR = 0.49, 95% CI: 0.26–0.92, p = 0.026) (Table 8).

***Table 8. Predictors of WHO guideline familiarity toward dengue among physicians**:*

Predictor	Adjusted OR	95% CI	p-value
Seen dengue cases	4.43	2.75–7.16	<0.001
Adequate resources	2.84	1.99–4.06	<0.001
Senior physician vs house officer	0.49	0.26–0.92	0.026
Disease knowledge score	0.99	0.98–1.01	0.203
Vector knowledge score	1.00	0.99–1.01	0.707
Attitude score	1.02	0.98–1.06	0.332

4. Discussion

This nationwide study identified a clear knowledge–practice gap in dengue management among physicians in Sudan. Although 40.0% of physicians demonstrated high dengue management practice, only 3.8% achieved high disease-knowledge scores, and nearly half had low disease knowledge. Vector knowledge was also limited, with 43.1% classified as having low vector knowledge. More importantly, disease knowledge was not independently associated with high practice. Instead, WHO guideline familiarity, perceived usefulness of WHO guidelines, and attitude were the main predictors of high dengue management practice. These findings suggest that clinical practice among physicians may be shaped more by guideline exposure, practical readiness, senior influences, and behavioral factors than by general dengue knowledge alone.

The low proportion of physicians with high disease knowledge is concerning, particularly in a country experiencing recurrent dengue outbreaks. In the present study, only 3.8% of physicians had high disease knowledge, while 48.8% had low disease knowledge. This level appears lower than that reported in Ethiopia, where 10.3% of healthcare professionals had high knowledge and 49.3% had moderate knowledge [13]. It is also lower than the Port Sudan study, where 55% of physicians demonstrated adequate knowledge [16], and the Pakistan study, where 19.6% had high knowledge and 65.1% had moderate knowledge [14]. These differences may reflect variations in study population, scoring systems, local outbreak exposure, and access to structured training. However, the finding remains important because inadequate recognition of dengue symptoms, warning signs, and diagnostic approaches may delay appropriate management, especially in outbreak settings.

Despite low disease knowledge, 40.0% of physicians in our study achieved high practice scores. This apparent mismatch supports the central knowledge–practice gap identified in this study. Disease knowledge had only a very weak correlation with practice scores, and vector knowledge showed almost no correlation with practice. This finding differs from the Port Sudan study, where knowledge was significantly associated with practice [16], but is consistent with the broader observation by Yusuf and Ibrahim that good knowledge does not necessarily lead to good practice [13]. Similar implementation science literature has shown that physicians' clinical behavior is influenced by multiple factors beyond

knowledge, including guideline awareness, agreement with recommendations, confidence, resource availability, organizational constraints, and system-level barriers [18,19].

WHO guideline familiarity emerged as one of the strongest determinants of high dengue management practice. Only 36.2% of physicians in our study reported familiarity with WHO dengue guidelines, meaning that nearly two-thirds lacked familiarity with the main international clinical guidance for dengue management. This proportion is higher than the 15% reported among Ethiopian healthcare professionals [13], but substantially lower than the 80.8% reported among medical professionals in Pakistan [14]. More importantly, physician's familiar with WHO dengue guidelines were 2.66 times more likely to demonstrate high practice, while those who believed that WHO guidelines improve dengue management had more than four-fold higher odds of high practice. This suggests that guideline familiarity and confidence in guideline usefulness may be more actionable determinants of practice than knowledge scores alone.

This finding is supported by dengue-specific educational intervention studies. In Florida, Doblecki-Lewis et al. showed that physician knowledge of dengue improved after an educational intervention [25]. Similarly, Han et al. reported that a dengue clinical case-management course improved physician practices in Puerto Rico [26]. These findings indicate that structured educational interventions, especially those linked to clinical guidelines, can improve physician preparedness. In the Sudanese context, where dengue management may occur in resource-limited and conflict-affected settings, passive dissemination of guidelines is unlikely to be sufficient. Instead, WHO guidance should be translated into short clinical algorithms, mobile-based decision tools, case-based training sessions, and facility-level protocols.

Attitude was also independently associated with high dengue management practice. In our study, 39.2% of physicians had favorable attitudes, 49.3% had neutral attitudes, and 11.5% had unfavorable attitudes. Attitude scores were positively associated with practice and each one-point increase in attitude score was associated with higher odds of high practice (AOR=1.07, p=0.002). This finding suggests that physicians’ beliefs regarding dengue seriousness, preventability, guideline usefulness, and professional responsibility may facilitate better clinical behavior. This aligns with behavioral theories such as the Theory of Planned Behavior and the Health Belief Model, which emphasize that behavior is influenced by perceived importance, motivation, perceived control, and belief in the effectiveness of action [27,28]. However, positive attitudes alone are not enough. In Pakistan, 72.5% of healthcare professionals had positive attitudes, yet only 17.6% had high practice scores [14]. Similarly, in Port Sudan, 94% had positive attitudes, but knowledge gaps persisted regarding severe dengue criteria, less common symptoms, and vector-control measures [16].

Training deficiency was one of the most important findings in the present study. Nearly three-quarters of physicians (74.4%) reported insufficient dengue-related training. This proportion is higher than the training gap reported in Pakistan, where 59.7% had never received formal dengue training [14], and higher than the Port Sudan study, where only 37% of physicians had attended dengue-related workshops [16]. In Ethiopia, the training gap was even more severe, with only 3.3% of healthcare professionals

reporting dengue-prevention training [13]. Importantly, Ethiopian healthcare professionals who received dengue training were more than ten times more likely to demonstrate high practice scores [13]. These findings strongly support the need for structured, repeated, and practical dengue training programs for physicians in Sudan.

Resource limitations were also common in our study. Medication shortages were reported by 64.3% of physicians, insufficient laboratory tools by 58.1%, and shortages of essential clinical equipment by 40.0%. Similar health-system barriers were reported in Ethiopia, where 67% of healthcare professionals indicated that adequate resources for dengue treatment were unavailable [13]. In Pakistan, only 50.8% of medical professionals reported that their facilities had sufficient resources for dengue treatment, while 42.8% reported lack of mosquito-control activities in their facilities [14]. These findings suggest that dengue management practice is not only an individual physician issue but also a health-system readiness issue. Even physicians with adequate knowledge and positive attitudes may be unable to follow recommended practice when diagnostic tests, laboratory monitoring, essential medications, and institutional protocols are unavailable.

The conflict context in Sudan likely intensified these barriers. The Port Sudan physician study emphasized that the ongoing war disrupted continuing professional development, displaced healthcare workers, weakened public health campaigns, and increased reliance on self-directed learning and digital sources [16]. This is consistent with our finding that guideline familiarity and training were major gaps. In such a setting, limited dengue preparedness should not be interpreted only as a physician-level deficiency, but also as a consequence of broader health-system disruption. Conflict may reduce access to training, interrupt referral pathways, weaken laboratory capacity, limit medication supply chains, and disrupt vector-control activities. Therefore, improving dengue practice in Sudan requires interventions that are feasible under instability, including remote training, recorded webinars, mobile-based guidelines, and simplified clinical decision-support tools.

The present study adds to previous KAP literature by shifting the focus from describing knowledge, attitudes, and practices to identifying determinants of high dengue management practice. Previous studies among healthcare professionals in Ethiopia, Pakistan, Iran, Togo, Ecuador, Texas, Indonesia, and Sudan have documented variable levels of dengue knowledge, attitudes, and practices [13–16,29–33]. However, our study shows that disease knowledge itself was not the main predictor of high practice. Instead, WHO guideline familiarity, perceived guideline usefulness, and attitudes were more important. This distinction is important because it suggests that interventions limited to general dengue awareness may not produce meaningful improvements in clinical management unless they are linked to guideline implementation and practical decision-making.

The findings have several policy and practice implications. First, dengue training for physicians should be practical, case-based, and focused on recognition of warning signs, triage, fluid management, laboratory monitoring, appropriate antipyretic use, avoidance of NSAIDs and aspirin, patient counseling, and referral criteria. Second, the WHO dengue guidelines should be converted into simplified algorithms, checklists,

and mobile-accessible protocols. Third, training should prioritize early-career physicians, general practitioners, and those working in primary hospitals and health centers. Fourth, health authorities should address structural barriers by improving access to blood cell count monitoring, dengue diagnostic testing, essential medications, and reporting systems. Finally, given the ongoing conflict, digital and remote training approaches may be more feasible than conventional in-person workshops.

5. Strengths and limitations

This study has several strengths. It included a large nationwide sample of physicians during a period of active dengue risk and health-system disruption. It also moved beyond a traditional KAP description by examining the knowledge–practice gap and identifying independent determinants of high dengue management practice. In addition, the study assessed guideline familiarity, perceived guideline usefulness, attitudes, resource availability, and readiness indicators, providing a broader understanding of physician practice behavior.

However, several limitations should be considered. The cross-sectional design prevents causal inference. The use of self-reported practice may introduce social desirability bias, as physicians may overreport recommended behaviors. The online convenience sampling approach may have overrepresented younger, internet-connected physicians and underrepresented those in remote or low-connectivity settings. Because probability-based sampling was not feasible during the conflict, the findings may not be fully generalizable to all physicians in Sudan. Finally, although the questionnaire was adapted from previous dengue KAP instruments and psychometric testing was conducted, some domains showed modest internal consistency, which may reflect the multidimensional nature of dengue knowledge, attitudes, practices, and readiness.

6. Conclusion

This study demonstrates that dengue management practice among physicians in Sudan is influenced more strongly by WHO guideline familiarity, perceived guideline usefulness, and attitudes than by disease knowledge alone. The findings highlight a clear knowledge–practice gap and suggest that improving dengue care requires practical training, guideline implementation, and health-system strengthening rather than knowledge-based education alone. In conflict-affected settings such as Sudan, accessible, standardized, and resource-sensitive interventions are urgently needed to improve physician preparedness and dengue outbreak response.

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the **Institutional Review Board (AHRC-IRB) of the Alazhari Health Research Center, Alzaiem Alazhari University**. The study was conducted in accordance with the principles of the Declaration of Helsinki and the National Guidelines for Ethical Conduct of

Research Involving Human Subjects issued by the Sudanese Ministry of Health. Electronic informed consent was obtained from all participants before questionnaire completion. Participation was voluntary, and all responses were collected anonymously and treated confidentially.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors received no specific funding for this work.

Authors' contributions

M.A.A.S. conceived the study, designed the study, supervised the project, coordinated data curation, performed data analysis, interpreted the findings, and wrote the original draft. T.S.M.S. contributed to methodology development, data analysis, interpretation of findings, and manuscript revision. M.F.A.Y., H.E.M.A., M.I.A.A., O.A.M.B., F.A.M.A., A.R.M.O.K., and A.A.A.T.Y. contributed to questionnaire development, data collection, literature review, and manuscript preparation. O.S., G.I.M.E., W.A.E.E.H., W.S.M.I., and E.Y.M.M. contributed to data collection, data cleaning, data organization, and manuscript revision. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

Acknowledgements

The authors would like to thank all physicians who participated in this study for their time and valuable contributions. The authors also acknowledge the professional networks and physician groups that facilitated the dissemination of the survey during the study period.

Use of artificial intelligence

The authors used ChatGPT (OpenAI, San Francisco, CA, USA) during the preparation of this manuscript to assist in organizing the manuscript to fit the journal guidelines. All outputs were critically reviewed and edited by the authors, who take full responsibility for the final content of the manuscript. No artificial intelligence tool was used to generate study data, perform statistical analyses, or determine the study findings and conclusions

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Supplementary Files

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- DengueQuestionnaire.pdf