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Research Article

Using a Cluster Survey to Reconstruct and Estimate the Magnitude of a Major Dengue Outbreak in El-Obeid, Sudan

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Abstract

Introduction: Dengue fever surveillance in El-Obeid, Sudan, identified approximately 572 cases. To estimate the outbreak's true magnitude, a community-wide cluster survey was conducted. **Methodology:** Eighty clusters, each comprising ten households, were chosen via systematic random sampling. Rapid diagnostic tests were used on blood samples from symptomatic and asymptomatic individuals within each household. **Results:** There were discrepancies between the official surveillance system and the cluster survey. The cluster survey revealed a delayed detection, a wider spread of the virus, and a significantly higher number of cases compared to the official data. The cluster survey of 1285 participants residing in approximately 4,800 households identified a high prevalence of dengue markers (35.3%). This translates to an estimated 323,604 individuals (extrapolated from total population) with potential past or present infection. About 24.7% of the sample were positive for IgM, 25.1% for IgG, and 1.7% for NS-1, indicating an estimated 14,930 individuals with potentially infectious cases. Investigations in El-Obeid City health facilities revealed critical shortcomings in the dengue outbreak response. These included severely limited communication between preventive and curative healthcare, a barely functional public health laboratory hindering diagnostics, and a shortage of trained staff, highlighting broader resource constraints. Additionally, inadequate public awareness campaigns failed to effectively reach the population. **Conclusions:** Combining data from both surveillance and the cluster survey provided valuable insights into the El-Obeid dengue outbreak. The survey revealed a delay in detection and underreporting by the existing system. It also likely increased awareness among healthcare workers and the public, potentially improving case detection and control measures. This integrated approach highlights the importance of using multiple data sources for a more comprehensive understanding of outbreaks.

Keywords: Dengue; Sudan; Cluster survey; Outbreak; Attack rate; Sentinel surveillance

Introduction

Dengue Fever (DF), a mosquito-borne viral illness, poses a significant public health threat, particularly in tropical and subtropical regions, including Sudan. DF is a self-limited illness currently lacking a specific antiviral treatment; secondary infections with different dengue virus serotypes can lead to the potentially fatal complications [1-3]. Sudan has a documented history of recurring dengue outbreaks, with episodes concentrated in eastern and western regions bordering countries with established dengue transmission [4-9].

In 2019, several Sudanese states experienced outbreaks of DF, culminating in El-Obeid City, North Kordofan. Despite the clear presence of an overwhelming outbreak in El-Obeid, the precise magnitude and geographic distribution remain unclear, with the potential for underestimation. This study employs a cluster survey approach to reconstruct the outbreak's timeline and estimate its true size. Our primary objectives are to definitively confirm the occurrence of the outbreak within El-Obeid City limits, assess its overall magnitude, and to assess the sensitivity, reliability, and timeliness of the sentinel surveillance system in detecting and monitoring the dengue outbreak within El-Obeid city.

Material and Methods

Study Setting

El-Obeid City, (Figure 1) the capital of North Kordofan State in Sudan, has an estimated population of 936,359 inhabitants. This semi-arid city experiences distinct wet and dry seasons. El-Obeid City serves as a critical transportation hub and regional commercial center for western Sudan. Yet, El-Obeid has unfortunately faced a longstanding challenge: a critical water shortage [10]. This scarcity compels residents to store water in various containers, a practice that inadvertently creates ideal breeding grounds for Aedes mosquitos, the primary vectors of dengue fever transmission.

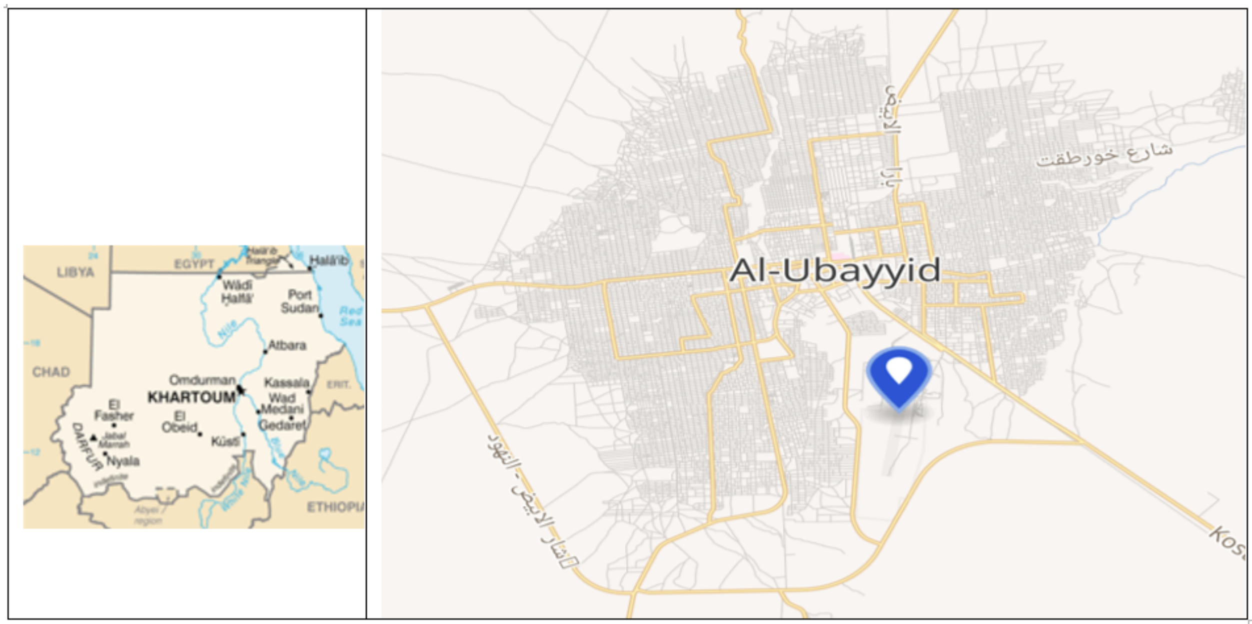

Figure 1: Map of El-Obeid, Capital City of North Kordofan. Map for North Kordofan state: bordering Northern, River Nile, White Nile, South Kordofan, West Kordofan, and North Darfur states

Study Design and Sampling

This study utilized a descriptive survey that collected data to gain a comprehensive understanding of the dengue fever outbreak's scale and spread within El-Obeid City. To ensure a representative sample across the entire city, a systematic random sampling technique was employed. El-Obeid City map was divided into a 27x27 grid system, resulting in a total of 729 individual pixels. From this grid, 80 sampling "pixel units" were chosen using systematic random sampling. Each pixel represented a square area measuring 400 meters wide (Figure 2). This specific size and number of pixels balanced capturing a representative sample with maintaining a manageable workload for the survey teams. Within each selected pixel (grid square), the first house was chosen randomly. To ensure ten households were included from each pixel, subsequent households were selected by identifying the nearest house to the previously chosen one.

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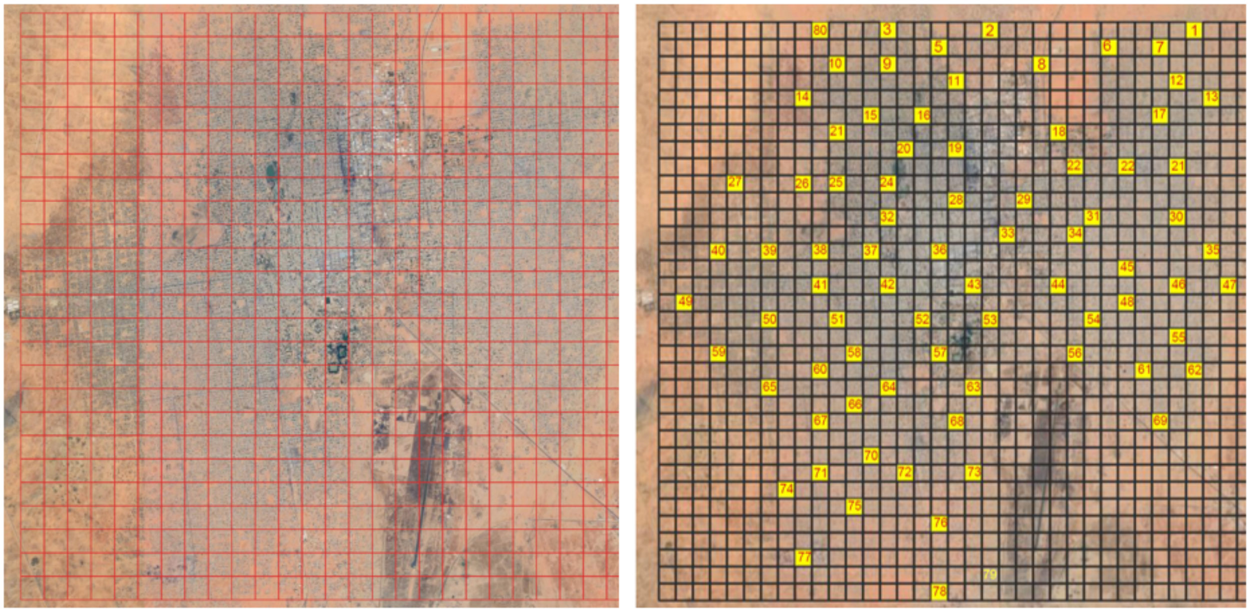


Figure 2: El-Obeid City map divided into a 27x27 grid system, resulting in a total of 729 individual pixels. From this grid; 80 sampling "pixel units" were chosen using systematic random sampling. Each pixel represented a square area measuring 400 meters wide

Survey Teams: Composition and Training

Survey teams were comprised of three key members, which included at least one female and one male, each contributing in collection of a specific data set. A senior medical student functioned as the primary interviewer, administering semi-structured questionnaires to gather detailed information from residents. An entomologist played a vital role in inspecting households, documenting the types of containers used for water storage and identifying potential mosquito breeding sites. The surveyors inquired about mosquito bite prevention methods employed by residents. A phlebotomist collected blood samples from two individuals within each household: one experiencing symptoms consistent with dengue fever and another asymptomatic individual.

To ensure effective communication and data collection in the field, all teams participated in a comprehensive role-playing exercise. This exercise simulated various scenarios they might encounter during household visits. The role-play covered introducing the objectives of the study and obtaining informed consent from household heads in a respectful manner. Should a household refuse to participate in the study, the team was trained to respect this decision and move immediately to the next household. The training also included addressing resident concerns professionally, and fostering strong teamwork to achieve survey goals. The local security authorities were informed about the objectives and movements of the teams in the field to ensure safety of the teams at all times.

Leading each team were laboratory technicians, chosen for their experience and expertise. Teams were instructed to prioritize respectful interactions with residents and avoid engaging in unnecessary arguments that could hinder the data collection process. This emphasis on respectful communication aimed to create a positive experience for residents and optimize survey completion rates within the shortest possible period of time.

Data Collection Tools

Each survey team received a comprehensive toolkit to ensure efficient data collection. This toolkit included three maps: a map pinpointing the specific pixel (grid square) they were assigned to visit, a road map guiding them to the designated pixel location, and a Google map showing the distribution of houses within that specific pixel. This combination of maps allowed for efficient navigation and facilitated the selection of the ten households to be surveyed within each grid.

Data collection relied on a multi-pronged approach. Teams utilized a semi-structured questionnaire designed to capture a wide range of information relevant to dengue fever transmission and potential risk factors. This questionnaire covered topics such as sociodemographic characteristics (age, gender, education level, etc.), for suspected cases the date of symptom onset and disease outcome, housing conditions (water storage practices and waste disposal methods), water sources used by the household, travel history within the past two weeks, mosquito control efforts employed by the household, and healthcare seeking behavior in the event of illness.

In addition to the questionnaire, trained field teams performed visual inspections. They observed the types of containers used for water storage within each household, documented water storage practices, searched for potential mosquito breeding sites, and inquired about mosquito bite prevention methods employed by residents. The phlebotomist collected 5 milliliters of blood from two individuals per household: one experiencing symptoms consistent with dengue fever and another asymptomatic individual. Blood samples were collected from 1,285 individuals residing within these households. Among these individuals, 645 exhibited symptoms suggestive of dengue fever, while the remaining 640 were asymptomatic (non-cases). The field work was conducted over three consecutive days (26-28 November, 2022). The survey team held meetings with the state health authorities to discuss and resolve challenges faced during management of the outbreak.

The investigation team maintained daily communication with surveillance officers to monitor disease spread, evaluate ongoing control measures, and collaboratively address challenges (staffing, training, resources, risk communication, and hospital case management) facing both surveillance and response activities.

Case Definition

A suspected case of dengue fever was defined as any individual residing in El-Obeid City between August 7th and September 5th, 2022, who presented with a high fever lasting for more than 2 days but less than 10 days, accompanied by at least two of the following signs and symptoms: headache, pain behind the eyes (retro-orbital pain), muscle aches (myalgia), joint pain (arthralgia), nosebleed (epistaxis), vomiting blood (hematemesis), black stools (melena), coughing up blood (hemoptysis), vomiting and abdominal pain. Platelet count was not included in this case definition [11].

Laboratory Testing

Commercially available rapid diagnostic test kits (SD Bioline Dengue Duo) provided by the World Health Organization (WHO) and UNICEF were used to detect the presence of dengue virus (DENV) in collected serum samples. These tests specifically target two biomarkers: Dengue virus non-structural protein 1 (NS1): This protein is secreted into the bloodstream during the acute phase of dengue infection, typically within the first 0-7 days after symptom onset. A positive NS1 test confirms a current dengue virus infection but does not distinguish between different serotypes of the virus. A negative NS1 result does not definitively rule out infection; follow-up testing is recommended in such cases. Anti-DENV IgM antibodies: These antibodies are produced by the immune system in response to a recent DENV infection. While a positive IgM antibody test can indicate a recent or current infection, these antibodies may persist for several months after recovery.

The SD Bioline Dengue Duo kit was chosen due to its reported sensitivity of 82.4% (95% Confidence Interval [CI]: 76.8-87.1) and specificity of 87.4% (95% CI: 82.8-91.2) [12]. This rapid, *in vitro* test utilizes two separate devices: one for NS1 antigen detection and another for IgG/IgM antibody detection.

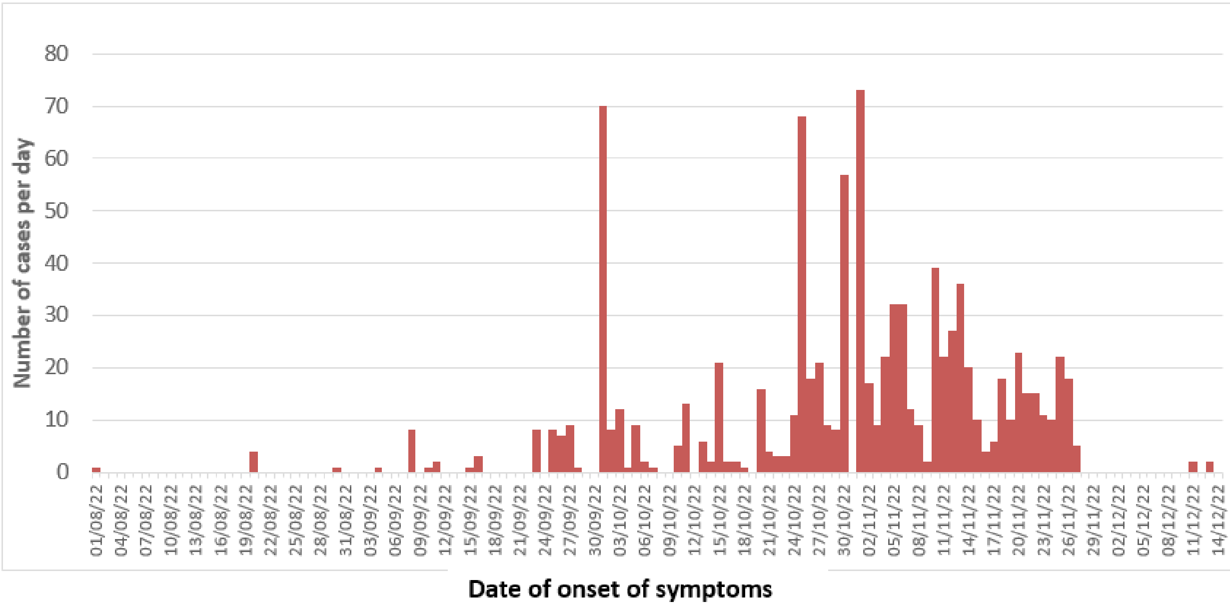
Data Analysis

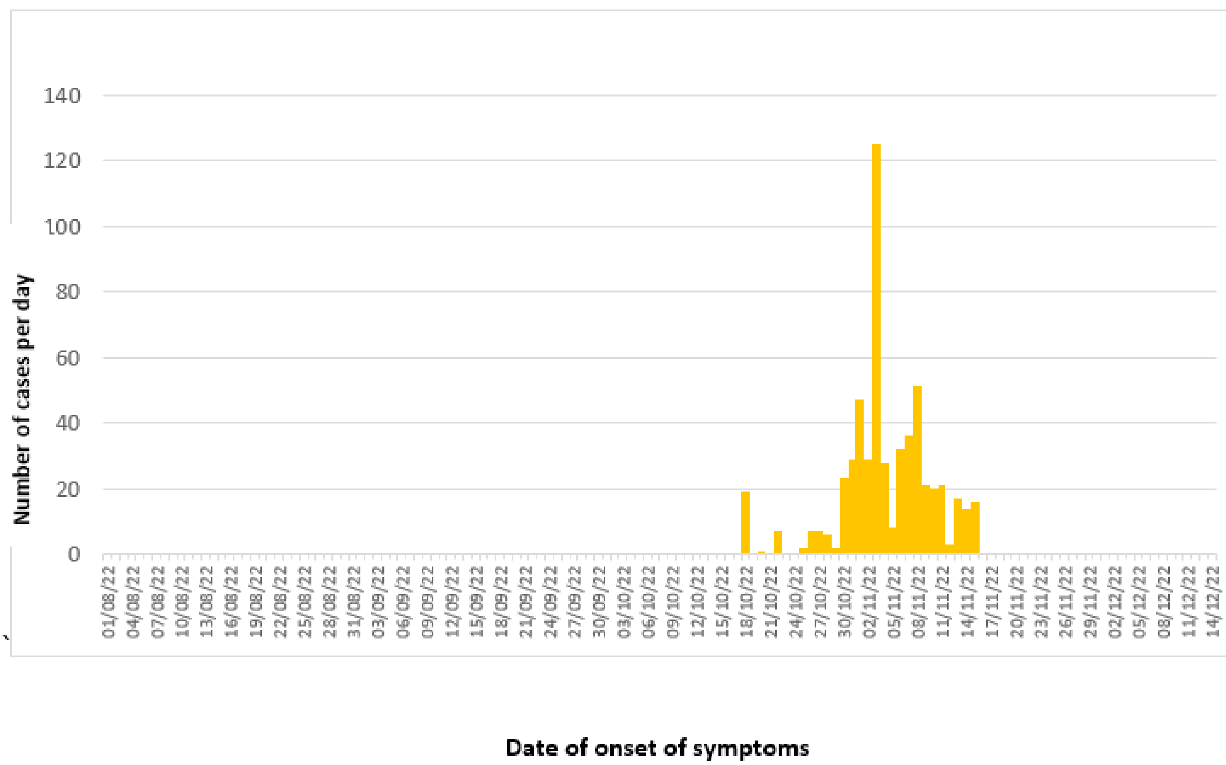
Data analysis for this study utilized two primary software programs. Microsoft Excel (version 10.0) facilitated initial data entry, basic analysis, and the summarization of group characteristics through descriptive statistics, including frequencies, means, and Standard Deviations (SD). Excel was used to generate epidemic curves, which visually represent the outbreak's progression over time.

This study adhered to ethical research principles and received approval from two relevant authorities: The Director General for Health Affairs in North Kordofan State and the University of Kordofan. Furthermore, the research benefitted from the collaboration of various stakeholders who participated in planning and implementing the different phases of the survey. These stakeholders included staff from the Federal and State Ministries of Health, faculty members, and students from the Faculty of Medicine at the University of Kordofan.

Results

Figure 3 (Upper) and Figure 3 (Lower), depicting the epidemic curves for the official surveillance system and cluster survey data (with identical scales for date and case count), highlight a critical finding. The reported duration of the outbreak varied. The existing surveillance system identified the first case (index case) on October 18th, 2022, whereas the cluster survey suggests an earlier start date of August 1st, 2022. The official field survey also indicated an earlier end date of November 15th, 2022, compared to the survey's suggestion of December 13th, 2022, based on the last identified case.





Figures 3 (Upper) and Figure 3 (Lower): Depicting the epidemic curves for the official surveillance system and cluster survey data (with identical scales for date), highlight a critical finding. The X-Axis shows the date and the Y-Axis shows the daily number of dengue cases.

Given an average family size of 6, the estimated number of individuals residing within the surveyed households is approximately 4,800. Out of 1285 participants tested, 454 (35.3% 95% CI: 32.7% - 38.0%) tested positive for at least one dengue virus marker (either IgM or IgG or NS-1,), indicating that 323,597 (299,600 - 348,144 persons had past or present infection to prior or current exposure. No samples tested positive for all three markers. The breakdown of other tests reveals: 317 (24.7% 95% CI: 22.3% - 27.1 %) were positive for IgM: 225,959 (204,526-248,399) persons, and 332 (25.1% 95% CI: 23.5% - 28.3%) positive for IgG: 236,676 (214,876 - 259,391) persons; and 22 (1.7% 95% CI: 1.0% - 2.5%) tested positive for the NS-1 antigen, a marker for recent infection. Based on the NS-1 positive rate, the estimated number of individuals with potentially infectious dengue cases in El-Obeid City is 14,930 (9,251 - 22,807).

Challenges Identified During Response Activities

The daily meetings and field visits conducted within El-Obeid City health facilities revealed critical limitations in the response to the dengue outbreak. A major concern identified was the severely limited communication between preventive and curative healthcare departments. This lack of coordination undoubtedly hampered the overall effectiveness of the response effort. The regional public health laboratory's barely functional state significantly hindered diagnostic capabilities. This, coupled with an acute shortage of trained staff, highlighted a broader issue of resource constraints within the healthcare system. Additionally, public awareness campaigns proved inadequate, failing to effectively disseminate crucial information to the population. The investigation identified a potential for improved response through the underutilized qualified personnel within El-Obeid. The Ministry of Health (SMOH) could have leveraged the expertise of staff at the university, military, police department, private sector, and various charity organizations.

Discussion

Discrepancies between the official surveillance system and a cluster survey

This study identified critical discrepancies between the official surveillance system and a cluster survey conducted in El-Obeid City during a 2022 dengue fever outbreak. The cluster survey revealed a delayed detection, a wider spread of the virus, and a significantly higher number of cases compared to the official data. These discrepancies highlight the limitations of relying solely on existing surveillance systems. Sentinel surveillance is designed to help early detection of cases but it is not expected to give an estimated number of cases during outbreaks because usually sentinel surveillance sites cover limited geographical areas [3]. Robust data collection and analysis from multiple sources, as demonstrated by the cluster survey, are crucial for timely detection, accurate estimates of the outbreak's magnitude, and effective response strategies.

By extrapolating from the cluster survey data, we estimate that a substantial portion of the El-Obeid population (323,604 individuals) could potentially test positive for dengue markers, with 11,931 potentially having infectious cases. This underscores the value of utilizing multiple data sources for a more comprehensive understanding of the magnitude of the outbreak. While the cluster survey data may not perfectly represent the entire population, it provided valuable insights that complemented the official surveillance system. These findings suggest a potentially wider spread of the virus and highlight the need for improved detection methods and more effective outbreak control strategies in El-Obeid City.

Potential challenges facing the sentinel surveillance system in North Kordofan State

North Kordofan State's sentinel surveillance system faces limitations in sensitivity, leading to potential underestimation of the outbreak's magnitude. Fragmented healthcare coordination, inadequate vector control, and a non-functional public health laboratory further hampered timely detection, effective response, and disease monitoring. Mitigating the outbreak and preventing dengue endemicity requires a comprehensive, well-coordinated response that addresses identified weaknesses. Strengthening surveillance and public health infrastructure is crucial; it demands investments in trained staff, improved reporting systems, and financial resources. This will enable robust disease surveillance for early detection, accurate case reporting, and effective outbreak monitoring [13]. Accurate estimates of dengue disease burden are important because they allow informed policy decisions, increase dengue awareness and help define funding and research priorities from different institutions (governments, donors, NGOs, corporations) [14]. Moreover, clear communication channels within Sudan's health system must be established to enhance coordination and ensure a unified response. Community engagement and vector control efforts are equally important. Public education campaigns promoting preventive measures like mosquito breeding site elimination and bed net use are essential. Collaboration with community leaders and neighboring health authorities will improve outreach, message resonance, and best practices in vector control. In rural areas, people may have misconceptions and poor understanding of DF transmission, and a negative attitude towards preventative practices [15].

Addressing El-Obeid's water shortage is a critical long-term solution. Implementing improved water infrastructure can reduce reliance on stored water and eliminate potential mosquito breeding sites. Promoting safe water storage practices, such as using covered containers, can further reduce mosquito breeding risks [16].

Building public trust in healthcare services and addressing treatment cost barriers are crucial aspects of mitigating the outbreak. Efforts to rebuild trust and address these barriers will encourage people to seek medical attention when needed, leading to earlier diagnosis and reduced transmission [17].

Conclusion

El-Obeid urgently needs a coordinated response to prevent local dengue transmission. Strengthening surveillance, establishing an entomology lab, and implementing robust vector control are crucial first steps. Enacting relevant public health legislation and ensuring proper solid waste management are essential for long-term prevention. Public awareness campaigns, collaboration with leaders, and improved inter-sectoral coordination are vital for building long-term resilience. Analysis of El-Obeid's outbreak data revealed discrepancies in case detection and spread, underlining the importance of using multiple data sources for effective outbreak response. Increased collaboration with these groups could have significantly bolstered the response efforts.

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Authors Disclaimer Statement

The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the World Health Organization (WHO), UNICEF, the University of Kordofan or the State Ministry of Health, North Kordofan.

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