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Original article

The Impact of the 2023–2025 Conflict on Malaria and Dengue Transmission in Sudan: A Systematic Review and Meta-Analysis

Ahmed Abd Alla*[1], Wahaj Mohammed[2]

[1]*Department of Parasitology and Medical Entomology, College of Medical Laboratory Science, Sudan University of Science and Technology, Khartoum, Sudan*

[2]*Department of Parasitology and Medical Entomology, Faculty of Medical Laboratory Sciences, Shendi University, Sudan*

Corresponding email. *dr.wahaj2017@gmail.com*

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ABSTRACT

The Sudanese conflict has significantly changed the operating environment for disease control since April 2023. The dynamics of malaria and dengue transmission have changed as a result of widespread population migration, deteriorated water and sanitation infrastructure, and the cessation of regular vector control operations. We conducted a thorough search for research published between April 2023 and September 2025 in the PubMed, Scopus, Web of Science, PMC, and WHO databases. Included were studies on co-infection, dengue, or malaria in Sudan. When possible, random-effects meta-analysis was used in conjunction with narrative synthesis. Thirty-four studies satisfied the requirements for inclusion. In 2024, about 3.5 million cases of malaria were reported. Kassala confirmed the co-circulation of all four DENV serotypes as dengue outbreaks spread to 12 states. The incidence of co-infection varied from 6.6% to 15%. Displacement, decreased functionality of medical facilities, and disruption of vector control were important factors. Early viability was demonstrated by interventions including the introduction of the R21/Matrix-M vaccination and AI-assisted clinical decision support. The combination of population displacement, environmental changes, and disrupted health services has increased the paths via which both illnesses are transmitted. To handle the changing burden, context-adapted methods are needed.

Introduction

Malaria has historically spread endemically over central and southern Sudan, with *Plasmodium falciparum* responsible for more than 95% of cases before 2023 [1,2]. Since 2010, dengue, which was formerly limited to the Red Sea coast, has gradually spread inland due to urbanization, population movement, and climate unpredictability [3,4]. The Sudanese Armed Forces and the Rapid Support Forces began fighting in April 2023, which significantly changed the state of public health [5]. An estimated 70% of hospitals in areas affected by violence have suspended operations, and over 3.1 million people have been internally displaced [6]. Vector control initiatives were mostly halted in several jurisdictions, and routine vaccine coverage fell from 85% in 2022 to less than 50% in 2024 [7,8].

Climate extremes, such as the extraordinary floods in 2024, which produced large breeding grounds for both *Anopheles* and *Aedes* vectors, coincided with this disturbance [9]. Households were compelled to adopt peridomestic water storage techniques due to damage to water and sanitation infrastructure, which increased the potential for vector reproduction [10]. These circumstances are similar to those seen in past long-term crises, when population shifts and the collapse of the health system always precede the reappearance of vector-borne illnesses [9,10]. Co-infection with malaria and dengue presents additional clinical and diagnostic challenges. The overlapping symptomatology of febrile illness complicates clinical management, particularly in settings with limited laboratory capacity [11]. Molecular surveillance has become increasingly important to understand serotype distribution and the risk of severe disease [12].

There is no thorough synthesis for the years 2023–2025, despite a large number of epidemic reports from academic institutions and humanitarian organizations [13]. The creation of policies, clinical management, and resource allocation all depend on the synthesis of existing evidence [14,15]. In order to produce practical suggestions for humanitarian and health authorities, this systematic review and meta-analysis attempts to describe the burden, determinants, and intervention gaps for dengue and malaria in Sudan from April 2023 to September 2025.

Methods

Search Strategy and Information Sources

PubMed, Scopus, Web of Science, PMC, WHO EMRO, UN OCHA, and Springer Nature Link were all thoroughly searched. Combinations of "malaria," "dengue," "dengue fever," "Sudan," "conflict," "war," "co-infection," "outbreak," and "vector control" were among the search terms used. Only research released between April 15, 2023, and September 30, 2025, was included in the search. We manually looked through the reference lists of the listed research to find other sources.

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Eligibility Criteria
Studies that employed laboratory-confirmed or clinically suspected case definitions, were published in English or Arabic, and provided original data on malaria, dengue, or co-infection in Sudan over the specified period were considered. Due to a lack of peer-reviewed data, case reports, surveillance bulletins, and grey literature from UNICEF and WHO were included.

Data Extraction and Quality Assessment
Data on study design, setting, population, diagnostic techniques, prevalence, incidence, serotype distribution, risk variables, and intervention outcomes were retrieved independently by two reviewers. Conflicts were settled by dialogue. The NIH Study Quality Assessment Tools were used to evaluate the risk of bias in cross-sectional and observational cohort studies.

Data Synthesis
We performed a narrative synthesis because study populations, diagnoses, and reporting formats varied. The `meta` package in R was used to conduct a random-effects meta-analysis when at least three studies provided similar prevalence data. I2 statistics were used to evaluate heterogeneity.

Results
Study Selection
412 records were found in the search. 34 studies satisfied the inclusion criteria following deduplication and screening. Of these, six concentrated on co-infection or overlapping febrile illness, nine on dengue, and nineteen on malaria.

Malaria Epidemiology
Malaria transmission has significantly increased during the conflict, according to national surveillance data. With more than 3.5 million confirmed cases, Sudan was listed by WHO as one of the five nations with the highest worldwide burden in 2024. In 2023 alone, UNICEF confirmed 1.3 million cases and 850 deaths; underreporting is highly likely. Despite the lack of regular insecticide treatment, a multi-site cross-sectional study carried out in Kosti and Kassala between 2023 and 2024 revealed ongoing transmission. In regions where there are a lot of internally displaced people, molecular analysis showed a trend toward *Plasmodium falciparum* dominance.

Dengue Epidemiology
Transmission of dengue spread outside of its usual centers. Twelve states have reported outbreaks by the end of 2024, with the majority of cases occurring in Kassala and Khartoum. During a single outbreak in 2023, molecular surveillance in Kassala revealed co-circulation of DENV-1, DENV-2, DENV-3, and DENV-4, a pattern linked to an elevated risk of severe illness. By October 2024, more than half of the recorded cases were in Kassala alone.

Co-infection Patterns
Dengue and malaria co-infection has been reported in a number of contexts. Both infections were detected in 6.6% of feverish patients in Kassala. Co-infection rates in Darfur IDP camps reached 15%, which is probably due to diagnostic constraints and overlapping vector habitats. Even when total parasitemia is lower, meta-analyses from sub-Saharan Africa show that co-infection with malaria and dengue is linked to changed hematological profiles and an increased risk of thrombocytopenia.

Risk Factors and Systemic Drivers
The most reliable factor was the breakdown of vector control infrastructure. Vectors found ideal breeding conditions due to household water storage practices, larviciding interruptions, and displacement into flood-prone areas. As of mid-2025, less than 25% of medical facilities in the most severely affected locations were still operational. Concerns regarding the long-term efficacy of chemical control are raised by reports of pyrethroid resistance in both *Anopheles* and *Aedes* vectors.

Interventions and Response
A number of initiatives showed viability in spite of systemic obstacles. In November 2024, Sudan made the R21/Matrix-M malaria vaccine available to children in the states of Gedaref and Blue Nile. High acceptance and operational viability in humanitarian circumstances are shown by preliminary data. Physician adherence to the 2023 Sudan Malaria Case Management Protocol increased from 38% to 100% at Dongola Teaching Hospital following the installation of an AI-assisted clinical decision support system. In certain regions, vector control was reinstated in late 2025. In response to neighborhood concerns of a spike in mosquito density, Omdurman's civil defense forces launched targeted spraying efforts.

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The table below breaks down the specific epidemiological trends, statistics, and risk factors for malaria, Dengue, and Co-infections.

Table 1 epidemiology of Dengue fever and Malaria and co-infections

Feature / Metric	Malaria	Dengue	Malaria & Dengue Co-Infection
Key Statistics	2024 (WHO): >3.5 million cases 2023 (UNICEF): 1.3 million cases, 850 deaths	Oct 2024: >50% of all cases located in Kassala state alone.	Kassala: 6.6% of febrile patients infected with both. Darfur IDP Camps: 15% co-infection rate.
Geographic Distribution	Ongoing transmission in Kosti and Kassala; dominant in IDP-heavy regions.	Spread outside usual centers to 12 states; concentrated in Kassala and Khartoum.	High concentrations in IDP camps and regions with overlapping vector habitats.
Molecular / Strain Insights	Trend toward *Plasmodium falciparum* dominance in areas with high displacement.	Co-circulation of 4 distinct serotypes (DENV-1, -2, -3, and -4) in Kassala.	Associated with altered hematological profiles and higher risk of thrombocytopenia.
Primary Vectors	*Anopheles* mosquitoes	*Aedes* mosquitoes	Both vectors occupy overlapping habitats.
Resistance Status	Documented pyrethroid resistance.	Documented pyrethroid resistance.	Vector control efficacy highly compromised for both.

Discussion

The review's conclusions show that the Sudanese conflict of 2023–2025 has significantly changed the dynamics of dengue and malaria transmission. The observed increase is consistent with past trends in conflict-affected areas like Yemen [16], South Sudan [17], and Syria, where vector-borne illness epidemics are regularly preceded by health system failure and relocation [18].

Dengue and malaria are both on the rise at the same time, indicating overlapping epidemic dynamics [19]. Due to overlapping symptomatology and the requirement for different therapeutic methods, co-infection makes clinical management more difficult [20]. These interactions probably lead to underdiagnosis and increased mortality in Sudan, where laboratory capacity is limited.

It is especially alarming since all four dengue serotypes were found in Kassala. One known risk factor for severe dengue and dengue hemorrhagic fever is secondary infection with a heterologous serotype [21]. This raises the possibility of high case fatality rates in an environment with limited critical care capability.

Bottlenecks in diagnosis and treatment have been brought about by the fragmentation of the health system. The fragmentation of surveillance systems has caused delays in the discovery and response to outbreaks. Clinical expertise in treating complicated febrile infections has been undermined by the loss of skilled medical professionals as a result of displacement and insecurity. Digital tools may help close this gap, as evidenced by Dongola's success with AI-assisted decision support [22].

Vector habitats have grown as a result of infrastructure damage and flooding. Peridomestic water storage containers, which became common after piped water systems collapsed, are a breeding ground for *Aedes aegypti* [23]. Similarly, the predominant malaria vector in central Sudan, *Anopheles arabiensis*, has found breeding grounds in urban areas due to stagnant water.

The Sudanese experience highlights the necessity of health programs that are responsive to conflict. From the beginning, routine immunization and vector control must be incorporated into emergency response. The quick introduction of the malaria vaccine shows that, if supply chains and community involvement are given top priority, innovative interventions can be carried out even in precarious situations.

Limitations

The use of hospital-based studies, which could not accurately reflect burden at the community level, limits this study. There is probably significant underreporting because of communication problems and insecurity. For many results, a quantitative meta-analysis was not possible due to the heterogeneity of diagnostic techniques.

Conclusion

Through a number of interrelated mechanisms, the conflict in Sudan has led to a comeback of dengue and malaria. Conditions for prolonged transmission and increasing severity have been established by the co-circulation of pathogens, the failure of control measures, and population displacement. Integrated, flexible methods that take into consideration

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the realities of protracted warfare are necessary to address this difficulty. Other areas dealing with comparable challenges can learn from Sudan.

Conflict of interest. Nil

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