

Diagnostic Challenges and Innovations in the Detection of Dengue and Malaria Co-infection: A Systematic Review

Sunday Thomas Sola¹⁾, Olaniyi Felix Sanni²⁾, Abah Michael Idoko¹⁾, Adamu Ishaku Akyala¹⁾, Emmanuel Awa Anya-Awa¹⁾, Kayode Akanbi³⁾

¹⁾Global health and Infectious Disease Control Institute, Nasarawa State University, Keffi, Nigeria, Africa

²⁾Research and Development, Fescosof Data Solutions, Ota, Nigeria, Africa

³⁾Laboratory Services, ECOWAS-Regional Centre for Surveillance and Disease Control, Africa

Received: May 27, 2025; Accepted: June 25, 2025; Available online: January 16, 2026

ABSTRACT

Background: Dengue and malaria co-infection pose significant diagnostic challenges due to overlapping symptoms, leading to potential misdiagnosis and severe health outcomes. This systematic review explores diagnostic challenges, recent advancements in diagnostic technologies, and the impact of rapid diagnostic tests (RDTs) on clinical outcomes.

Subjects and Method: This systematic review accesses the diagnostic challenges and innovations in detecting dengue and malaria co-infection in four African countries (Cameroon, Kenya, Nigeria, and Sudan). A systematic search was conducted using several of electronic databases, such as PubMed, Google Scholar, Medline, Web of Science, and Scopus. The literature search across five databases (2014–2024) yielded 135 studies; 10 met inclusion criteria. These studies, mostly quantitative, used diagnostic methods like microscopy, RDTs, ELISA, PCR, and machine learning, focusing on febrile patients. Inclusion criteria required peer-reviewed English articles involving both diseases. Three studies used mixed methods and were appraised using CASP tools.

Results: From the 10 articles used in this review several key themes were identified such as diagnostic accuracy, technological advancements, clinical impact of RDTs, and practice recommendations. The review found significant variations in diagnostic methods, including microscopy, serological tests, PCR, and RDTs. Traditional methods like microscopy, while commonly used, often suffer from variable accuracy due to dependency on operator skill and equipment quality. Innovations such as PCR and advanced serological tests offer higher accuracy but face barriers related to cost and accessibility in resource-limited settings. RDTs showed potential in improving diagnostic timeliness and accuracy, enhancing clinical outcomes. However, their sensitivity and specificity varied, highlighting the need for further validation and standardization.

Conclusion: The study advocates for continuous innovation in diagnostic technologies and the implementation of cost-effective, accurate, and accessible diagnostic methods.

Keywords: dengue, malaria, co-infection, rapid diagnostic tests

Correspondence:

Olaniyi Felix Sanni. Research and Development, Fescosof Data Solutions, Nnigeria. Email: fescosofanalysis@gmail.com.

Cite this as:

Sola ST, Sanni OF, Idoko AM, Akyala AI, Akanbi K. Diagnostic Challenges and Innovations in the Detection of Dengue and Malaria Co-infection: A Systematic Review. *J Epidemiol Public Health*. 11(1): 90-107. <https://doi.org/10.26911/jepublichealth.2026.11.01.08>.



© Sunday Thomas Sola. Published by Master's Program of Public Health, Universitas Sebelas Maret, Surakarta. This open-access article is distributed under the terms of the [Creative Commons Attribution 4.0 International \(CC BY 4.0\)](https://creativecommons.org/licenses/by/4.0/). Re-use is permitted for any purpose, provided attribution is given to the author and the source is cited.

BACKGROUND

Malaria and dengue fever are significant public health concerns, particularly in tropical and subtropical regions where both diseases are endemic, particularly in sub-Saharan Africa. They are among the most prevalent vector-borne diseases worldwide. According to (Bhatt *et al.*, 2013) and Salam *et al.* (Salam *et al.*, 2018), there are 390 million dengue cases annually, of which 96 million develop clinical symptoms. These symptoms result in 20-25,000 fatalities annually, primarily among children in developing countries. Malaria, which is caused by *Plasmodium* parasites, and dengue, which is caused by the dengue virus, exhibit comparable clinical symptoms, including fever, headache, and joint pain. Consequently, it isn't easy to make an accurate diagnosis. Misdiagnosis can result in the administration of ineffective treatment, which can exacerbate health outcomes and contribute to the dissemination of these diseases (Kolawole *et al.*, 2017; Miri, 2021).

Traditional diagnostic methods for malaria involve microscopy and rapid diagnostic tests (RDTs). In contrast, dengue diagnosis frequently incorporates molecular techniques, such as reverse transcription-polymerase chain reaction (RT-PCR) and serological tests, such as enzyme-linked immunosorbent assay (ELISA). Although microscopy is highly specific for malaria, it necessitates trained personnel and is labour-intensive (Ayorinde *et al.*, 2016). RDTs provide faster results; however, their specificity and sensitivity are inconsistent (Noche *et al.*, 2023). In resource-limited settings, RT-PCR is restricted by cost and availability, and serological assays for dengue can cross-react with other flaviviruses despite its high accuracy (Ahmed *et al.*, 2021).

Their co-infections further complicate the diagnosis and treatment of malaria and dengue. The prevalence of co-infections has been emphasised in various studies, including the 7.8% co-infection rate reported by Galani *et al.* (Galani *et al.*, 2020) in Ngaoundere, Cameroon, and the 22% rate among internally displaced persons in North Darfur, Sudan (Ahmed *et al.*, 2021). Improved diagnostic approaches are required to accurately identify and manage these co-infections due to the potential for diagnostic cross-reactivity and overlapping symptoms (Moses *et al.*, 2016). These challenges are being addressed by promising diagnostic technologies that have recently been developed. Machine learning algorithms have demonstrated the potential to improve diagnostic accuracy by analysing complex datasets to distinguish between dengue and malaria infections (Vu *et al.*, 2023).

Furthermore, the field is being transformed by the development of multiplex assays that can simultaneously detect multiple pathogens and the discovery of novel biomarkers (Vu *et al.*, 2023). The method of diagnosing febrile illnesses in resource-limited settings has been revolutionised by rapid diagnostic tests (RDTs), which offer results that are both accessible and timely. Research has illustrated the effectiveness of RDTs in the identification of dengue antibodies in suspected malaria patients, thereby facilitating the timely and appropriate administration of treatment (Miri, 2021). Nevertheless, the necessity of ongoing evaluation and enhancement is emphasised by the variability in the performance of RDTs (Noche *et al.*, 2023).

In resource-limited settings, the accurate diagnosis of malaria and dengue remains a significant challenge despite these advancements. There is a requirement for more thorough comparative studies that assess

the performance of various diagnostic tools, as well as research that concentrates on the implementation and efficacy of advanced diagnostic technologies in real-world environments (Edwards *et al.*, 2016). Furthermore, it is imperative to create and evaluate diagnostic tools that are both user-friendly and inexpensive and that are specifically designed for resource-constrained environments (Alsedig *et al.*, 2023). The objective of this systematic review is to offer a thorough examination of the diagnostic methods for malaria and dengue, as well as the impact of rapid diagnostic tests on clinical outcomes and recent advancements in diagnostic technologies. This review aims to alleviate the disease burden in Africa's malaria and dengue-endemic regions by addressing diagnostic challenges and proposing recommendations for development.

SUBJECTS AND METHOD

1. Study Design

Literature search

This systematic review was conducted to consolidate the existing research on the diagnostic challenges and innovations associated with the detection of dengue and

malaria co-infection. The review concentrated on research conducted in African regions where these diseases are prevalent, including Cameroon, Kenya, Nigeria, and Sudan. A comprehensive analysis of diagnostic methods, their accuracy, recent technological advancements, and the impact of these innovations on clinical outcomes was the objective. A systematic search was conducted to identify pertinent studies published between January 2014 and May 2024, in a variety of electronic databases, such as PubMed, Google Scholar, Medline, Web of Science, and Scopus. Search terms associated with malaria, dengue, co-infection, rapid diagnostic tests, diagnostic methods, and specific African countries were integrated into the search strategy. The following keywords were utilised: "malaria," "dengue," "co-infection," "diagnosis," "rapid diagnostic tests," "machine learning," "PCR," "serological tests," and "diagnostic accuracy." and country-specific terms such as "Cameroon," "Kenya," "Nigeria," and "Sudan." In order to effectively combine these concepts, Boolean operators (AND, OR) were implemented (see Table 1 for Search Term).

Table 1. Search Term

Databases	Search Terms	Date
PubMed	(Plasmodium OR malaria) AND dengue AND (severe OR complicated OR complication) (malaria and dengue co-infection, co-infection in Africa)	27 May 2024
Scopus	(Plasmodium OR malaria) AND dengue AND (severe OR complicated OR complication) (malaria and dengue co-infection, co-infection in Africa) Search option: All fields	27 May 2024
Google Scholar	(Plasmodium OR malaria) AND dengue AND (severe OR complicated OR complication) (malaria and dengue co-infection, co-infection in Africa) Search option: All fields	27 May 2024
Medline	(Plasmodium OR malaria) AND dengue AND (severe OR complicated OR complication) (malaria and dengue co-infection, co-infection in Africa) Search option: All fields	27 May 2024

Databases	Search Terms	Date
Web of Science	(Plasmodium OR malaria) AND dengue AND (severe OR complicated OR complication) (malaria and dengue co-infection, co-infection in Africa) Search option: All fields	27 May 2024

A total of 135 studies related to the diagnostic challenges and innovations in detecting dengue and malaria co-infections were identified during the initial search. Thirty-five studies were identified as potentially eligible after the removal of duplicates and the evaluation of titles and abstracts for relevance. It was further

refined to a list of 10 studies that satisfied all the inclusion criteria through a full-text review. These investigations were published between 2017 and 2023 and covered four African countries: Cameroon, Kenya, Nigeria, and Sudan. (See figure 1 for the PRISMA flow chart).

Prisma flow chart of the article selectins process

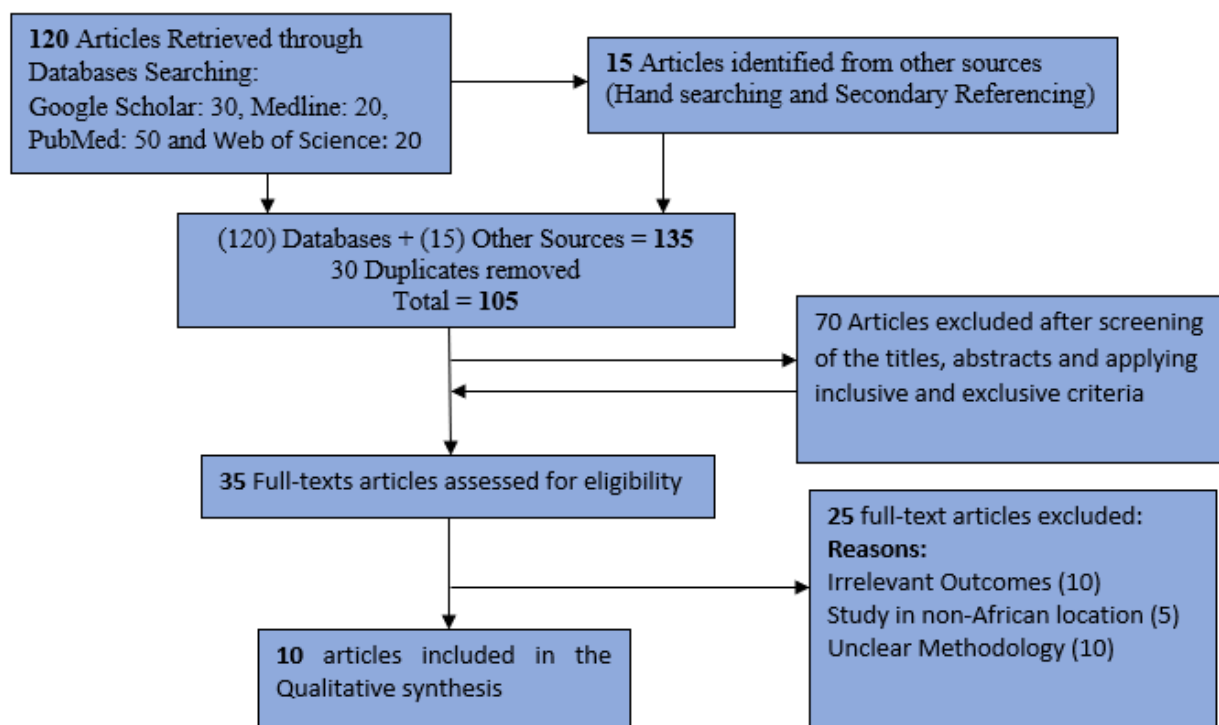


Figure 1: PRISMA Flow Chart Illustrating the Article Selection Process for Studies on Diagnostic Challenges and Innovations in Dengue and Malaria Co-infection (2014–2024)

This systematic review encompassed a total of ten studies that satisfied the inclusion criteria. The research was conducted in four African countries: Cameroon (Noche *et al.*, 2023); (Galani *et al.*, 2020)), Kenya (Vu *et al.*, 2023)), Nigeria (Mustapha *et al.*, 2017), (Miri, 2021) and (Kolawole *et al.*,

2017); (Onyedibe *et al.*, 2018); (Linda, & George, 2021)) and Sudan (Ahmed *et al.*, 2021); (Alsedig *et al.*, 2023). The dates of publication varied from 2014 to 2023. A combination of cross-sectional, cohort, and observational studies comprised the ten selected studies. They conducted a

comprehensive evaluation of a diverse array of diagnostic methods, such as microscopy, rapid diagnostic tests (RDTs), serological tests (ELISA), molecular techniques (RT-PCR), and innovative approaches such as machine learning algorithms. The studies were conducted in both rural and urban contexts. They involved a variety of populations, with a primary focus on febrile patients who were suspected of having malaria and dengue. The sample sizes were highly variable, ranging from 100 to over 500 participants.

A comprehensive search was conducted across several databases using the following terms: (*Plasmodium OR malaria*) AND dengue AND (*severe OR complicated OR complication*), along with additional keywords such as *malaria and dengue co-infection* and *co-infection in Africa*. The databases searched included PubMed, Scopus, Google Scholar, Medline, and Web of Science

2. Inclusion Criteria

The review included articles that were peer-reviewed and published between 2017 and 2023. Only studies written in English were considered. Eligible studies involved febrile patients undergoing diagnostic tests for both malaria and dengue fever and specifically focused on dengue and malaria co-infection. Included studies utilized molecular, serological, or clinical diagnostic methods and were conducted in specified African countries. Furthermore, the review considered studies published in peer-reviewed journals that provided data on diagnostic accuracy, prevalence of co-

infection, or the impact of diagnostic innovations.

3. Exclusion Criteria

The review excluded non-peer-reviewed articles, such as editorials, commentaries, and letters. Articles written in languages other than English were not included. Studies that did not involve diagnostic evaluations for both malaria and dengue fever, or those not focused on co-infection, were excluded. Additionally, case reports, reviews, editorials, and conference abstracts were omitted. Studies that lacked sufficient data on diagnostic outcomes or did not clearly describe diagnostic methodologies were also excluded.

4. Operational Definition of Variables

Diagnostic Methods: Refers to tools such as microscopy, RDTs (Rapid Diagnostic Tests), ELISA, RT-PCR, and machine learning used to detect malaria and dengue infections.

Diagnostic Accuracy: The ability of a method to correctly identify patients with co-infection.

Innovation: New or improved diagnostic technologies such as machine learning algorithms or multiplex assays.

Clinical Impact: Outcomes influenced by the use of diagnostic methods, including timeliness of treatment and reduction in morbidity/mortality.

5. Study Instruments

Data were extracted using a structured form. For appraisal, the CASP tools were used to assess both qualitative and quantitative studies.

Appraisal of the Selected Papers

Table 2. Qualitative CASP Appraisal

Primary Study Author (Year)	Criteria												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Alsedig et al. (2023)	2	2	2	2	2	2	2	2	2	2	1	2	23
Vu et al. (2023)	2	2	2	2	2	2	2	1	2	2	2	2	23

Primary Study Author (Year)	Criteria												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Miri (2021)	2	2	2	2	2	2	2	2	2	2	2	2	24
Galani et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Onyedibe et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	2	24
Kolawole et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24
Mustapha et al (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24

Description of the question criteria:

- 1 = Focused issue
- 2 = Appropriate method
- 3 = Acceptable recruitment
- 4 = Accurate measurement
- 5 = Data collection
- 6 = Adequate participants
- 7 = Clear results
- 8 = Rigorous analysis
- 9 = Clear findings
- 10 = Local applicability
- 11 = Research value
- 12 = Ethical considerations

Answer score description:

- 0 = No
- 1 = Can't tell
- 2 = Yes

Table 3. Quantitative CASP Appraisal

Primary Study Author (Year)	Criteria												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
Alsedig et al. (2023)	2	2	2	2	2	2	2	2	2	2	1	2	23
Vu et al. (2023)	2	2	2	2	2	2	2	1	2	2	2	2	23
Miri (2021)	2	2	2	2	2	2	2	2	2	2	2	2	24
Galani et al. (2020)	2	2	2	2	2	2	2	2	2	2	2	2	24
Onyedibe et al. (2018)	2	2	2	2	2	2	2	2	2	2	2	2	24
Kolawole et al. (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24
Mustapha et al (2017)	2	2	2	2	2	2	2	2	2	2	2	2	24

Description of the question criteria:

- 1 = Focused issue
- 2 = Appropriate method
- 3 = Acceptable recruitment
- 4 = Accurate measurement
- 5 = Data collection
- 6 = Adequate participants
- 7 = Clear results

- 8 = Rigorous analysis
- 9 = Clear findings
- 10 = Local applicability
- 11 = Research value
- 12 = Ethical considerations

Answer score description:

- 0 = No
- 1 = Can't tell
- 2 = Yes

Mixed/Qualitative Research Design Papers

In qualitative research, non-numerical data, such as text, video, or audio, are gathered and analysed in order to get a better understanding of ideas, perspectives, or experiences. It is possible to utilise it to gain an in-depth understanding of an issue or to come up with fresh ideas for study (Bhandari., 2023). Of the ten papers selected, three of them were both mixed research design method but predominantly qualitative designs which is (Noche *et al.*, 2023); (Linda *et al.*, 2021) and (Ahmed *et al.*, 2021). This papers were appraised utilising the qualitative Critical Appraisal Skills Programme (CASP) evaluation instruments (CASP, 2017). (see CASP in Table 2)

Noche *et al.* (2023) research, utilized clinical observations and interviews with patients and healthcare providers (24 Medical Doctors and 36 Nurses). Laboratory tests (microscopy for malaria and serological tests for dengue) were used to support the clinical findings with 200 febrile patients. Clinical diagnosis records, microscopy for malaria, serological test kits for dengue were used in the descriptive study. The study was conducted in hospitals of Bangangte, Cameroon. The study focused on clinical observations and descriptive data on the diagnosis of malaria and dengue fever among febrile patients.

Linda *et al.* 2021) conducted a study investigating the seroprevalence of Dengue

Virus IgM, malaria parasitemia, and hematological parameters among 125 HIV-infected and 63 HIV negative individuals in Awka, Nigeria. The study employed a mixed-methods approach, combining qualitative insights into patient experiences and symptoms with quantitative analysis of serological and hematological data. Data collection involved both clinical observations and laboratory tests, ensuring comprehensive evaluation of the research objectives.

Ahmed *et al.* (2021) study took place in Port Sudan and investigated the incidence of dengue infection among 110 febrile patients through descriptive analysis of clinical and laboratory findings. It was a cross-sectional descriptive data collection using blood samples and patient interviews. Serological tests were conducted to detect dengue infections that utilized interview guides, serological tests kits and PCR equipment for detecting dengue infections.

Quantitative Papers

In this systematic review, nine articles were chosen that employed quantitative methodologies. This was also evaluated using CASP appraisal tool (see quantitative CASP appraisal in Table 3). These articles include (Alsedig, & Abdallah, 2023), (Vu *et al.*, 2023), (Miri, 2021), (Galani 2020), (Onyedibe *et al.*, 2018), (Kolawole *et al.*, 2017), and (Mustapha *et al.*, 2017).

Alsedig *et al.* (2023) conducted a cross-sectional investigation in Kassala, Eastern Sudan, during the dengue

transmission season. The study focused on the prevalence of malaria and dengue co-infections among 395 febrile patients. Malaria and dengue were detected using RDTs, PCR, and serological assays. RDTs, PCR devices, serological test kits, and blood collection kits were employed to conduct blood sample collection and laboratory testing for the detection of malaria and dengue.

Vu, *et al.* (2023) conducted a cohort study in Kenya from 2014 to 2019, comparing clinician diagnosis with machine learning algorithms involving 113 febrile children. The diagnosis was made using clinical assessments, laboratory testing (PCR, RDTs), and machine learning algorithms. Blood sample collection and clinical evaluation methods were carried out. The data was analysed using machine learning algorithms and laboratory testing (PCR, RDTs).

In an effort to identify dengue antibodies, Miri (2021) investigation conducted a cross-sectional study in Jos, Nigeria, focusing on 94 febrile patients who were suspected of having malaria. The blood samples were tested for IgM and IgG dengue antibodies using ELISA. The ELISA kits, blood collection kits, and clinical records were used to analyse the blood sample collection and laboratory testing process.

Galani *et al.* (2020) conducted a cross-sectional study among 174 febrile patients at Ngaoundere Regional Hospital, Cameroon, with a specific focus on the prevalence of dengue-malaria co-infections. Blood samples were collected and subsequently subjected to laboratory testing using RDTs, PCR instruments, ELISA kits, and blood collection kits to identify dengue and malaria.

In order to investigate the prevalence of Dengue Virus infection among 529

febrile patients presumptively diagnosed with malaria in Maiduguri and Jos Plateau, Nigeria. Onyedibe *et al.*, (2018) conducted a cross-sectional study (246 patients from Jos and 283 febrile participants in Maiduguri). The investigation's quantitative methodology concentrated on the prevalence of Dengue Virus infection as determined by laboratory testing.

Kolawole *et al.* (2017) conducted a cross-sectional investigation in the Ilorin metropolis, Nigeria, with 176 febrile patients to investigate the association between concurrent dengue and malaria infections. Dengue and malaria were detected using rapid diagnostic tests (RDTs) and PCR. The study adopted the use of RDTs, PCR devices, and blood collection kits for the collection of blood samples and laboratory testing to detect dengue and malaria.

A survey was conducted by Mustapha *et al.* (2017) to evaluate the prevalence of malaria and anti-Dengue Virus IgG among 178 febrile HIV-infected patients who were consenting patients at a tertiary hospital in Abuja, Nigeria. The study employed a quantitative research design, with a particular emphasis on seroprevalence rates as determined by laboratory testing. The data collection process involved the use of serological assays to detect IgG antibodies against Dengue Virus and microscopic examination for malaria parasites. Valuable insights into co-infection rates among HIV-infected individuals were provided by the research design and data collection methodologies, which were appropriate for achieving the study's objectives.

6. Data Analysis

The data analysis followed a narrative synthesis approach in line with systematic review methodology. CASP checklists were used to assess the quality of each study, ensuring methodological rigor. Findings

were compared and interpreted based on relevance, consistency, and evidence strength across different geographical and clinical contexts. Visual tools such as PRISMA flowcharts and summary tables were used to enhance clarity and reproducibility.

The included studies were analysed for common themes such as diagnostic accuracy, innovations in diagnostic technologies, the clinical impact of rapid diagnostic tests (RDTs), and strategies for improving diagnostic outcomes in resource-limited settings. Both qualitative and quantitative findings were extracted and grouped according to these themes.

RESULTS

A. Themes

Themes 1: Diagnostic Methods and Their Accuracy

This theme incorporates the challenges associated with accurately diagnosing dengue and malaria, particularly when they co-infect a patient, as well as the diverse diagnostic methods employed. Accurate diagnosis is difficult due to the overlapping clinical symptoms of dengue and malaria. Misdiagnosis is exacerbated by the constraints of diagnostic instruments, particularly in resource-limited environments. Rapid Diagnostic Tests (RDTs) and Polymerase Chain Reaction (PCR) are conventional diagnostic procedures; however, they have inherent constraints. For effective treatment of dengue and malaria, it is essential to have an accurate diagnosis. A study was conducted in Cameroon by Noche, *et al.* (2023), which involved 200 participants, 36 nurses, and 24 medical physicians. The study emphasised the inadequacies of RDTs and PCR in accurately diagnosing co-infections as a result of the overlapping clinical symptoms. In the same vein, Onyedibe *et al.* (2018) investigated

the prevalence of dengue in patients who were presumptively diagnosed with malaria in Nigeria, which revealed substantial diagnostic challenges. The necessity of enhanced diagnostic instruments to effectively distinguish between the two infections was underscored in both studies. Linda *et al.* (2021) conducted a study on the seroprevalence of dengue and malaria in HIV-infected individuals in Nigeria. Detailed serological and haematological analyses were employed in the study to identify diagnostic challenges, particularly in immunocompromised patients. The results emphasise the significance of taking patient-specific factors into account when selecting diagnostic methodologies.

Themes 2: Innovations and Advancements in Diagnostic Technologies

This theme emphasises the most recent developments and innovations in diagnostic technologies, such as the utilisation of machine learning algorithms to enhance diagnostic accuracy and efficiency. Advancements can considerably improve the accuracy and speed of diagnosing dengue and malaria in diagnostic technologies, such as machine learning algorithms. These developments are especially advantageous in resource-constrained environments, where conventional diagnostic instruments may be less effective. Vu *et al.* (2023) investigated the potential of machine learning algorithms to identify acute dengue infections in Kenyan children, demonstrating that these algorithms could surpass conventional clinical diagnostics in terms of speed and accuracy. Galani *et al.* (2020) conducted a study in Cameroon that illustrated the potential of advanced PCR techniques and next-generation sequencing to enhance diagnostic accuracy significantly. These advancements are indispensable in overcoming the constraints of conventional diagnostic methodologies. They

assure more cost-effective, accurate, and swift diagnostics, which are especially advantageous in resource-constrained, high-burden environments.

Theme 3: Impact of Rapid Diagnostic Tests on Clinical Outcomes

The clinical impact and prevalence of co-infections of dengue and malaria, as well as the patient outcomes, are the focus of this theme. It can result in more severe clinical presentations and complicate treatment protocols when both diseases are coinfecting. It is imperative to have access to comprehensive clinical data in order to comprehend the full extent of the effects of these co-infections on patients. The rapid turnover time and simplicity of RDTs make them a popular choice for the early detection of dengue and malaria. Nevertheless, their influence on clinical outcomes is inconsistent. Miri (2021) assessed the detection of IgM and IgG antibodies in febrile patients in Nigeria, underscoring the significance of rapid diagnostic tests (RDTs) in the early diagnosis and initiation of treatment. The research determined that the provision of prompt and appropriate treatment could significantly enhance patient outcomes using timely and accurate RDT results. In Abuja, Nigeria, Mustapha *et al.* (2017) surveyed febrile HIV-infected patients. They discovered that the use of RDTs facilitated the early diagnosis and management of co-infections, thereby reducing morbidity and mortality. The cost-effectiveness and accessibility of RDTs in resource-limited settings were emphasised in the study. (Kolawole *et al.* (2017) also investigated the influence of RDTs in Ilorin, Nigeria. They verified that they were essential in the clinical management of febrile patients, particularly in the differentiation between dengue and malaria.

Theme 4: Recommendations for Improving Diagnostic Accuracy in Resource-Limited Settings

This theme encompasses qualitative insights from patient experiences and healthcare responses during dengue and malaria epidemics. Patient narratives offer valuable insights into the social and affective consequences of co-infections with dengue and malaria. Healthcare responses during epidemics underscore systemic strengths, shortcomings in outbreak management, and methods for enhancing diagnostic accuracy in resource-limited settings through a multifaceted approach. In their investigation of internally displaced individuals in North Darfur, Sudan, Ahmed & Weaver, (2021) offered valuable insights into the significance of training healthcare professionals in the interpretation of results and the use of diagnostic instruments. The study underscored the necessity of creating diagnostic methods that are both user-friendly and cost-effective and that can be readily implemented in low-resource environments. Alsedig *et al.* (2023) conducted a study on the prevalence of dengue and malaria co-infections in Kassala, Sudan. They suggested that the healthcare infrastructure be strengthened to enhance access to diagnostic facilities. The study also recommended that community awareness and education regarding the symptoms and hazards of co-infection be improved in order to facilitate early diagnosis and treatment.

B. Practice-Based Solutions and Recommendations

Implementation of Machine Learning Algorithms:

Vu *et al.* (2023) have demonstrated that advanced diagnostic tools, such as machine learning algorithms, can substantially improve the accuracy of dengue and malaria co-infection diagnosis. These technologies should be integrated

into healthcare facilities, particularly in endemic regions, to supplement conventional diagnostic methods.

Healthcare Workers Training: Diagnostic errors can be reduced by providing healthcare workers with comprehensive training programmes that cover the correct use of RDTs and the interpretation of results. In resource-limited environments, Ahmed, *et al.* (2021) underscored the significance of this type of training.

Regular Quality Control and Calibration: The reliability and accuracy of RDTs can be improved by ensuring that they undergo regular quality control and calibration. Diagnostic equipment should be subject to routine inspections and maintenance schedules by facilities.

Affordable and Accessible Testing Kits: In resource-limited environments, there is a requirement for the creation of diagnostic kits that are both user-friendly and cost-effective. These kits should be extensively disseminated. To alleviate the burden on healthcare systems, these devices should be capable of simultaneously detecting both dengue and malaria.

Investment in Diagnostic Facilities: It is imperative to invest in healthcare infrastructure, particularly diagnostic facilities. Alsedig *et al.* (2023) suggested that healthcare systems be fortified in order to enhance diagnostic services' accessibility.

Campaigns for Public Health: Quicker healthcare-seeking behaviour can be facilitated by conducting public health campaigns to educate communities about the symptoms, hazards, and importance of early diagnosis of dengue and malaria.

C. Recommendations

Adopt a Multi-Disciplinary Approach: Healthcare systems should adopt a multi-disciplinary approach involving epidemiologists, clinicians, public health experts, and data scientists to develop comprehensive diagnostic strategies for dengue and malaria co-infections.

Policy and Funding Support: Governments and international health organisations should prioritise funding and policy support for research and development of innovative diagnostic technologies. Ensuring sustained financial support will enable continuous improvement and implementation of these technologies.

Regular Review and Update of Diagnostic Protocols: Diagnostic protocols should be regularly reviewed and updated based on the latest research findings and technological advancements. Continuous professional development programs for healthcare workers should be instituted to keep them abreast of new diagnostic methods and protocols.

Encouraging Local Production of Diagnostic Kits: Promoting local production of diagnostic kits can reduce costs and improve supply chain reliability. Governments should provide incentives and support for local manufacturers to produce high-quality diagnostic tools.

Incorporate Point-of-Care Testing: Point-of-care testing (POCT) should be widely adopted, especially in remote and rural areas. POCT allows for rapid diagnosis and immediate treatment decisions, which are crucial for managing co-infections.

Table 4. Data Extraction

S/N	Reference	Country	Study Design / Method	Setting / Participants	Sample Size	Study Objective / Surveillance Focus	Appraisal Score	Key Themes / Notes
1	Noche et al., (2023)	Cameroon	Mixed method (clinical + interviews)	Hospitals in Bangangte; febrile patients and healthcare workers	260	Examine diagnostic challenges in febrile patients with suspected infections	8	Diagnostic accuracy, limitations of RDTs and clinical diagnosis
2	Linda et al., (2021)	Nigeria	Mixed methods (serological and qualitative)	Health centers in Awka; HIV-positive and HIV-negative individuals	188	Assess seroprevalence and hematological changes in co-infected patients	8	Diagnostic accuracy, epidemiology of co-infection
3	Ahmed et al., (2021)	Sudan	Qualitative descriptive study	Camps in North Darfur; internally displaced febrile patients	76	Investigate diagnostic access and outcomes during an epidemic	8	Challenges in epidemics, user-friendly diagnostics needed
4	Alsedig et al., (2023)	Sudan	Quantitative cross-sectional	Kassala hospitals; febrile patients during dengue season	395	Measure prevalence of malaria-dengue co-infection	8	Prevalence, impact of co-infection, diagnostic accessibility
5	Vu et al., (2023)	Kenya	Cohort study	Multiple hospitals; febrile children (2014-2019)	113	Compare diagnostic accuracy of clinicians vs machine learning	8	Diagnostic innovation, machine learning models
6	Miri., (2021)	Nigeria	Quantitative cross-sectional	Health center in Jos; febrile patients	94	Detect IgM/IgG antibodies for dengue in suspected malaria patients	8	Impact of RDTs, antibody detection
7	Galani et al., (2020)	Cameroon	Quantitative study	Ngaoundere Regional Hospital; febrile patients	174	Determine co-infection prevalence and diagnostic performance	8	PCR and ELISA-based innovations, co-infection identification
8	Onyedibe et al., (2018)	Nigeria	Cross-sectional study	Hospitals in Maiduguri and Jos Plateau; febrile patients	529	Assess dengue presence in malaria-suspected cases	8	Diagnostic challenges with presumptive malaria diagnosis
9	Kolawole et al., (2017)	Nigeria	Quantitative study	Hospital in Ilorin; febrile patients	176	Evaluate concurrent dengue-malaria infection and diagnostic tools	8	Clinical use of RDTs, infection overlap
10	Mustapha et al., (2017)	Nigeria	Seroprevalence survey	Tertiary hospital in Abuja; HIV-infected febrile patients	178	Measure dengue IgG seroprevalence in HIV-positive patients	8	Diagnostic accuracy, HIV-related diagnostic complexities

DISCUSSION

This review uniquely highlights the diagnostic landscape of dengue and malaria co-infection specifically within the African context, focusing on four high-burden countries: Cameroon, Kenya, Nigeria, and Sudan. Unlike previous reviews, which often generalize findings across diverse geographic regions or concentrate on individual infections, this study provides a region-specific synthesis that captures the interplay of diagnostic challenges, innovations, and clinical realities in resource-limited settings. It also integrates both qualitative and quantitative evidence, incorporating not only laboratory-based diagnostics but also the lived experiences of healthcare workers and patients during epidemics.

Accurate diagnostic methods are underscored by the systematic reviews, which emphasise the prevalence of co-infections involving dengue and malaria. It is consistent with the research conducted by Salam *et al.* (2018), which underscored the global prevalence of co-infections and suggested the necessity of comprehensive diagnostic tools to distinguish between these infections effectively. Additionally, Kotepui *et al.* (2023) examined the unique cytokine profiles associated with malaria co-infections, which underscores the importance of precise diagnostics in order to manage these cases effectively. In contrast, Agrawal *et al.* (2022) criticised the current quality of clinical and laboratory data on co-infections, positing that the accuracy and reliability of existing methodologies may be inadequate. The study underscored the necessity of enhanced diagnostic methods by highlighting the absence of high-quality clinical and laboratory data on co-infections. Phuoc *et al.* (2019) substantiate this critique by

emphasising the inconsistencies in diagnostic techniques and the variability in clinical prognostic models for severe dengue.

The literature that has been reviewed reflects advancements in diagnostic technologies. Sylvestre *et al.* (2022) conducted a review that examined data-driven methods for dengue prediction and surveillance using real-world and Big Data. This exploration supports the review, indicating that technology is being leveraged to improve diagnostic and predictive capabilities. Furthermore, Leung *et al.* (2022) conducted a review of dengue transmission prediction models, emphasising the current advancements and future directions in diagnostic technologies. In regions with high prevalence rates, these innovations are essential for the early detection and management of dengue and malaria. Nevertheless, Trunfio *et al.* (2017) highlighted that technological advancements have not yet entirely resolved all diagnostic challenges, indicating that bacterial co-infections in dengue remain poorly understood. Barrera *et al.* (2022) similarly observed the limitations in the clinical presentation and diagnosis of leptospirosis and co-infections, suggesting that novel technologies may still fall short in comprehensive diagnostics.

The influence of rapid diagnostic tests (RDTs) on clinical outcomes is a recurring theme in this investigation. This result is consistent with the study conducted by Lim, & Tanna (2017), which conducted a systematic review of the economic impact of rapid diagnostic tests for dengue, demonstrating their importance in clinical settings. The results indicated that RDTs can result in improved clinical outcomes by providing timely and accurate diagnoses, which are essential for effective treatment

and management Bowman *et al.* (2014) implicitly support the utility of rapid diagnostics in managing disease epidemics by evaluating the relationship between vector indices and dengue transmission. Their findings corroborate this.

Nevertheless, the positive influence of rapid diagnostic tests (RDTs) on clinical outcomes was attested by Lim *et al.* (2017) and (Bowman *et al.* (2014) study. Conversely, Gwee, *et al.* (2021) identified the obstacles associated with the global importation of dengue, suggesting that the efficacy of RDTs may differ considerably among various environments. Moreover, Horstick, *et al.* (2014) conducted a comparison of the effectiveness of various WHO dengue case classifications, indicating that rapid tests may not consistently enhance clinical outcomes as a result of classification discrepancies.

Across the studies, there is a critical recommendation to enhance diagnostic accuracy in resource-limited settings. Mahmud *et al.* (2019) conducted evaluations that concentrated on environmental management for dengue control, suggesting systematic approaches that can be implemented in resource-limited environments. This study is consistent with the necessity of diagnostic instruments that are both accessible and dependable in these types of environments. Additionally, Pérez *et al.* (2007) conducted a review of community-based dengue control programmes in support of this outcome. They emphasised the significance of local and affordable diagnostic solutions and provided recommendations for improving diagnostic accuracy in resource-limited settings. Oliveira *et al.* (2019) also addressed the financial implications of dengue program, suggesting that financial constraints may impede the implementation of precise diagnostic methods. In the same vein,

Flórez *et al.* (2023) underscored that the current diagnostic methods may not be sufficient to address the genetic factors associated with severe dengue, particularly in resource-limited settings.

In conclusion, the systematic review emphasises the ongoing challenges and significant advancements in the diagnosis of dengue and malaria co-infections. Although conventional diagnostic methods have their limitations, emerging technologies such as molecular diagnostics and POCTs provide promising solutions. RDTs have a beneficial effect on clinical outcomes; however, there are still obstacles to their implementation. A comprehensive approach that encompasses capacity building, infrastructure development, and policy support is necessary to enhance diagnostic accuracy in resource-limited settings. Ultimately, these measures can improve patient outcomes and reduce the global burden of dengue and malaria co-infections by enhancing the detection and management of these diseases. A comprehensive approach is necessary to enhance the diagnostic accuracy of co-infections with dengue and malaria. This study encompasses the implementation of state-of-the-art diagnostic technologies, the provision of adequate instruction to healthcare professionals, and substantial investments in laboratory infrastructure and policy support. These measures have the potential to improve disease management by reducing the morbidity and mortality that are associated with these co-infections. Systematic advances in healthcare practices and innovative diagnostic solutions are urgently required, particularly in resource-limited environments. The global health community can substantially improve patient outcomes and reduce the overall disease burden by addressing these needs, thereby enhancing the detection and

management of dengue and malaria co-infections.

These limitations must be recognised despite the valuable insights that have been obtained from this systematic review. The research designs, contexts, and populations of the studies included in this review were highly diverse. This heterogeneity presents a challenge in terms of comparing results directly and formulating consistent conclusions. The research primarily concentrated on specific regions, with a particular emphasis on Africa and certain areas of Asia. The generalizability of the findings to other regions with varying epidemiological patterns and healthcare infrastructure may be influenced by this geographic limitation. The diagnostic methods employed in the investigations were highly diverse, encompassing microscopy, serological tests, PCR, and RDTs. This variation has the potential to result in discrepancies in the reported accuracy and efficacy of diagnostic methods. The diagnostic accuracy and clinical outcomes documented in the studies were potentially influenced by factors such as environmental conditions, healthcare worker proficiency, and patient adherence to follow-up, which were not consistently controlled or reported. It is imperative to address the identified limitations, including study heterogeneity, geographic constraints, and potential publication bias, in order to facilitate future research.

AUTHOR CONTRIBUTION

Sunday Thomas Sola: Data acquisition, critical revision, and final approval for publishing. Felix Sanni: Conceptualization, methodology design, Literature search, data extraction, analysis of findings, and draft of the manuscript. Abah Michael Idoko: literature screening and quality assessment, interpretation of results, and writing.

Adamu Ishaku Akyala: methodological guidance, protocol compliance, and manuscript review. Emmanuel Awa Anya-Awa: data management and visualization, data synthesis, and manuscript revision. Kayode Akanbi: literature review, contributed to discussion, and ensured PRISMA compliance.

CONFLICT OF INTEREST

There was no competing interest among the authors.

FUNDING AND SPONSORSHIP

No external funding, sponsorship, grants, or financial assistance was received for this publication.

ACKNOWLEDGEMENT

We sincerely thank the Authors for their invaluable contributions and steadfast dedication, which have been instrumental in the success of this study. Their consistent support has played a vital role in driving this project forward.

REFERENCES

- Agrawal V, Rai P, Rai P, Narula H, Pandey S. (2023). There is a lack of quality clinical and laboratory data on co-infections among malaria patients despite several published systematic reviews of the literature. *Trop Doct.* 53(1): 5–6. doi: 10.1177/0049475522-1136178.
- Ahmed AAAA, Ahmed TB, Ahmed MAI, Gaafar ESM, Abdelrahman NAM, Adam NKA, et al. (2020). Incidence of dengue infection among febrile patients in Port Sudan. *J Med Health-Care.* 1–6. doi: 10.47363/JMHC/-2021(3)166.
- Ahmed A, Eldigail M, Elduma A, Breima T, Dietrich I, Ali Y, Weaver SC (2021). First report of epidemic dengue fever

- and malaria co-infections among internally displaced persons in humanitarian camps of North Darfur, Sudan. *Int J Infect Dis.* 108: 513–516, doi: 10.1016/j.ijid.2021.05.052.
- Alsedig K, Eldigail MH, Elduma AH, Elaagip A, Altahir O, Siam HA, Ali Y, et al. (2023). Prevalence of malaria and dengue co-infections among febrile patients during dengue transmission season in Kassala, eastern Sudan. *PLOS Negl Trop Dis.* 17(10): e0011660. doi: 10.1371/journal.pntd.0011660.
- Ayorinde AF, Oyeyiga AM, Nosegbe NO, Folarin OA (2016). A survey of malaria and some arboviral infections among suspected febrile patients visiting a health centre in Simawa, Ogun State, Nigeria. *J Infect Public Health.* 9(1): 52–59, doi: 10.1016/j.jiph.2015.06.009.
- Barrera ELP, Bello S, Gallego-Lopez GM, Atero N, Santamaría ER, Bautista A (2022). Distribution, frequency and clinical presentation of leptospirosis and coinfections: a systematic review protocol. *BMJ Open.* 12(12): e055187. doi: 10.1136/bmjopen-2021-055187.
- Bhatt S, Gething PW, Brady OJ, Messina JP, Farlow AW, Moyes CL, Drake JM, et al. (2013). The global distribution and burden of dengue. *Nature.* 496(7446): 504–507. doi: 10.1038/nature12060.
- Bowman LR, Runge-Ranzinger S, McCall PJ (2014). Assessing the Relationship between Vector Indices and Dengue Transmission: A Systematic Review of the Evidence. *PLoS Negl Trop Dis.* 8(5): e2848. doi: 10.1371/journal.pntd.0002848.
- CASP (2017). Critical Appraisal Skills Programme, (CASP) for Qualitative checklist.
- Edwards MD, Morris GAJ, Burr SE, Walther M (2012). Evaluating the frequency of bacterial co-infections in children recruited into a malaria pathogenesis study in The Gambia, West Africa using molecular methods. *Mol Cell Probes.* 26(4): 151–158. doi: 10.1016/j.mcp.2012.04.003.
- Flórez JES, Cardona ÁMS, Jaramillo BNR, Naranjo MA, Cardona LSG, Rendón ÁPE (2023). Immune system gene polymorphisms associated with severe dengue in Latin America: a systematic review. *Rev Inst Med Trop São Paulo.* 65: 65, doi: 10.1590/s1678-9946202-365058.
- Galani BRT, Mapouokam DW, Simo FBN, Mohamadou H, Chuisseu PDD, Njintang NY, Moundipa PF (2021). Investigation of dengue–malaria coinfection among febrile patients consulting at Ngaoundere Regional Hospital, Cameroon. *J Med Virol.* 93(6): 3350–3361. doi: 10.1002/jmv.26732.
- Gwee X, Chua P, Pang J (2021). Global dengue importation: a systematic review. *BMC Infect Dis.* 21. doi: 10.1186/s12879-021-06740-1.
- Horstick O, Jaenisch T, Martinez E, Kroeger A, See LLC, Farrar J, Ranzinger SR (2014). Comparing the Usefulness of the 1997 and 2009 WHO Dengue Case Classification: A Systematic Literature Review. *Am Soc Trop Med Hyg.* 91(3): 621–634. doi: 10.4269/ajtmh.13-0676.
- Kolawole OM, Seriki AA, Irekeola AA, Bello KE (2017a). Dengue virus and malaria concurrent infection among febrile subjects within Ilorin metropolis, Nigeria. *J Med Virol.* 1347–1353, doi: 10.1002/jmv.24788.
- Kotepui M, Mala W, Kwankaew P, Kotepui KU, Masangkay FR, Wilairatana P (2023). Distinct cytokine profiles in

- malaria coinfections: A systematic review. *PLOS Negl Trop Dis.* 17(1): e0011061. doi: 10.1371/journal.pntd.-0011061.
- Leung XY, Islam RM, Adhami M, Ilic D, McDonald L, Palawaththa S, Diug B, et al. (2023). A systematic review of dengue outbreak prediction models: Current scenario and future directions. *PLOS Negl Trop Dis.* 17(2): e0010631. doi: 10.1371/journal.pntd.-0010631.
- Lim JK, Alexander N, Di Tanna GL (2017). A systematic review of the economic impact of rapid diagnostic tests for dengue. *BMC Health Serv Res.* 17(1): 850. doi: 10.1186/s12913-017-2789-8.
- Mahmud MAF, Abdul Mutalip MH, Lodz NA, Muhammad EN, Yoep N, Hashim MH, Paiwai F, et al. (2019). Environmental management for dengue control: a systematic review protocol. *BMJ Open.* 9(5): e026101. doi: 10.1136/bmjopen-2018-026101.
- Miri NF (2021). Detection of IgM and IgG Dengue antibodies in febrile patients suspected of malaria attending health center in Jos, Nigeria. *Ann Med Lab Sci.* 1(1): 27–35. doi: 10.51374/annalsmls.2021.1.1.0018.
- Morse JM (2005). What Is Qualitative Research?. *Qual Health Res.* 15(7): 859–860. doi: 10.1177/1049732305279135.
- Moses A, Atting I, Inyang O (2016). Evidence of Overlapping Infections of Dengue, Malaria and Typhoid in Febrile Patients Attending a Tertiary Health Facility in Uyo, South-South Nigeria. *Br J Med Med Res.* 17(3): 1–9. doi: 10.9734/BJMMR/2016/27668.
- Mustapha J, Emeribe AU, Nasir IA (2017). Survey of malaria and anti-dengue virus IgG among febrile HIV-infected patients attending a tertiary hospital in Abuja, Nigeria. *HIV/AIDS - Res Palliat Care.* 9: 145–151. doi: 10.2147/HIV.S134023.
- Noche CD, Ewondo EN, Simo FN, Kwetche PRF, Assob CN (2023). Clinical and biological diagnosis of malaria and dengue fever among febrile patients in hospitals of Bangangte, Cameroon. *Int J Biol Chem Sci.* 17(2): 475–483. doi: 10.4314/ijbcs.v17i2.15.
- Okoye EL, Egbufoama VC, George OC (2021). Determination of Dengue Virus IGM Seroprevalence, Malaria Parasitaemia and Some Haematological Parameters of HIV Infected Individuals in Awka, Nigeria. *J Adv Microbiol.* 17–29. doi: 10.9734/jamb-2021/v21i1230410.
- Oliveira LN da S, Itria A, Lima EC (2019). Cost of illness and program of dengue: A systematic review. *PLOS ONE.* 14(2): e0211401. doi: 10.1371/journal.pone.0211401.
- Onyedibe K, Dawurung J, Iroezindu M, Shehu N, Okolo M, Shobowale E, Afolaranmi T, et al. (2018). A cross sectional study of dengue virus infection in febrile patients presumptively diagnosed of malaria in Maiduguri and Jos plateau, Nigeria. *Malawi Med J.* 30(4):276-282. doi: 10.4314/mmj.v30i4.11.
- Pérez D, Lefèvre P, Sánchez L, Van der Stuyft P (2007). Comment on: What do community-based dengue control programmes achieve? A systematic review of published evaluations. *Trans R Soc Trop Med Hyg.* 101(6): 630–631. doi: 10.1016/j.trstmh.2007.02.010.
- Phuoc DT, Quynh LK, Khanh LVD, Phuc TO, Sy HL, Ngoc TL, Khanh LP (2019). Clinical prognostic models for severe dengue: a systematic review protocol. *Wellcome Open Res.* 4: 12.

- doi: 10.12688/wellcomeopenres.1503-3.2.
- Salam N, Mustafa S, Hafiz A, Chaudhary AA, Deeba F, Parveen S (2018). Global prevalence and distribution of coinfection of malaria, dengue and chikungunya: a systematic review. *BMC Public Health*. 18(1): 710. doi: 10.1186/s12889-018-5626-z.
- Sylvestre E, Joachim C, Cécilia-Joseph E, Bouzillé G, Campillo-Gimenez B, Cuggia M, Cabié A (2022). Data-driven methods for dengue prediction and surveillance using real-world and Big Data: A systematic review. *PLOS Negl Trop Dis*. 16(1): e0010056. doi: 10.1371/journal.pntd.0010056.
- Trunfio M, Savoldi A, Viganò O, Monforte AD (2017). Bacterial coinfections in dengue virus disease: what we know and what is still obscure about an emerging concern. *Infection*. 45(1): 1–10. doi: 10.1007/s15010-016-0927-6.
- Vu DM, Krystosik AR, Ndenga BA, Mutuku FM, Ripp K, Liu E, Bosire CM, et al. (2023). Detection of acute dengue virus infection, with and without concurrent malaria infection, in a cohort of febrile children in Kenya, 2014–2019, by clinicians or machine learning algorithms. *PLOS Glob Public Health*. 3(7): e0001950. doi: 10.1371/journal.pgph.0001950.